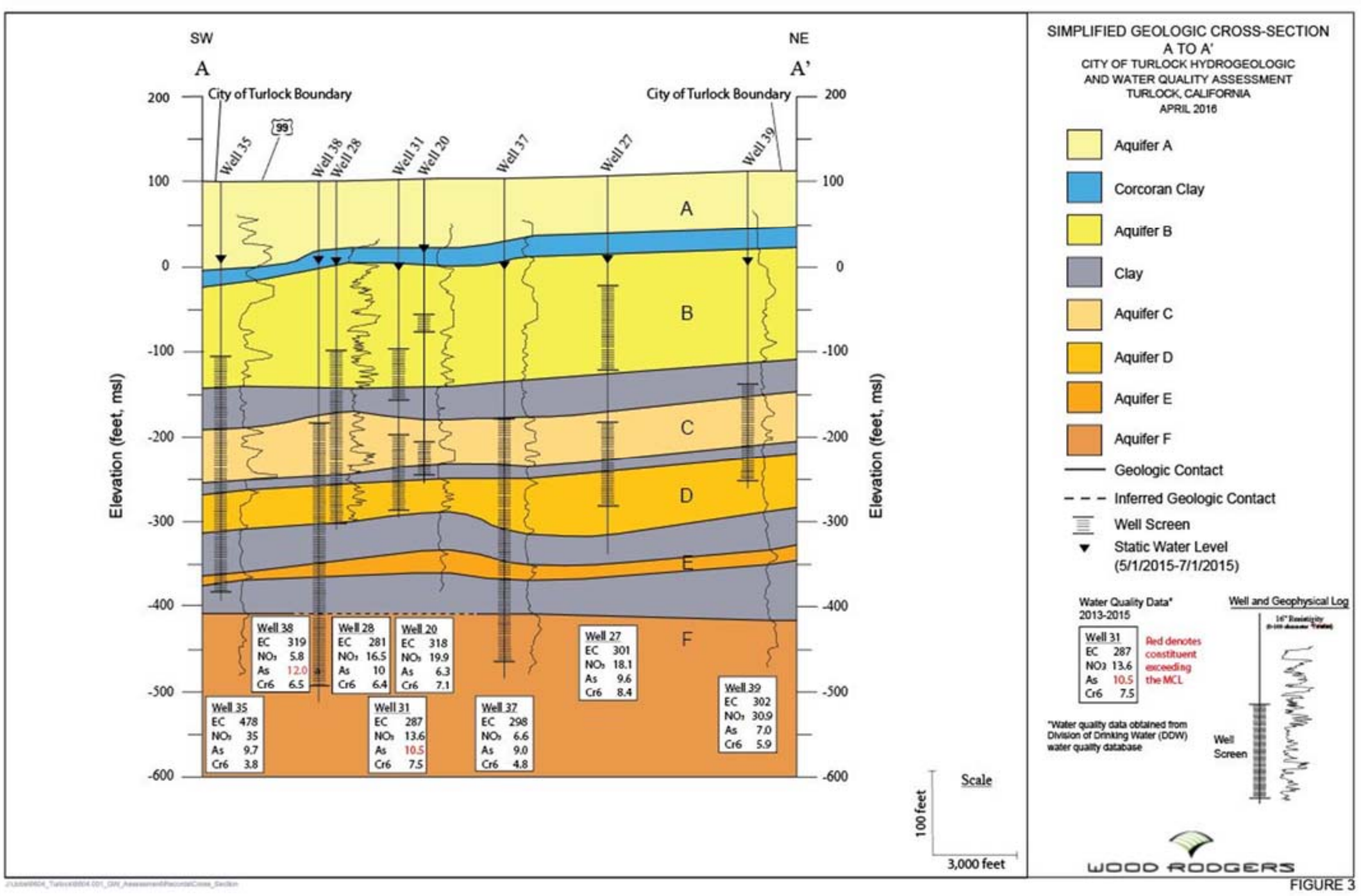
Hydrogeologic and Water Quality Assessment Report



Prepared for:

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City of Turlock
Hydrogeologic and Water Quality Assessment Report

Certificate and Seals

Date: July 6, 2016

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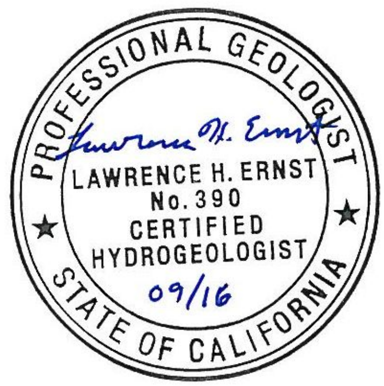

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Executive Summary

The City of Turlock (City) relies solely on groundwater to meet its municipal water demands. Groundwater is pumped directly into the City's distribution system to approximately 18,500 service connections. In 2014, the City pumped almost 6.5 billion gallons of groundwater from the underlying groundwater basin.

The City's well field consists of 25 municipal supply production wells. Of the 25 municipal supply wells, 21 are classified as active and four are inactive (Wells 10, 24, 28, and 38). Two of the active wells are currently on stand-by status. The main water quality concerns for the City are elevated nitrate and arsenic. The four inactive wells are currently not in service either due to concentrations of arsenic, which are at or above the California Division of Drinking Water (DDW) maximum contaminant level (MCL) of 10 micrograms per liter (µg/L), or concentrations of nitrate (as NO_3) above the MCL of 45 milligrams per liter (mg/L).

This Hydrogeologic and Water Quality Assessment Report characterizes six freshwater bearing aquifers underlying the City, designated as Aquifers A through F (from shallow to deep) and the associated water quality. Observed water quality trends of the characterized aquifers are:

- Elevated nitrate (as NO_3) occurs across the entire City; however, the highest concentrations are found in the shallow sediments and Aquifer B, which may indicate downward migration through sediments and via existing wells.
- Wells with high arsenic concentrations are more prominent in the northwest portion of the City than any other area. Many of these wells are screened across multiple aquifer zones as well as clay layers. No single aquifer was identified to contribute to the elevated concentrations of arsenic; however, it was observed that wells completed in Aquifer D could have elevated arsenic. It is also possible that the clay layers are contributing to elevated arsenic.
- In Aquifer F and below a depth of 550 feet to 600 feet, groundwater has elevated concentrations of total dissolved solids, which are close to or exceed DDW secondary requirements for potable water.

Existing well data and well testing conducted in several of the City's wells suggest that the highest groundwater production is in the northwest portion of the City; however, arsenic concentrations are elevated in this area. In the southeast, well testing and existing data suggest the aquifer system can produce between 1,000 and 2,000 gallons per minute (gpm), with specific capacities likely between 10 and 30 gallons per minute per foot (gpm/foot) of drawdown. The calculated aquifer transmissivity for Aquifer D is approximately 135,500 gallons per day per foot (gpd/foot) and a hydraulic conductivity of 6.6×10^{-4} gpd/ft^2. The analysis suggests news wells (2,000 gpm) constructed 1,000 feet apart and in the same aquifer will likely have 10 feet of mutual pumping interference.

An analysis of the distribution of groundwater quality, well production and specific capacities identified the southern portion of the City to develop additional groundwater, which will have the best chance of producing groundwater with acceptable water quality. Development in the northwest and northeast area of the City is possible, but will require additional site-specific and depth-specific assessment to characterize water quality for specific aquifer zones.

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1 Introduction

The City meets its municipal water demand through a network of 25 production wells. Of the 25 production wells, 21 are classified as active and four are inactive (Wells 10, 24, 28, and 38). Two of the active wells are currently on stand-by status, as shown in **Figure 1**. Groundwater is pumped directly through the City's distribution system to approximately 18,500 service connections. The four inactive wells are currently offline due to water quality issues.

This report characterizes groundwater quality, production capabilities, and aquifer properties of the underlying hydrogeologic system and provides recommendations for locations of future municipal wells. The recommendations were selected to help target the best possible water quality without the need for treatment. Also, this report provides an assessment of the current operation and quality of the groundwater produced by the City's well field. Data reviewed and analyzed for this report was furnished by the City, the California State Water Resources Control Board – Division of Drinking Water (DDW), the California Department of Water Resources (DWR), published geologic and hydrogeologic reports and work conducted by Wood Rodgers, Inc. Records provided by the City include the DWR Water Well Driller's Reports, geophysical surveys from boreholes, depth to groundwater measurements (1989 through July 2015), water quality data (1989 through 2015), and monthly production data. The DDW's "California Drinking Water" database (current to November 2015) in conjunction with the City's records provide the historical water quality data.

2 Location and Physical Setting

The City is south of the City of Modesto and north of the City of Merced, along the State Highway 99 corridor in Stanislaus County. The City is in the San Joaquin Valley, which is the southern portion of the Central Valley of California. The San Joaquin Valley is a large asymmetrical trough measuring 200 miles long and up to 70 miles wide, bordered on the east by the Sierra Nevada Mountains and on the west by the Coast Range Mountains. Topography within the City is flat, with the ground surface sloping from northeast to southwest with approximate elevations of 125 feet above mean sea level (MSL) to 90 feet MSL. In the vicinity of the City, land use historically has included agricultural and associated industry. Within the City limits, residential, industrial, and general commercial are the primary land uses.

The San Joaquin Valley consists of two hydrologic areas: the south referred to as the Tulare Lake Hydrologic Region and the north as the San Joaquin Valley Hydrologic Region, where the City is. The San Joaquin Hydrologic Region covers an area of approximately 15,200 square miles and includes counties of Calaveras, Tuolumne, Mariposa, Madera, San Joaquin, and Stanislaus (DWR, 2003).

Major rivers are located both north and west of the City, with the San Joaquin River approximately eight miles west and the Tuolumne River roughly six miles to the north. There are no major streams or rivers located within the City limits. The Turlock Irrigation District (TID) operates and maintains several lined canals within the City, located parallel to West Taylor Road in the north, Canal Road in the central portion of the City, and East Harding Road.

3 Geology

3.1 Geologic Setting

The San Joaquin Valley (Valley) consists of geologic layers of marine sediments overlain by continental sourced sediments (alluvium) deposited during erosion of the surrounding mountain ranges and flooding events. The alluvial deposits shed from the surrounding mountain ranges thicken towards the axis of the Valley and can reach up to 30,000 feet in thickness (Thiros, 2010). The Valley extends to the Sacramento-San Joaquin Delta to the north, the Sierra Nevada Mountains to the east, the Coast Range Mountains to the west, and the Tehachapi and San Emigdio Mountains to the south. The San Joaquin River flows from the high Sierra Nevada Mountains to the Valley floor, where it flows north toward the Sacramento-San Joaquin Delta. A network of streams and washes converge with the river, in some places terminating in topographically closed sinks, such as Tulare Lake, Kern Lake, and Buena Vista Lake (Galloway, 1999). Most streams draining the western slope of the valley are intermittent (ephemeral).

The City’s well field pumps groundwater from the underlying Turlock Groundwater Subbasin (Subbasin) (DWR Basin No. 5-22.03) of the larger San Joaquin Valley Groundwater Basin. The Subbasin covers approximately 347,000 acres, or 542 square miles, between the Tuolumne and Merced Rivers and is bound on the west by the San Joaquin River and on the east by crystalline basement rock of the Sierra Nevada foothills.

3.2 Conceptual Geologic Model

The geologic formations that make up the primary freshwater-bearing units within the Subbasin include (from youngest to oldest): the Modesto Formation, Riverbank Formation, Turlock Lake Formation, and the Mehrten Formation. These formations were deposited on older, marine sourced sediments which typically contain groundwater with high concentrations of TDS making them unusable for potable water supply. As shown in **Figure 2**, only the Modesto Formation is present at the ground surface within the City. All of the sediments in this area have a uniform dip of approximately one to three degrees to the southwest resulting from the uplift of the Sierra Nevada Mountains. The geologic formations form an alluvial wedge, which thicken from the Valley margins toward the axis of the structural trough, which is slightly west of the San Joaquin River (DWR, 2006).

Each of these formations are described in more detail below, including a depiction of the depositional environment and the primary sedimentary characteristics (grain size distribution).

3.2.1 Modesto Formation

The Modesto Formation is of late Pleistocene, with an age of one million years ago (1 Mya) to recent. Gravel, sand, silt, and clay deposited by alluvial fans extend from the Kern River drainage on the south to the Sacramento River in the north (Marchand and Allwardt, 1981). The Modesto Formation (Figure 2) is the only geologic unit exposed at the ground surface within the City and extends to an approximate depth of 100 feet in the northwest and 60 feet in the northeast. To the east of the City, smaller outcrops of the Modesto Formation are observed along low-lying drainage areas and river channels within the Sierra Nevada foothills.

3.2.2 Riverbank Formation

The Riverbank Formation of middle Pleistocene age (about 1.5 Mya to 1 Mya) underlies the extent of the Modesto Formation. The thickness of the formation increases westward, with a thickness of generally less than 200 feet. The formation consists primarily of sand with scattered gravel and silt lenses. A majority of the Riverbank Formation outcrops east of the City between the TID Main Canal and the TID Highline Canal. However, smaller portions of the formation are observed to outcrop along low-lying drainage areas and river channels throughout areas east of the City.

3.2.3 Turlock Lake Formation

The Turlock Lake Formation of late Pliocene age (2.5 Mya 1.5 Mya) underlies the Riverbank Formation. The thickness of the unit increases westward but is less than 600 feet. The formation consists primarily of arkosic alluvium, mostly of fine sand and silt grading upward into coarse sand and occasional coarse pebbly sand or gravel of granitic, metamorphic, volcanic and quartz (Marchand and Allwardt, 1981). While the Turlock Lake Formation contains significant layers of sandy material, it also contains highly silica-cemented sandstone layers (duripan) which characteristically has little permeability. The Turlock Lake Formation is the primary aquifer for deep wells within the City.

The Corcoran Clay Member occurs in the upper part of the Turlock Lake Formation and ranges in thickness from 10 feet to 100 feet. The Corcoran Clay is dark greenish-gray in color and commonly referred to by well drillers as “the blue clay” was deposited in a closed lacustrine environment. The Corcoran Clay is known to contain compressible geologic material that, when dewatered, has resulted in land subsidence within the Valley.

3.2.4 Mehrten Formation

The Mehrten Formation is Miocene to late Pliocene in age (5 Mya 2.5 Mya) and consists of a sequence of volcaniclastic and volcanic rocks. The Mehrten Formation is comprised of two distinct geologic units, the Upper Mehrten, and the Lower Mehrten Formation. The Upper Mehrten Formation consists of gravels, well sorted black andesitic sands (reported by well drillers as “black sands”) and interbedded blue to brown silts and clays (DWR, 1974). The Lower Mehrten Formation consists of dense volcanic flows of tuff breccias with interbedded conglomerates and sandstones. The tuff breccias act as confining layers among the conglomerates and sandstones. The Mehrten Formation ranges in thickness from 200 feet along the Sierra Nevada foothills east of the City to over 600 feet in the vicinity of the City. Under the City, the Mehrten Formation contains significant high-yielding aquifers; however, poor water quality, including high total dissolved solids (TDS) and arsenic, would preclude it use for municipal water supplies without extensive treatment.

4 Hydrogeology

4.1 Hydrogeologic Cross-Section

A simplified geologic cross-section was prepared to depict the underlying geologic formations. Geophysical surveys, including resistivity and spontaneous potential logs, provided for the City's wells were digitized and used in conjunction with the DWR Well Completion Reports to create a city-wide cross section (identified as A-A' in **Figure 3**) depicting the subsurface geology in the northern portion of the City. The spatial distribution of available geophysical logs was more concentrated in the northern portion of the City. The limited geophysical logs did not allow for sufficient correlation of the geologic units in the south. In the north, major aquifer units and clay layers were identified and correlated between boreholes to illustrate the extent and depth of each aquifer, as well as the confining layers. The limited available data suggests that the same aquifers exist in the southern portion of the City. To further aide in the hydrogeologic understanding, water quality data (from 2012 through 2015) for electrical conductance, nitrate (as NO_3), arsenic, and Cr 6+ are shown on the cross-section to illustrate the water quality of the formations penetrated by the City's well field. The location of the geologic cross-section (A-A') is shown in Figure 2.

The spontaneous potential (SP) logs depict relative changes in water quality with respect TDS. The SP logs were used to help identify and characterize the depth to brackish water, or groundwater with elevated TDS above 500 milligrams per liter (mg/L). Throughout the City, it was identified that groundwater becomes brackish at depths between 550 feet and 600 feet. At a depth of approximately 1,000 feet, groundwater likely becomes saline (TDS over 2,000 mg/L) based on our interpretation of nearby Department of Conservation, Division of Oil, Gas, and Geothermal Resources (DOGGR) well logs.

4.2 Freshwater Aquifer System

For this study, the freshwater-bearing aquifer system underlying the City has been characterized with six primary aquifers (from shallow to deep): Aquifers A through F. Aquifer A is unconfined where saturated, whereas Aquifers B through F is semi-confined to confined. The aquifer nomenclature in this report was established by correlating regional clay layers which separated continuous gravel and sand intervals.

4.2.1 Aquifer A (Elevation +100 feet to +25 feet MSL)

Aquifer A is likely unconfined to semi-confined and is present from the ground surface to an approximate depth of up to 100 feet below ground surface (bgs) along the western boundary of the City, and decreases in depth to the east, as shown in Figure 3. Aquifer A is likely a combination of the Modesto, Riverbank, and upper Turlock Lake Formations. Below Aquifer A, a local clay layer was able to be correlated across the City. Based on the lithologic descriptions in the Well Completion Reports, this clay layer is characterized as the Corcoran Clay and likely acts an aquitard which help reduce vertical groundwater movement between Aquifer A and Aquifer B, where the aquifers are not inter-connected by wells.

4.2.2 Aquifer B (Elevation +25 feet to -150 feet MSL)

Based on lithologic descriptions from the Well Completion Reports, Aquifer B is likely the top of the uppermost aquifer within the Turlock Lake Formation. Aquifer B extends to a depth of 250 feet bgs and is approximately 150 feet thick. Aquifer B contains highly permeable sand and gravel layers. Below Aquifer B, a clay layer able to be correlated across the City and likely acts as an aquitard which helps to reduce vertical movement of groundwater.

4.2.3 Aquifer C (Elevation -150 feet to -250 feet MSL)

Based on lithologic descriptions from the Well Completion Reports and available geophysical logs, Aquifer C is likely the Turlock Lake Formation.

The top of Aquifer C is approximately 300 feet bgs in the west to 250 feet bgs in the east and is approximately 50 to 70 feet thick. Aquifer C consists of interbedded sand and clay. Below Aquifer C, a clay layer was correlated across the City separating Aquifer C and Aquifer D.

4.2.4 Aquifer D (Elevation -220 feet to -320 feet MSL)

Aquifer D consists of interbedded sand and clay, with less developed sand layers than the shallower aquifer zones. The top of Aquifer D is approximately 375 feet bgs in the west, and 310 feet bgs in the east. Continuous clay layers were correlated across the top and bottom of Aquifer D, the shallower clay being relatively thin (approximately 25 feet thick) and the deeper clay approximately 50 feet thick, as shown in Figure 3.

4.2.5 Aquifer E (Elevation -325 feet to -375 feet MSL)

The top of Aquifer E is approximately 450 feet bgs in the west and 425 feet bgs in the east and consists of a thin sand layer of relatively good permeability, as indicated in the geophysical logs. The approximate thickness of this aquifer is 20 feet and very few City wells are screened within Aquifer E. Below Aquifer E, a 50-foot thick clay layer was correlated across the City, separating Aquifer E from Aquifer F.

4.2.6 Aquifer F (Below Elevation -410 feet MSL)

The top of Aquifer F occurs at approximately 500 feet bgs and appears to be clay-dominated, with relatively thin zones of developed black sand. The water quality in Aquifer F degrades with depth regarding TDS and not suitable for potable supply by the City. Aquifer F is likely part of the Mehrten Formation based on the lithologic descriptions from the Well Completion Reports.

Below the freshwater-bearing aquifers are the Valley Springs and Ione Formations, respectively, which are confined groundwater aquifers containing brackish to saline groundwater. These formations historically had a higher hydraulic head (pressure) which resulted in saline water upwelling into the shallower aquifers where wells were drilled too deep. These formations can also contain significant amounts of methane gas which can create problems with pumping equipment, generate consumer complaints of “milky water,” and poses a safety concern as methane gas can create an explosive environment. The interface between fresh groundwater and saline groundwater is described herein as the base of freshwater, which occurs approximately 1,000 feet bgs beneath the City.

5 City of Turlock Well Field

5.1 Well Field Summary

The City currently maintains 25 production wells as part of its municipal water supply well field. As shown in Table 1, 19 wells are classified as active, four are inactive (Wells 10, 24, 28, and 38), and two are active but are currently on standby wells status (Wells 31 and 32). The four inactive wells and the two standby wells are currently not in use due to water quality concerns, as discussed in Section 6.4.

Table 1
City Well Field Status

Well	DDW Station Code	Well Status	Well	DDW Station Code	Well Status
Well 3	5010019-003	Active	Well 29	5010019-029	Active
Well 4	5010019-004	Active	Well 30	5010019-030	Active
Well 8	5010019-008	Active	Well 31	5010019-031	Standby/ Active
Well 10	5010019-010	Inactive	Well 32	5010019-032	Standby/ Active
Well 13	5010019-013	Active	Well 33	5010019-033	Active
Well 14	5010019-014	Active	Well 34	5010019-034	Active
Well 15	5010019-015	Active	Well 35	5010019-035	Active
Well 19	5010019-019	Active	Well 36	5010019-036	Active
Well 20	5010019-020	Active	Well 37	5010019-037RW37	Active
Well 22	5010019-022	Active	Well 38	5010019-038RW38	Inactive
Well 24	5010019-024	Inactive	Well 39	5010019-039RW39	Active
Well 27	5010019-027	Active	Well 40	5010019-040	Active
Well 28	5010019-028 M	Inactive			

The City has permanently removed 14 municipal wells from service for various reasons over the years. Thirteen of the wells are reported to have been destroyed and one well has been converted into a groundwater level monitoring station (Well 2). The reasons for each well destruction are shown in **Table 2**. The locations of all active, inactive, standby, and abandoned/destroyed City wells are shown in Figure 1. City wells were constructed using either the cable-tool or rotary drilling methods, with total depths ranging from 220 to 615 feet bgs.

Table 2
Destroyed/Abandoned City Wells

Well	Well Status	Reported Operation/ Water Qaulity Issues
Well 1	Destroyed	Mechanical failure of pump/oil in water (Abandoned in 1998)
Well 2	Abandoned	High Arsenic/High Sand Production (Closed in 2002)
Well 5	Destroyed	PCE/Nitrate/Arsenic Contamination (Abandoned in 1992)
Well 6	Destroyed	Casing Failure (Equipment removed in 1992)
Well 7	Destroyed	Pump Failure (Abandoned in 1988)
Well 9	Destroyed	Carbon Tetrachloride (Turned off in 1999)
Well 11	Destroyed	High Sand Production (Closed in 1988)
Well 12	Destroyed	Casing Failure (Abandoned in 1981)
Well 16	Destroyed	Elevated Nitrate and PCE (Closed in 2000)
Well 17	Destroyed	Elevated Nitrate (Closed in 1999)
Well 18	Destroyed	Casing Failure (Abandoned in 1999)
Well 23	Destroyed	Low yield, high sand production (Abandoned in 1994)
Well 25	Destroyed	High Nitrate/Arsenic (Abandoned in 1990)
Well 26	Destroyed	High Arsenic/Manganese and Hydrogen Sulfide

The City utilizes SCADA (Supervisory Control and Data Acquisition) to monitor groundwater levels in its well field. Wells 2, 10, 24, 38, and 39 currently have SCADA installed.

Data reviewed for this report include DWR Well Completion Reports, groundwater levels, water quality, site locations, and production data. The City monitors depth to groundwater levels at least semi-annually in all of the City's wells which provide a comprehensive dataset to assess for changes over time. Evaluation of year to year spring depth to groundwater level measurements allow a determination of the annual increase or decrease of groundwater in storage in the subbasin and to identify long-term trends. Groundwater levels are typically at their highest point in early spring following winter precipitation which, in part, recharges the Subbasin. Fall groundwater measurements record the lowest depth to groundwater, following the peak summer demand season.

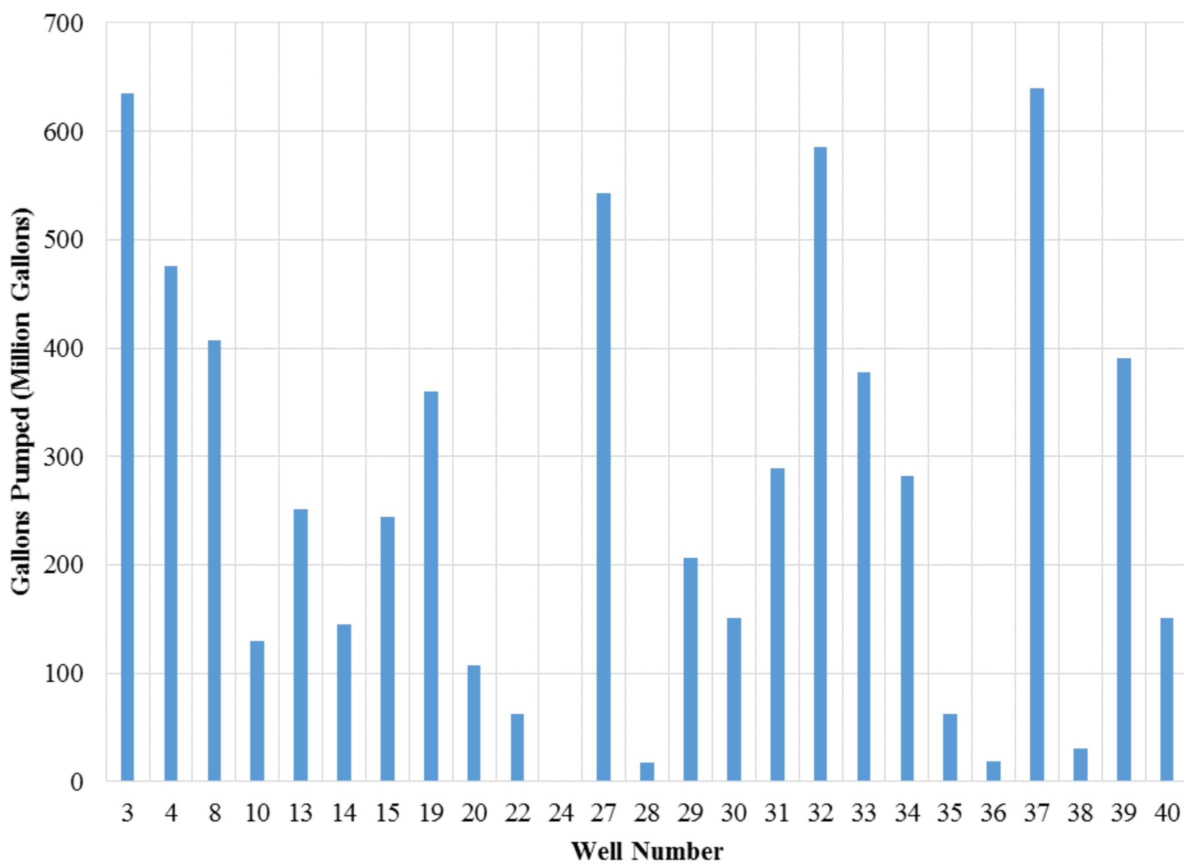
For each City well, a comprehensive history and narrative are provided in Section 10 of this report. Also, Volume 2 of the Appendix includes a site map, a data summary sheet, well construction profile, groundwater level hydrographs, water quality graphs, and production data. Well construction information and the most recent well production/testing information is summarized in Table 3 (located at the end of the report).

5.2 Well Field Production

Average annual well field production from 2008 through 2014 totaled almost 7.1 billion gallons. In 2014 alone, the City's well field produced approximately 6.5 billion gallons of water into the system, likely in response to current statewide drought.

In 2014, Wells 3, 27, 32, and 37 were the highest producing City wells, as shown in **Table 4**. Wells 22, 24, 28, 35, 36, and 38 were the lowest producing in 2014. **Table 5** includes a summary of groundwater production from 2008 through 2014.

Table 4
2014 City Well Field Production



6 Groundwater Conditions

6.1 Groundwater Levels

Depth to groundwater measurements have been recorded on a regular basis in Stanislaus County since the early 1950's by DWR and in the City's well field since the mid-1980s. Depth to groundwater measurements in the City's wells was plotted on hydrographs to depict groundwater conditions over time. These hydrographs are provided for each well in Section 10 of this report.

The dataset includes measurements for both static (non-pumping conditions) and pumping groundwater levels within the well field and suggests a slight decline in groundwater levels, with average declines between 0.5 and 2 feet per year from 1989 to 2015. Spring (i.e. peak) static groundwater levels have ranged between 25 and 70 feet bgs in the well field over the period of record. Seasonal groundwater level fluctuations of up to 50 feet have been documented in City wells. In spring of 2015, depth to groundwater measurements in the well field were between 40 to 70 feet bgs.

Depth to groundwater measurements from the City's well field was used to generate groundwater elevation contour maps to illustrate groundwater conditions in fall 2014 and spring 2015. As shown in **Figure 4**, fall groundwater contour elevations depict a pumping depression centered under the northwest portion of the City. Groundwater elevations ranged from approximately 20 feet MSL (approximately 70 to 80 feet bgs) under the perimeter of the City to an elevation of approximately 6 feet below MSL (approximately 100 feet bgs) within the depression. In spring 2015, groundwater elevations recovered by as much as 50 feet beneath the City, as shown in **Figure 5**, illustrating that the Subbasin receives seasonal recharge from winter precipitation.

6.2 Groundwater Movement

Groundwater movement is a function of groundwater recharge, naturally occurring gradients, and local and regional groundwater pumping. The natural groundwater flow direction is towards the southwest, following the regional dip of the basement rock and sedimentary units (DWR, 2003). No impairments or restrictive structures have been identified to groundwater flow.

The vertical hydraulic gradient within the City is unknown due to the lack of aquifer-specific monitoring wells.

6.3 Groundwater Quality Overview

Groundwater quality varies due to chemical reactions as water moves through geologic materials. Groundwater contamination can be a result of naturally-occurring compounds or anthropogenic sources. Naturally occurring contaminants of concern within the City include TDS, arsenic, and hexavalent chromium (Cr^{6+}). Anthropogenic contamination within the City include nitrates, fuel, solvents, and synthetic organic compounds (SOC).

The DDW regulates public water systems to ensure drinking water meets quality standards. DDW drinking water standards are more stringent than those enacted and enforced by the United States Environmental Protection Agency (EPA). Public Water Systems are required to report water quality data to the DDW, which maintains a comprehensive water quality database. In addition to the DDW water quality dataset, the City maintains an in-house water quality dataset. The DDW database and the City's water quality data were combined to evaluate historical trends, to identify current or previous exceedances above current maximum contaminant levels (MCLs), and to provide a tool to help guide future groundwater resource protection and development programs. The combined dataset contains water quality data from 1989 through January of 2015.

Table 6 below lists the respective MCLs for the constituents of concern found in City wells. Drinking water MCLs are classified as either primary (health-based) or secondary (may affect the taste, odor, or appearance of drinking water). Secondary standards often have a range of concentrations as guidelines.

Table 6
Primary and Secondary MCLs for Constituents of Concern Found in City Wells

Constituent	Units	Primary MCL	Secondary MCL		
			Recommended	Upper	Short Term
Arsenic	µg/L	10	-	-	-
Nitrate (as NO_3)	mg/L	45	-	-	-
Hexavalent Chromium (Cr-6)	µg/L	10	-	-	-
Total Dissolved Solids	mg/L	N/A	500	1,000	1,500
Carbon Tetrachloride (TCE)	µg/L	0.5	-	-	-
Tetrachloroethylene (PCE)	µg/L	5	-	-	-
Ethylene Dibromide (EDB)	µg/L	0.05	-	-	-

6.4 Current Water Quality

The City currently has 19 active groundwater wells which produce water that meets all DDW drinking water quality standards. Groundwater quality varies throughout the City, with both location and depth. To better understand the occurrence of and to identify probable aquifers with poor water quality, the water quality data were spatially plotted and analyzed to identify trends or areas within the City where elevated constituents occur. Select water quality data and well construction (screened intervals) were projected onto the geologic cross-section (Figure 3) to illustrate the aquifers penetrated and the respective water quality. A discussion of the occurrence of primary constituents of concern is provided below.

6.4.1 Arsenic

Arsenic is a naturally-occurring element found in rocks and minerals. Its presence in groundwater is a result of the dissolution of the naturally occurring element from sediments in the geologic formations, which is typical of Sierran-sourced sediments.

The spatial distribution of arsenic data indicates that wells constructed west of Geer Road and north of West Main Street have elevated concentrations of arsenic, as shown in **Figure 6**. Wells in this area have long screen intervals across multiple aquifers and clay layers, limiting the identification of a single aquifer which may be contributing to elevated arsenic concentrations that are near or exceed the current MCL of 10 micrograms per liter (µg/L). Wells with long screen intervals adjacent to both sand and clay layers may have higher concentrations of arsenic. Another trend that was observed is that wells completed in Aquifer D (Figure 3) could have elevated arsenic. Monitoring wells with single-aquifer completions in the northwest portion of the City are recommended to help identify zone-specific concentrations of arsenic.

6.4.2 Nitrate (as NO_3)

Nitrate is an anthropogenic contaminant which normally does not occur in the subsurface. Elevated concentrations of nitrate are widespread in the San Joaquin Valley and are introduced into shallow aquifers through applied fertilizer, leaky sewer systems, septic systems, and animal impoundments. Historical nitrate data indicate increasing concentrations in some of the City's wells over the period of record. Water quality trends suggest that Aquifers A and B (Figure 3) likely have concentrations of nitrate over the MCL of 45 mg/L.

As shown in **Figure 7**, there is a random spatial distribution of elevated concentrations of nitrate. The water quality data indicate that nitrate concentrations can have temporary spikes as observed in Wells 14, 19, 20, suggesting that when a well is idle, water moves from shallow aquifers downward into deeper aquifers. Wells that connect multiple aquifers can become conduits that allow shallow groundwater with elevated nitrate to migrate into deeper aquifers. In addition, shallow groundwater with elevated nitrate can migrate into deeper aquifers due to downward groundwater gradients.

Wells completed above a depth of approximately 250 feet bgs within the City typically have nitrate concentrations that are elevated.

6.4.3 Hexavalent Chromium (Cr^{6+})

Hexavalent chromium is both naturally-occurring and introduced into the environment through industrial uses. Discharge of contaminated water to land surface (i.e. chrome plating, cooling system discharges) is often the anthropogenic cause of elevated concentrations when background levels are low. In July 2015, the DDW established a new MCL for Cr^{6+} at 10 µg/L. Before the establishment of the Cr^{6+} MCL, only Total Chromium (which assumed all chromium occurred in the form of Cr^{6+}) was regulated by the EPA and DDW with an MCL of 50 µg/L.

Concentrations of naturally-occurring Cr^{6+} above the MCL of 10 µg/L have been observed along the western side of the San Joaquin Valley, as experienced by the Cities of Newman and Patterson. The City's well field data suggest that Cr^{6+} background levels are below the MCL, with an average concentration of 5.6 µg/L. The maximum reported concentration of 8.4 µg/L was reported in Well 27, as shown in **Figure 8**.

6.4.4 Total Dissolved Solids

TDS is a direct measurement of the dissolved salts in water, which can be used to determine the relative salinity of groundwater. TDS is a regulated contaminant; however, the MCL is a secondary (aesthetic) standard to regulate taste. As noted above, TDS has a recommended MCL of 500 mg/L, an upper threshold of 1,000 mg/L and a short-term MCL of 1,500 mg/L. The average concentration of TDS across the City's well field is 282 mg/L, below the recommended MCL of 500 mg/L. Concentrations did exceed the Recommended Limit in one well (Well 32), which was reported at 510 mg/L, as shown in **Figure 9**. Wells with slightly elevated TDS (Wells 32 and 36) have boreholes or original pilot holes drilled to depths of 600 feet bgs and 585 feet bgs, respectively, which suggest that Aquifer F may have elevated TDS.

Historical groundwater quality data indicate that concentrations of TDS have increased over the period of record, but are still within the DDW recommended MCL. Wells with deep boreholes or improperly destroyed pilot holes likely allow deeper more saline water to up-well into the well structures.

6.5 Known Contamination Sites

Groundwater contamination can come from naturally occurring or anthropogenic sources. Anthropogenic contamination occurs as a result of overlying land uses where contaminants enter and migrate throughout the underlying hydrogeologic system.

Overlying land uses pose a threat to groundwater contamination through accidental releases of hydrocarbons, solvents, and other volatile or synthetic organic compounds. Typical sources include petroleum products, dry cleaner solvents, pesticides, herbicides, and other industrial processes.

The State Water Resources Control Board's (SWRCB) GeoTracker is a data management system that allows public access to identified activities that have or have the potential to impacted groundwater quality. The sites include active remediation, post-cleanup monitoring, or closed sites and include permitted underground storage tank (UST), leaking underground storage tanks (LUST), Department of Defense, and Site Cleanup Programs.

Using the current dataset from GeoTracker[1], 111 cases were identified within the City, including one US EPA Superfund Site. The sites include:

- 24 Open Sites (characterized as Inactive, Eligible for Closure, Remediation, Site Assessment, or Verification Monitoring)
- 88 Closed Sites
- Valley Wood Preserving Superfund site

Of these 24 open sites, one is characterized as a land disposal site, Valley Wood Preserving (VWP), 13 are considered open but are either inactive or eligible for closure, four are actively undergoing remediation, two are in the site assessment phase, and four are going through verification monitoring. The VWP site was designated an EPA Superfund cleanup site in 1989. Currently, residual contamination remains onsite and in-situ remediation is ongoing[2]. A land use covenant was finalized in 2007 which restricts future use of the property to industrial and commercial use only.

The most common groundwater contaminants within the City are fuels and associated volatile organic compounds (VOCs). Tetrachloroethylene (PCE), chromium, lead, and other heavy metals have been detected in the City's wells, as shown in **Figure 10**. Figure 10 depicts the City wells that have been destroyed due to contamination by anthropogenic sources.

6.6 Unregulated Contaminants and Future Regulations

The DDW is required to adopt the federal drinking water regulations as set forth by the EPA, and often adopts more stringent regulations. The Safe Drinking Water Act of 1996 requires that the

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[1] http://geotracker.waterboards.ca.gov/data_download.asp, accessed on April 5, 2016
[2] https://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/vwsoalphabetic/Valley+Wood+Preserving,+Inc.?OpenDocument

EPA issue a list of no more than 30 unregulated contaminants once every five years, known as the Unregulated Contaminant Monitoring Rule (UCMR), which water systems are required to monitor for and report. The monitoring program under UCMR collects data to determine the occurrence of contaminants that may be present in tap water, but which currently do not have EPA drinking water standards. The program provides the basis for potential future regulatory actions and identifies contaminants which may affect public health.

On December 11, 2015, the EPA proposed the fourth UCMR (UCMR 4), which outlines monitoring for 30 chemical contaminants between 2018 and 2020[3]. Monitoring under UCMR 4 consists of ten cyanotoxins/groups; two metals; eight pesticides plus one pesticide manufacturing byproduct; three brominated haloacetic acid groups of disinfection byproducts; three alcohols; and three semivolatile organic chemicals.

Upcoming regulations from the SWRCB include for point-of-entry and point-of-use treatment, surface water augmentation using recycled water, and cross connection control. There are currently no additional constituents listed as being potentially regulated.

6.7 Contaminant Migration

Groundwater flows through porous sediments both laterally and vertically based on the physical properties of the formations (i.e. hydraulic conductivity) as well as hydraulic head (vertical groundwater gradient). Permeability and porosity of the geologic formations significantly affect the rate and direction of groundwater flow. Vertical groundwater movement is impeded by clay layers, whereas horizontal movement through sand and gravel layers will follow the groundwater gradient. Contaminants in groundwater can be transported based on aquifer properties and hydraulic gradients, or through well structures that are completed within multiple aquifers or have inadequate seals.

The underlying hydrogeologic system consists of two distinct aquifers, the unconfined and confined aquifers. The Corcoran Clay is a regional confining layer that separates the two aquifers. The unconfined aquifer system (Aquifer A) is mostly dewatered, likely isolated zones of shallow perched groundwater. Contaminants in Aquifer A can be mobilized and transported by surface water infiltrating and migrating downward into the subsurface. Aquifer A has been susceptible to point-source contamination from overlying land uses. Aquifers B through F occurs beneath the Corcoran Clay. Many of these aquifers are interconnected by City wells that provide conduits for direct downward migration of contamination.

The hydrogeologic system has a downward groundwater gradient, meaning groundwater has the natural tendency to flow downward into deeper aquifers with lower static water levels. The artificial lowering of groundwater levels by production wells can increase the propensity for the downward migration of contamination. Increasing concentrations of nitrate (as NO_3) over time have been documented in the City's well field, indicating nitrate is likely migrating downward from shallow aquifers into the deeper aquifers.

Poorer quality water can also be pulled upwards (up-coning) due to pumping wells where they intersect or are in proximity to aquifers with elevated contaminants. Improperly destroyed pilot holes or test holes can act as conduits allowing deeper, poor quality water to migrate vertically

[3] https://www.epa.gov/dwucmr/fourth-unregulated-contaminant-monitoring-rule

upwards. City wells where the pilot holes or boreholes extend into Aquifer F have relatively higher concentrations of TDS, indicating either up-coning of poor quality water or that the target aquifer contains poor quality water. Well 37 has a bentonite seal placed in the annular space below the well structure, which was likely designed to inhibit up-coning of poor quality water.

7 Well Field Interference Assessment

7.1 Well Field Interference

To evaluate potential pumping interference between existing and future City wells, Wood Rodgers designed a well testing program to define the aquifer characteristics and calculate potential interference within the City's well field. Radial impacts, or the formation of cones of depression, are related to the aquifer characteristics and can have consequences of artificially lowering the groundwater level in nearby wells.

7.2 Well Interference Testing Program

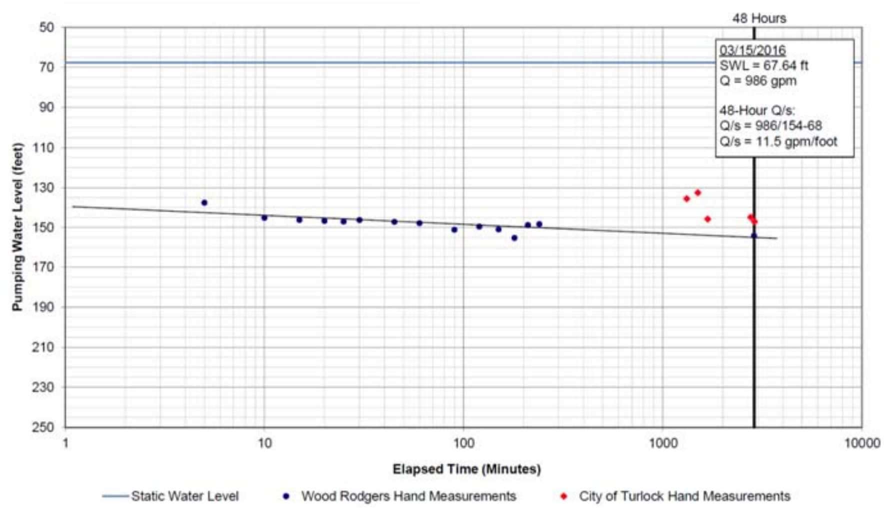
The well testing program utilized existing City wells located near the four actively monitored SCADA locations. Wells identified as candidates for testing and observation were evaluated regarding well construction (e.g. well depth and well screen intervals) and operational capacity.

Based upon available well construction information and input from City staff, Wood Rodgers identified Well 8 as most favorable to conduct well interference testing. Well 8 is located in the eastern portion of the City's well field and is approximately 2,400 feet from Well 24, which is monitored by SCADA. Well 8 and Well 24 have similar well construction; Well 8 has well screen between 350 and 420 feet (Aquifer D), and Well 24 has well screen from 140 to 250 feet (Aquifer B) and 290 to 400 feet (Aquifer D). Aquifer D exists throughout the northern portion of the City, and likely continues to the south. To record a response in the non-pumping well (Well 24), Wood Rodgers determined that the well test would need to be a minimum duration of 48 hours..

7.3 Well Testing

On March 15, 2016, Well 8 was turned on for a 48-hour period and pumped at an average flow rate of 986 gallons per minute (gpm). Before the test, the static water level was measured 68 feet below the top of the casing (TOC). After 48-hours of continuous pumping, the pumping water level was measured at 154 feet below TOC, with a total drawdown of 86 feet. The calculated 48-hour specific capacity (Q/s) was 11.5 gpm per foot (gpm/foot) of drawdown, as shown below in **Figure 11**. The maximum measured drawdown in Well 24 was 1.4 feet.

Figure 11
48-Hour Constant Rate Test Well 8

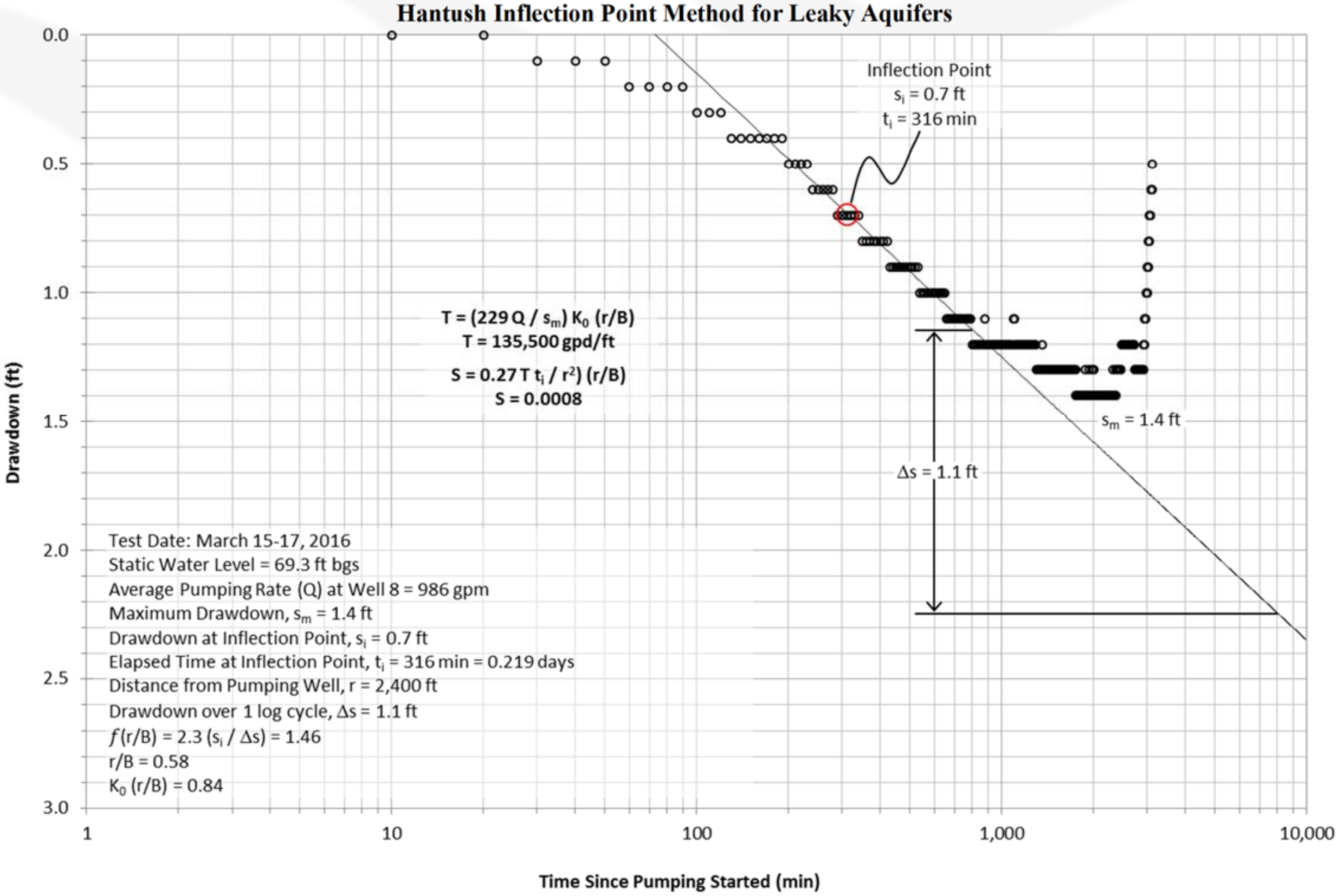


7.4 Test Analysis and Assumptions

Data obtained from the well testing were evaluated using the Hantush Inflection-Point (HIP) method, developed by Hantush (1956) to determine aquifer transmissivity (T) and Storativity (S), as shown below in **Figure 12**. The HIP solution approximates the aquifer as a "leaky confined two-aquifer system." Some of the assumptions for the HIP solution are listed below:

- The aquifer is leaky
- Aquifer has infinite areal extent
- Aquifer is homogeneous, isotropic and of uniform thickness over the area influenced by the pump test
- Prior to pumping, the piezometric surface and the water table are horizontal over the area that will be influenced by the test
- The aquifer is pumped at a constant discharge rate
- The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow
- The flow in the aquitard is vertical
- Diameter of the pumping well is very small so that storage in the well can be neglected
- The drawdown in the un-pumped aquifer (or in the aquitard if there is no un-pumped aquifer) is negligible

Figure 12
Hantush Inflection Point Method for Leaky Aquifers



From the data collected, the aquifer T and S were calculated. Transmissivity is defined as the rate of flow under a unit hydraulic gradient through a unit width of aquifer of given saturated thickness. Storativity is defined as the volume of water released from storage per unit surface area of a confined aquifer per unit decline in hydraulic head. It is also known as the coefficient of storage and storage coefficient and is a unit less number. The analysis estimated that Aquifer D has a T of approximately 135,500 gallons per day per foot (gpd/foot) of drawdown and an S of 0.0008.

The hydraulic conductivity can be calculated from the T and aquifer thickness (b) by:

$$T = Kb$$

Where:

T: *Transmissivity*
K: *Hydraulic Conductivity*
b: *Aquifer thickness*

Rearranging the equation and using the calculated T and an aquifer thickness of 90 feet, the hydraulic conductivity was calculated to be 1,505 gpd/ft^2, indicating a relatively coarse sand aquifer.

The geophysical logs suggest that both Aquifer B and Aquifer C have coarser-grained sediments than Aquifer D. Assigning the estimated aquifer characteristics to Aquifer B and Aquifer C would likely result in a more conservative estimation of T and S.

Table 7
Aquifer Characteristics of Aquifer D

Pumping Well	Observation Well Used in Solution	Distance from Pumping Well (feet)	Calculated Aquifer Transmissivity (gpd/ft of drawdown)	Storativity	Hydraulic Conductivity (gpd/ft^2)
Well 8	Well 24	2,400	135,500	0.0008	1,505

7.5 Estimated Pumping Interference

Using the estimated aquifer characteristics, pumping interference in nearby wells was projected using an analytical model. **Table 8** below illustrates calculated interference in wells at various distances from the pumping well. A pumping cycle of seven days was simulated at flow rates of 1,000 gpm and 2,000 gpm.

Table 8
Estimated Well Interference

Distance from Pumping Well (feet)	1,000 gpm	2,000 gpm
	Calculated Interference (feet)	Calculated Interference (feet)
1,000	5.0	10.0
1,500	4.0	8.5
2,000	3.8	7.6
2,500	3.5	6.9

For planning purposes, new wells with a design capacity of 2,000 gpm will likely cause 10 feet of mutual pumping interference in wells constructed in the same aquifers located 1,000 feet apart.

8 Recommended Well Locations

Wood Rodgers divided the City into quadrants (shown in **Figure 13**) to assess each area's suitability for new well construction concerning water quality and production capability. The quadrants are divided by the north-south Geer/Lander Roads and the east-west Canal Road and include the City's Sphere of Influence. Each quadrant was assessed based on the ability to construct new wells concerning acceptable water quality and well yield. City-owned property, proximity to water distribution infrastructure and parcels with sufficient size for the construction of municipal groundwater wells were evaluated to identify suitable candidate locations. Several of the properties which are privately owned were strategically located to meet future growth, in addition to being able to accommodate potential water storage. Figure 13 illustrates the average well capacity (2014 data) for each of the City's active wells as well as potential candidate well sites.

Candidate well sites will require detailed analyses identifying site access, well construction equipment size requirements, proximity to known groundwater contamination sites (Figure 10) and poor quality water, and DDW regulatory setback requirements. For well sites meeting the above-ground requirements, a subsurface assessment should be implemented. The evaluation should include an exploratory drilling program to identify the aquifer depth(s), lithologic characteristics, and water quality.

8.1 Northwest City Quadrant

The City currently operates ten wells in the northwest area of the City. Based on Wood Rodgers' analysis of groundwater quality in this quadrant, five of the wells produce water with arsenic concentrations of 9 µg/L or above. The vertical distribution of elevated arsenic is currently not very well understood, as the existing wells screen multiple aquifer zones and clay layers. There are likely aquifer zones which have acceptable water quality regarding arsenic. To better understand the vertical distribution of arsenic, the City should assess new well sites with depth-specific monitoring wells. Existing City wells in this quadrant are equipped to produce between 840 gpm and 3,000 gpm, with an average of 1,720 gpm. Specific capacities range between 11 and 54 gpm/foot of drawdown.

New wells constructed in this area should be designed with sufficient annular seals below Aquifers A and B to a depth of approximately 250 feet to avoid potential nitrate contamination. New wells will need to be selectively screened to target aquifer intervals with the best water quality. As shown in **Figure 14**, Ferreira Ranch Park is a good candidate site due to its adequate access for test hole and production well drilling and its proximity to a 10-inch water distribution main.

8.2 Northeast City Quadrant

The City currently has six wells in the northeast area of the City. Nitrate concentrations have exceeded the MCL in several of the wells constructed in the shallow aquifers, which suggests Aquifers A and B may be interconnected, allowing the downward migration of poor quality groundwater. Arsenic concentrations are below the MCL. City wells in this quadrant produce between 540 gpm and 1,580 gpm, with an average of 1,100 gpm. Specific capacities range between 6 and 50 gpm/foot of drawdown.

New wells constructed in this area should be designed with sufficient annular seals below Aquifers A and B to avoid elevated nitrate concentrations. Potential well sites will require exploratory drilling programs with depth-specific water quality assessments. New wells will need to be designed to screen the aquifer intervals selectively with the best water quality.

As shown in Figures 15 through 17, three candidate locations were identified for potential municipal well development. Two of the candidate sites referred to as the Eastern Storm Basin North and South Sites (**Figures 15 and 16**), are located along the eastern boundary of the City. The selected locations are on the high ground between the storm pond depressions. A 12-inch distribution main is located just west of the candidate locations underneath Country Walk Lane. The third candidate location is just east of the City limit on East Monte Vista Avenue. The candidate site is in the southeast portion of the Larsa Banquet Hall property as shown in **Figure 17**. This site has sufficient area to construct a municipal supply well (with approximately 100 feet by 150 feet of open space), appears to be unused, and is proximate to a 10-inch water distribution main.

8.3 Southeast City Quadrant

There are currently four City wells constructed in the southwest area of the City. Three of these wells have acceptable water quality. Well 10 has PCE above the MCL and has been moved to inactive status. Existing City wells in this quadrant are equipped to produce between 440 gpm and 2,305 gpm, with an average of approximately 1,500 gpm. Specific capacities range between 27 and over 50 gpm/foot of drawdown.

The southeast area is identified as a potential growth area, as indicated by the City's Sphere of Influence. Limited data exist for the freshwater aquifer system in this area. A site-specific exploratory drilling program should be implemented to collect depth-specific data to design a new municipal well in this area. Annular seals will need to be designed to terminate below the shallow/near-surface contamination.

Two candidate locations were selected based on open land and proximity to water distribution mains. As shown in **Figure 18**, an undeveloped parcel at the intersection of East Linwood Avenue and Golf Road was selected due to its size and proximity to a 12-inch water distribution main. This location is also strategically located to serve future development in the southeast area of the City. The property is currently privately owned. The second site, as shown in **Figure 19**, is located on East Glenwood Avenue near the intersection with Amberwood Lane. The candidate site is on private property; however, it is close to a 10-inch water distribution main and has sufficient open area for the construction of a new municipal well. The site can also likely accommodate a new storage reservoir.

8.4 Southwest City Quadrant

In the southwest area of the City, arsenic concentrations are acceptable and below the MCL. Nitrate concentrations have increased in this area but are still below the MCL. It appears that increasing nitrate concentrations have relatively stabilized in this area. Concentrations of TDS are also favorable within the freshwater aquifer system at this location.

Existing City wells in this quadrant are equipped to produce between 1,000 gpm and 1,200 gpm, with an average of 1,100 gpm. Specific capacities range between 9 and 26 gpm/foot of drawdown.

The southwest area is identified as a potential growth area, as indicated by the City's Sphere of Influence. Limited data exist for the freshwater aquifer system in this area. Candidate well site locations will require site- and depth-specific assessments before designing a new municipal well and should not be located near the abundant animal enclosures in that area.

9 Conclusions and Recommendations

9.1 Conclusions

- The City has adequate groundwater resources to supply current and future municipal water demands.
- Inter-aquifer mixing appears to be occurring in City wells which have well screen in both the shallow and deeper aquifers, where shallow groundwater flows downward into deeper aquifers when wells are idle, resulting in spikes in nitrate concentrations.
- Nitrate concentrations are elevated across the entire City and have been increasing in several wells constructed in the shallow aquifers, further indicating that contamination is likely migrating downward.
- Elevated arsenic concentrations are highest in the northwest sector of the City.
- City wells completed within Aquifer D and/or clay layers are likely contributing to elevated concentrations of arsenic.
- Wells constructed to a depth of 600 feet (Aquifer F) will likely have elevated TDS.
- Analysis of the well testing program suggests that at a pumping rate of approximately 1,000 gpm, mutual pumping interference of fewer than two feet can be expected in wells completed in the same aquifer(s) and located 2,500 feet from each other.
- At a pumping rate of approximately 2,000 gpm, wells constructed in Aquifers B and D and located 1,000 feet from each other will experience an estimated 10 feet of mutual pumping interference.
- Some of the newer low-yielding wells (Wells 34 and 39) have well screen and gravel envelope material that was improperly designed (i.e. small slot size openings and small gravel envelope gradation), resulting in a reduced specific capacity in the wells.

9.2 General Recommendations

- Test holes for site exploration should be drilled to depths of not more than 600 feet and be geophysically logged to identify the interface of fresh and brackish water. Test holes/pilot holes should be destroyed with an impermeable material to prevent upward migration of poorer quality water.
- All future well sites should be assessed with depth-specific water quality exploration to refine the understanding and occurrence of elevated arsenic concentrations and to help establish the vertical gradation between aquifers.
- New wells should be selectively screened within the freshwater aquifers identified (while avoiding clay layers) that will meet the City’s water quality and capacity objectives.
- New wells should be designed to provide a long service life, allow for groundwater level monitoring, and provide acceptable sand control.

9.3 Well Design Recommendations

- Selectively screen aquifers with favorable water quality.
- Do not screen clay formations.
- Gravel envelope selection should not be over conservative, which is reducing well yields of some existing wells.
- Wells should be deigned to provide access for the measurement of water levels.
- Seal off aquifers of poor water quality with continuous annular seals.
- Do not screen aquifers of different hydraulic heads or water quality.

9.4 Well-Specific Recommendations

9.4.1 Well 10

Assess well to determine if it can be modified to improve water quality.

9.4.2 Wells 14 and 19

Both wells have shallow perforations which promote the downward migration of water from Aquifer B to deeper aquifers when they are idle. Long periods of down time for these wells should be avoided to help preserve the water quality of the deeper aquifers.

9.4.3 Well 20

The water quality data suggest that arsenic and nitrate concentrations exhibit an inverse relationship, meaning when concentrations of nitrate are lower, concentrations of arsenic are higher, and vice versa. This relationship suggests groundwater from the shallower aquifers is mixing with the deeper aquifers. Implementing a strategic pumping program may help improve water quality produced from Well 20.

9.4.4 Well 24

The well screen intervals in Well 24 start at 140 feet bgs within the upper portion of Aquifer B, which is known to contain high concentrations of nitrate within the northeast sector of the City. The well structure is currently acting as a conduit, moving water from Aquifer B to Aquifers C and D. Well 24 should either be modified in an attempt to improve water quality or destroyed to stop the downward migration of contamination.

9.4.5 Well 31

Well 31 could be used to test if Aquifer D is a major source of high arsenic concentrations for wells in the Northeast quadrant. It is recommended that the bottom of this well be sealed off to a depth of 340 feet bgs and re-tested to determine if water quality improves.

9.4.6 Well 32

Wood Rodgers prepared a plan to repair Well 32 that includes sealing off the lower portion of Aquifer D to help improve water quality. Execution of this plan is recommended.

9.4.7 Well 38

Well 38 has a single well screen interval from 285 to 595 feet bgs. Because of the long well screen interval and the high concentration of arsenic, Well 38 should be profiled to determine depth-specific water quality. If an aquifer with a high concentration of arsenic is identified, this information could be used to design and implement a well modification program. In addition, this information could possibly be used to help design new wells and to modify nearby wells.

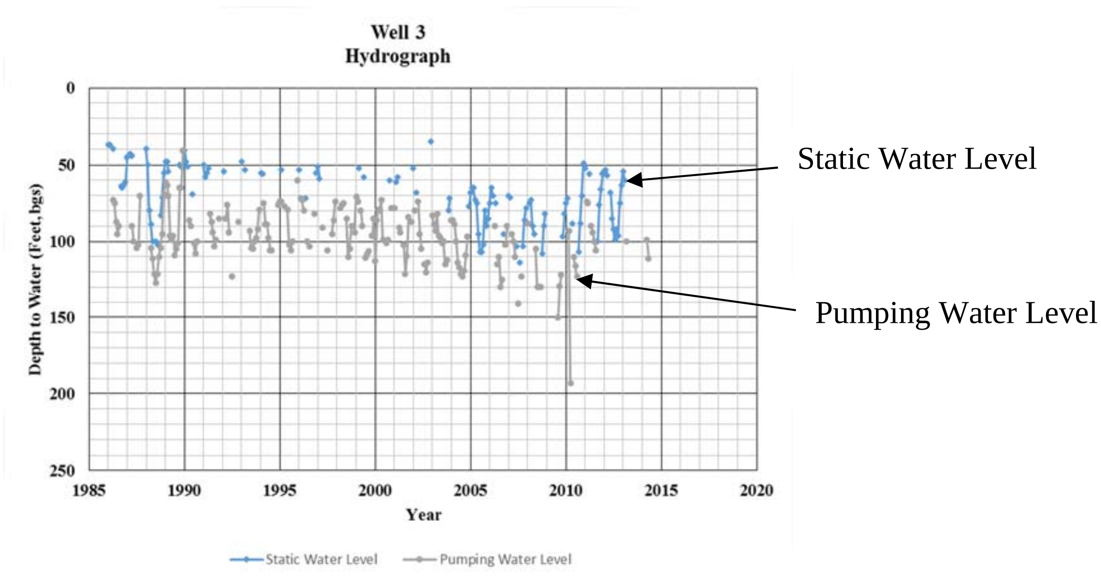
9.4.8 Well 39

Because of the low specific capacity of this well (6 gpm/foot of drawdown), this well has significant drawdown for the current capacity. A well re-development program may be warranted to improve the well yield. This well has a very conservative design with small well screen slot size and small gravel envelope material, which are likely two reasons for the low specific capacity for this well.

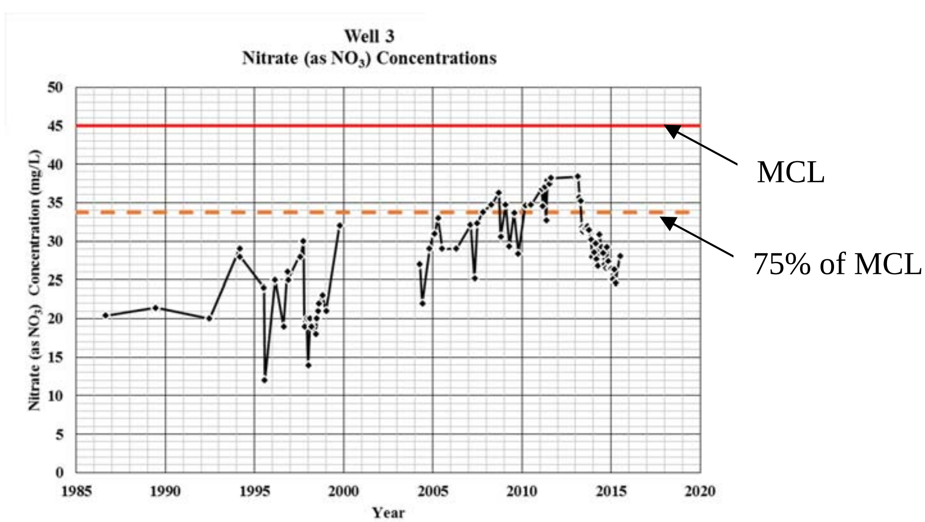
10 Detailed Well Site Narratives

In the following section, groundwater and water quality trends are discussed in more detail for each of the City's wells. Detailed groundwater level hydrographs and water quality graphs are included in the Appendix of this report.

Groundwater data were plotted on hydrographs and depicts depth to static and pumping groundwater levels (as feet, bgs) over time, as shown in the example below.



Historic water quality data were plotted for arsenic, nitrate (as NO_3), Cr^{6+} and TDS. The red line illustrated on the water quality graphs represent the constituent's respective MCLs, and the dashed orange lines depict the 75 percent value of the respective MCLs, as shown below.



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10.1 Well 3 (Active)

Well Construction

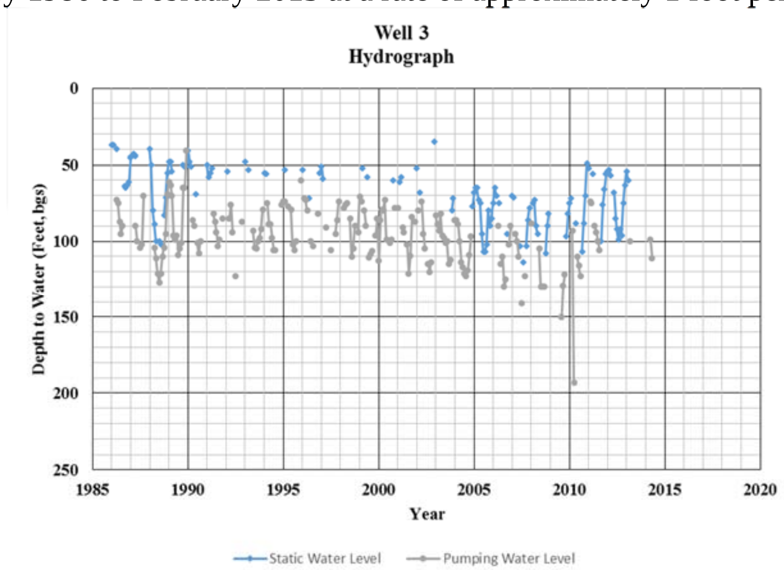
Well 3 is located at 2801 Greer Road, as shown in Figure 1. Well 3 was constructed by the cable tool drilling method in November of 1972, presently making this well 43 years old. The well was drilled to a depth of 365 feet. A 20-inch conductor casing and a sanitary seal are set to a depth of 84 feet. The upper portion of the well consists of a 16-inch diameter steel casing extending from the ground surface to a depth of 184 feet. Within the 16-inch diameter casing is a 14-inch diameter steel casing that extends from 156 to 256 feet. A 12-inch diameter steel casing extends from 252 to 352 feet, with pre-cut vertical slots from 156 to 352 feet. The remaining 13 feet of the well is uncased and open borehole.

Well Equipment and Production

Well 3 is equipped with a 100 horsepower electric motor and a Byron Jackson vertical turbine pump set to a depth of 180 feet. In 2014, the well was reported to produce 635,339,000 gallons of groundwater to the system (approximately 10% of the total well field production) at an average rate of 1,218 gpm and a specific capacity of approximately 24 gpm/foot of drawdown. Well 3 is equipped with a sand separator, indicating current or historic sand production, which is typical of a cable tool well.

Groundwater Levels

Groundwater levels have been measured in Well 3 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 60 feet bgs (February 2013). Groundwater level declines were observed from 1986 to 2005, with steeper declines from 2005 through 2010 where water levels declined to a depth of 70 feet. In 2011, water levels recovered to a depth of 50 feet. Spring static water levels have declined by 23 feet from February 1986 to February 2013 at a rate of approximately 1 foot per year.

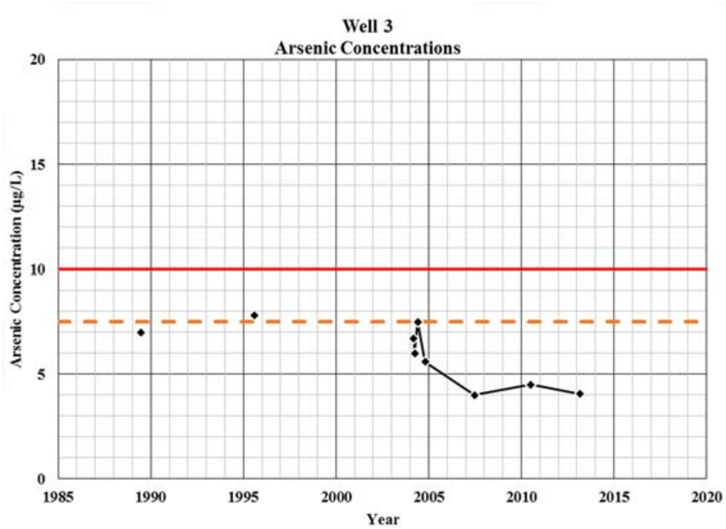


Water Quality

Water quality records indicate that the water produced from Well 3 currently meets all DDW primary and secondary drinking water requirements. Well 3 is currently active and provides untreated water to the system.

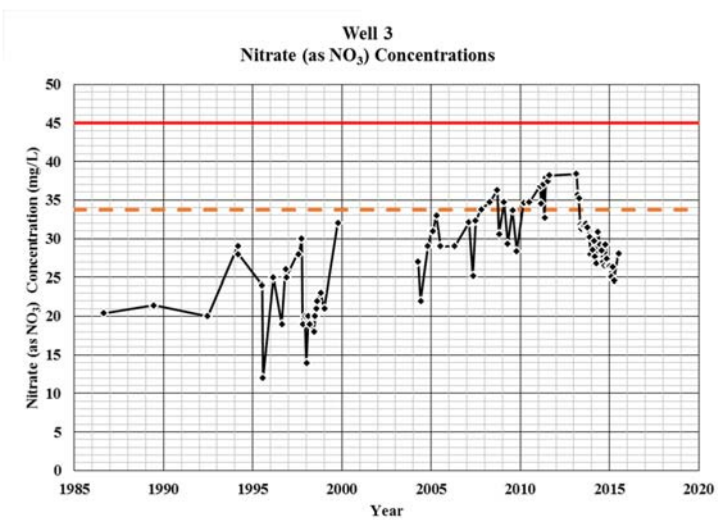
Arsenic

Well 3 produces water with arsenic concentrations below the MCL of 10 µg/L. Over the period of record, arsenic concentrations exhibit an overall decreasing trend. Prior to 2004, concentrations were relatively stable between 6 µg/L and 7.8 µg/L. Subsequently, concentrations reduced below 5 µg/L and appear to have stabilized near 4 µg/L. The most recent concentration of 4 µg/L was reported in 2013.



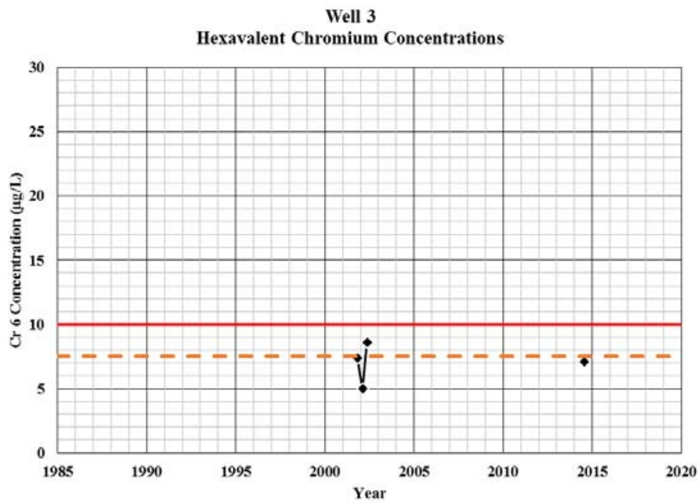
Nitrate (as NO_3)

Well 3 produces water with concentrations of nitrate below the MCL of 45 mg/L. Over the period of record, nitrate concentrations steadily increased to a high of 38.4 mg/L. In 2013 the trend reversed and concentrations decreased. The most recent concentration reported was 28 mg/L in 2015.



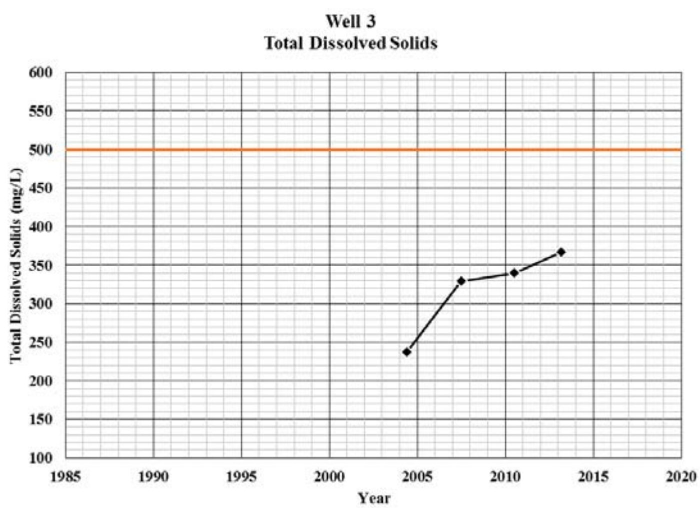
Hexavalent Chromium

Cr^{6+} concentrations are below the MCL of 10 µg/L, with the most recent concentration recorded at 7.1 µg/L in 2014. Data from 2001 and 2002 indicate varying concentrations; however, this is likely due to laboratory methods at the time.



Total Dissolved Solids

Since 2004, concentrations of TDS have increased at a rate of 14 mg/L per year. The most recent reported concentration in 2013 was 370 mg/L. The water produced from Well 3 is currently below the Recommended Limit of 500 mg/L for TDS. However, if the concentration continues to increase, Well 3 could produce water which exceeds the Recommended Limit in just over 10 years.



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10.2 Well 4 (Active)

Well Construction

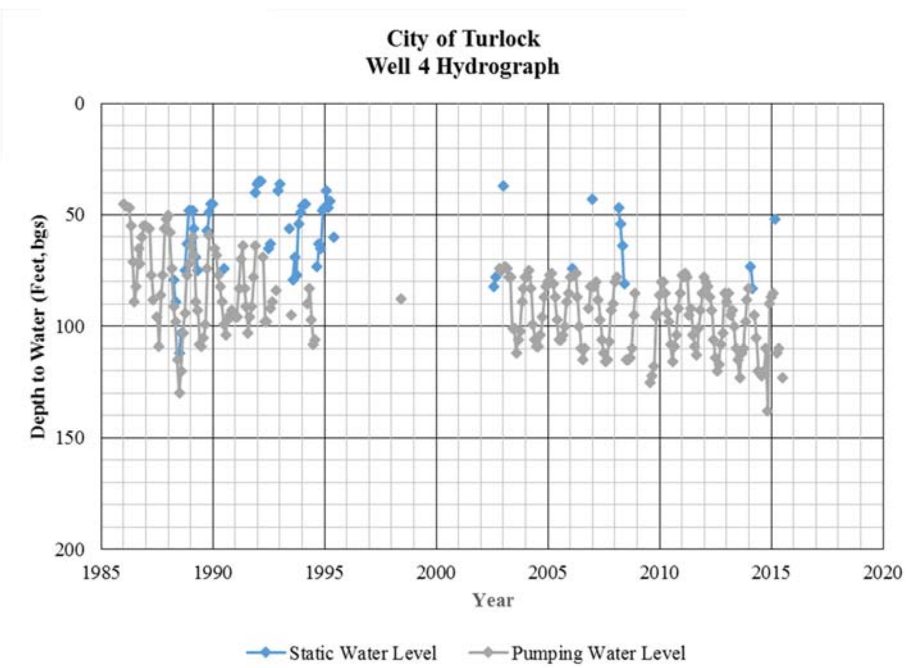
Well 4 is located at 1402 N. Tully Road, as shown in Figure 1. Well 4 was constructed by the cable tool drilling method in March 1976, presently making this well 40 years old. The well was drilled to a depth of 352 feet. A 20-inch conductor casing and a sanitary seal are set to a depth of 53 feet. The upper portion of the well consists of a 16-inch diameter steel casing extending from the ground surface to a depth of 176 feet. Within the 16-inch diameter casing is a 14-inch diameter steel casing that extends from 154 to 254 feet. A 12-inch diameter steel casing extends from 244 to 344 feet, with pre-cut vertical slots from 158 to 340 feet. The remaining 8 feet of the well is uncased and open borehole.

Well Equipment and Production

Well 4 is equipped with a 100 horsepower electric motor and a Peerless vertical turbine oil-lubricated pump set to a depth of 210 feet. The well is reported to produce an average of 1,038 gpm to the system with a specific capacity of approximately 15 gpm/foot of drawdown. In 2014, Well 4 produced 475,192,000 gallons of groundwater, approximately 7% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 4 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 52 feet (March 1, 2015). Spring static water levels have declined by 17 feet from March 1992 to March 2015 at a rate of approximately 0.7 feet per year. Seasonal fluctuations of up to 40 feet have been documented in the pumping water level measurements.

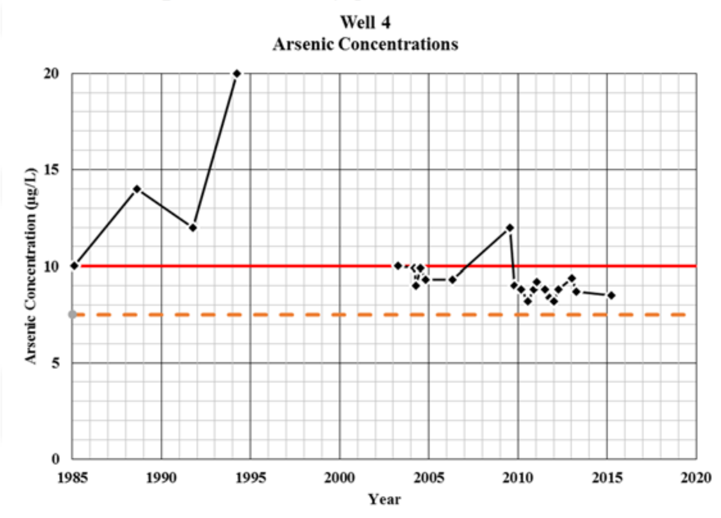


Water Quality

Water quality records indicate that the water produced from Well 4 currently meets all DDW primary and secondary drinking water requirements. Well 4 is currently active and provides untreated water to the system.

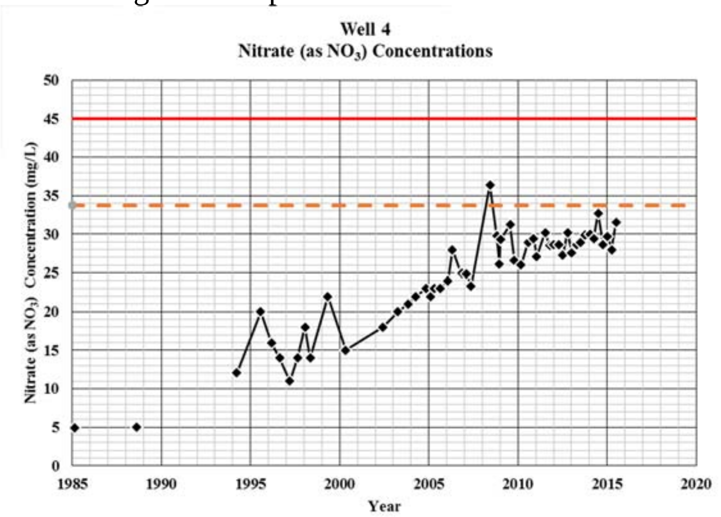
Arsenic

Concentrations of arsenic have historically exceeded the current MCL. Since 2003, concentrations have been decreasing and are currently below the MCL. In 2009, there was one anomalous high result of 12 µg/L, but concentrations have continued to range between 8 µg/L and 9.5 µg/L. The most recent concentration was reported at 8.5 µg/L in 2015.



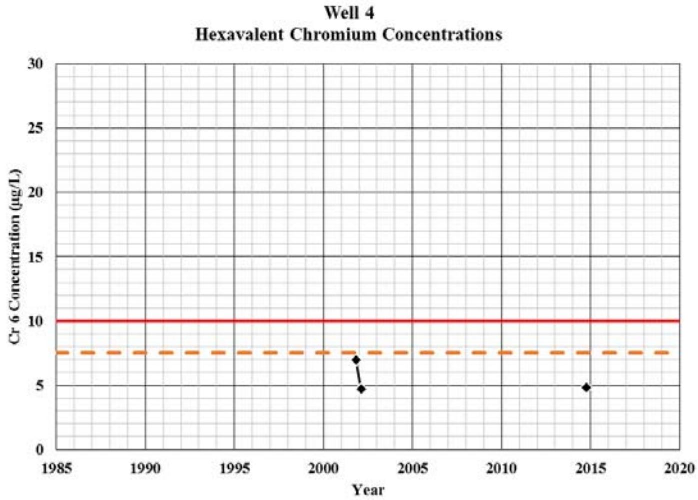
Nitrate (as NO_3)

Concentrations of nitrate (as NO_3) increased steadily from 1985 to 2009 at a rate of approximately one mg/L per year, from 5 mg/L to 32.1 mg/L. In 2009, the trend began to stabilize with apparent seasonal fluctuations. Since 2009, concentrations have ranged between 26 and 33 mg/L. The most recent concentration of 31.5 mg/L was reported in 2015.



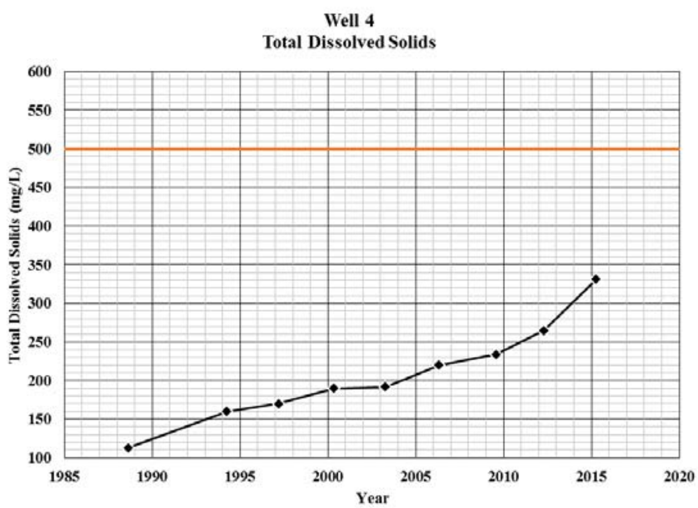
Hexavalent Chromium

Concentrations of Cr^{6+} from 2002 and 2014 indicate the water produced is below the MCL. The most recent concentration of 4.8 µg/L was reported in 2014.



Total Dissolved Solids

TDS concentrations have increased at a rate of approximately 8 mg/L per year over the period of record, from 113 mg/L in 1988 to 331 mg/L in 2015. The water produced is below the Recommended Limit of 500 mg/L for TDS. The City should continue to track concentrations of TDS in the produced water.



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10.3 Well 8 (Active)

Well Construction

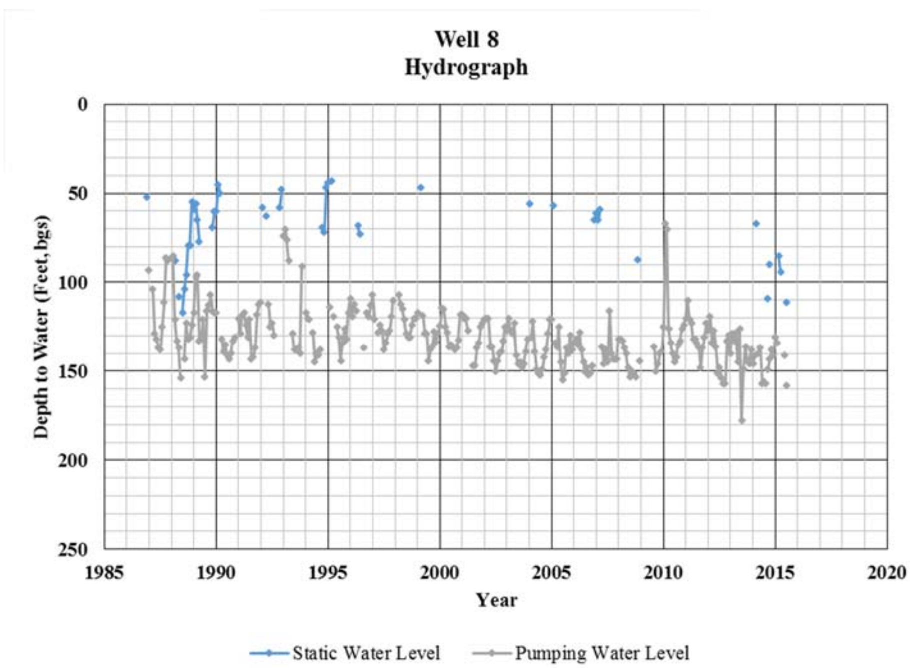
Well 8 is located at 1690 Palmer Drive, as shown in Figure 1. Well 8 was constructed by the reverse rotary drilling method in 1978, presently making this well 38 years old. A test hole was drilled to a depth of 600 feet, with a final borehole depth of 450 feet and the well casing set at a depth of 430 feet. The test hole was sealed or filled with an unknown material. A 20-inch conductor casing and sanitary seal are set to a depth of 60 feet. The well consists of a 14-inch diameter steel casing extending from the ground surface to a depth of 430 feet with Johnson well screen extending from 350 to 420 feet.

Well Equipment and Production

Well 8 is equipped with a U.S. Motor 125 horsepower electric motor and an oil-lubricated vertical turbine pump set to a depth of 210 feet. In 2014, the well was reported to produce an average of 780 gpm to the system with a specific capacity of approximately 30 gpm/foot of drawdown. Well 8 produced 407,684,400 gallons of groundwater, approximately 6% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 8 since 1986 and include both static and pumping water level measurements, with the majority of measurements obtained while the pump was operating. Static groundwater level trends are difficult to ascertain with limited measurements. The most recent spring high static groundwater level measurement was 85 feet (March 2015). This measurement may have been influenced by recent pumping. Spring static water levels have declined by 42 feet from March 1995 to March 2015 at a rate of approximately two feet per year.

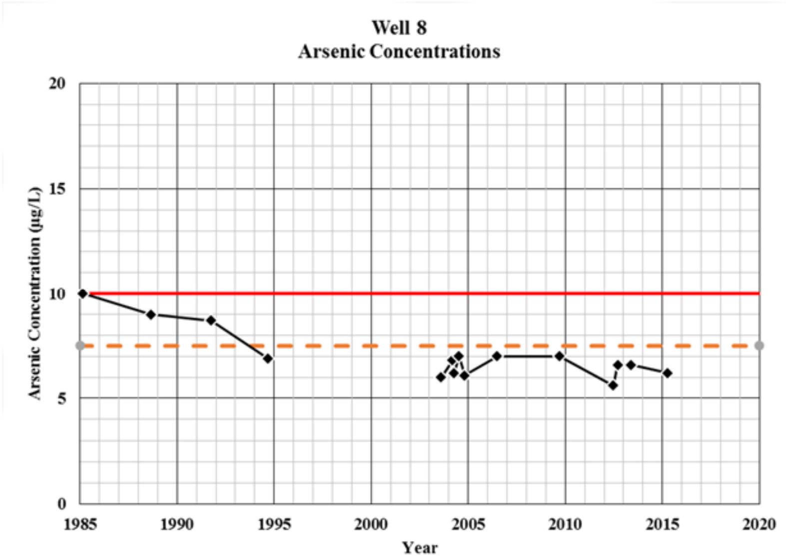


Water Quality

Water quality records indicate that the water produced from Well 8 currently meets all DDW primary and secondary drinking water requirements. Well 8 is currently active and provides untreated water to the system.

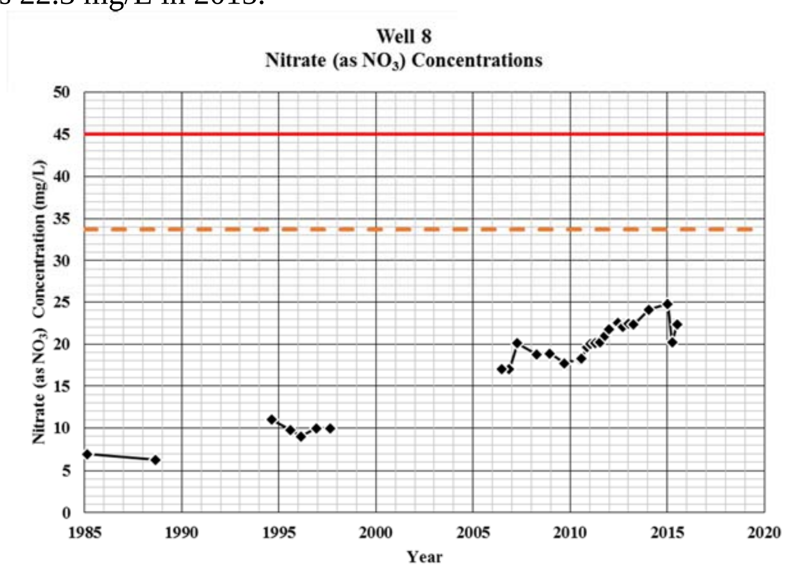
Arsenic

Prior to 1995, concentrations of arsenic were decreasing, which is likely related to laboratory methods improving and the lowering of the minimum detection level. Since 1994, concentrations of arsenic have remained stable, ranging between 5 and 7 µg/L. The most recent concentration of 6.1 µg/L was recorded in 2015.



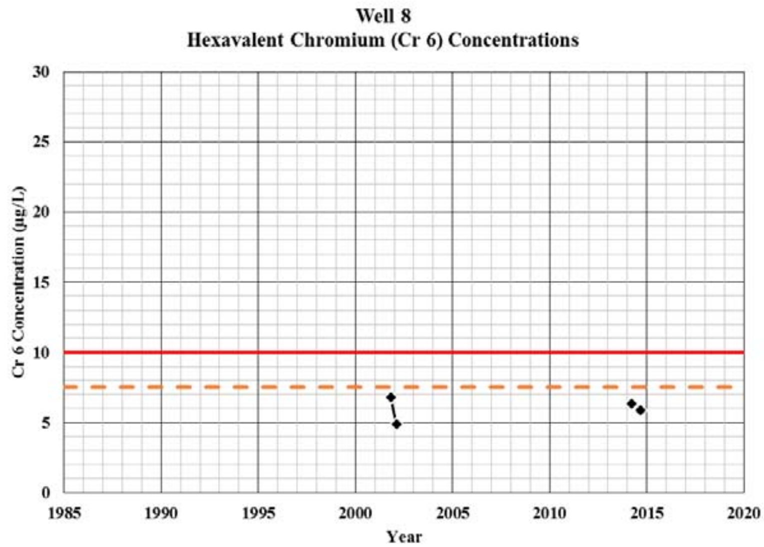
Nitrate (as NO_3)

Historic nitrate (as NO_3) data indicate an increasing trend from 7 mg/L in 1985 to 25 mg/L in 2015; however, in 2015, concentrations appeared to decrease. The most recent reported concentration was 22.3 mg/L in 2015.



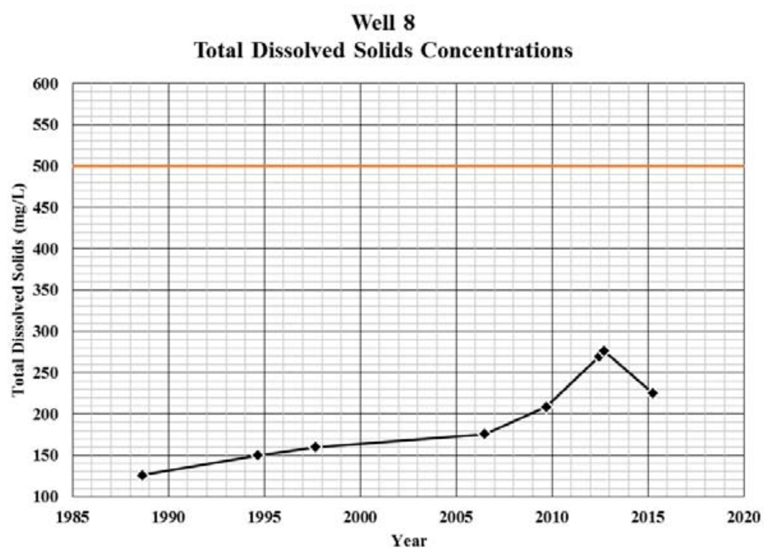
Hexavalent Chromium

Concentrations of Cr^{6+} in 2002 and 2014 are below the MCL of 10 µg/L, with the most recent concentration of 5.9 µg/L recorded in 2014.



Total Dissolved Solids

TDS concentrations have increased over the period of record at a rate of approximately 4 mg/L per year, from 126 mg/L in 1988 to 225 mg/L in 2015.



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10.4 Well 10 (Inactive)

Well Location and Construction

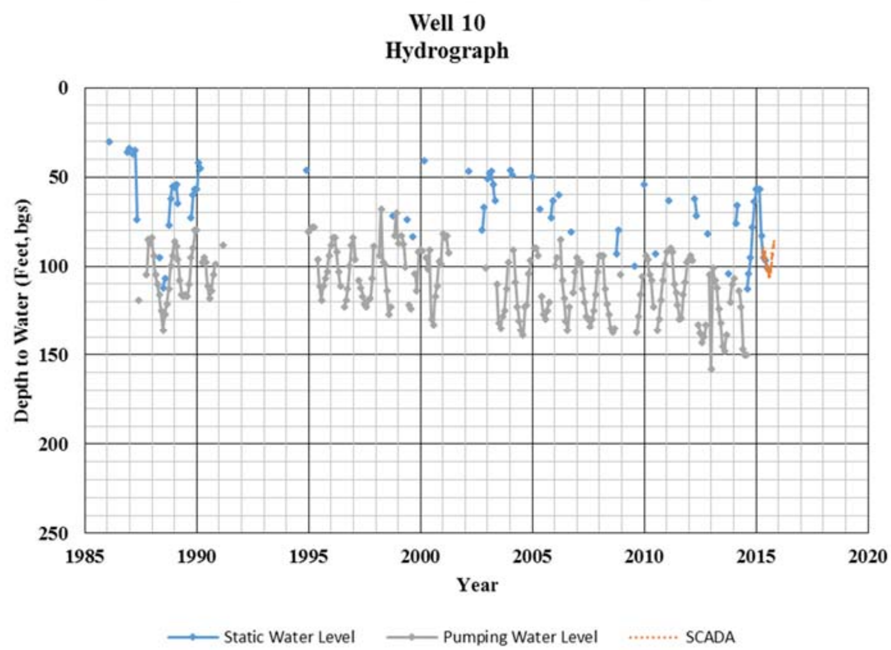
Well 10 is located at 1435 Merritt Street, as shown in Figure 1. Well 10 was constructed by the cable tool drilling method in 1947, presently making this well 69 years old. The well was drilled to a depth of 302 feet. The upper portion of the well consists of a 22-inch diameter steel casing extending from the ground surface to 45 feet. A 16-inch diameter steel casing extends from 45 to 287 feet. Perforated intervals are unknown for this well. The remaining 15 feet of the well is uncased and open borehole.

Well Equipment and Production

The well is equipped with a 60 horsepower motor and a Peerless vertical turbine water-lubricated pump set to a depth of 210 feet. The well is reported to produce an average of 440 gpm to the system with a specific capacity of approximately 30 gpm/foot of drawdown. In 2014, Well 10 produced 129,900,000 gallons of groundwater, approximately 2% of the total well field production, before the well was taken offline in September of 2014 due to PCE contamination.

Groundwater Levels

Groundwater levels have been measured in Well 10 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 57 feet (March 2015). Spring static water levels have declined by 27 feet from February 1986 to February 2015 at a rate of approximately one foot per year.

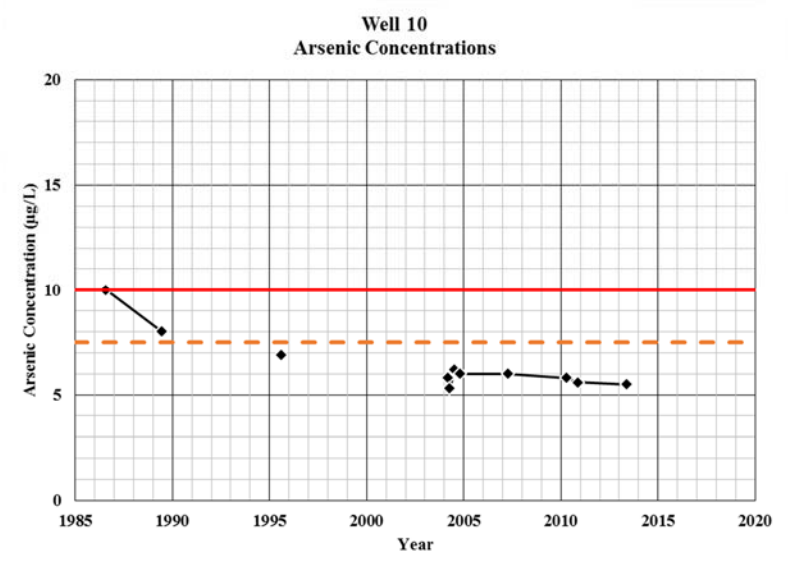


Water Quality

Water quality records indicate that the water produced from Well 10 has met all DDW primary and secondary drinking water requirements with the exception of PCE. Well 10 is currently inactive and does not provide water to the system.

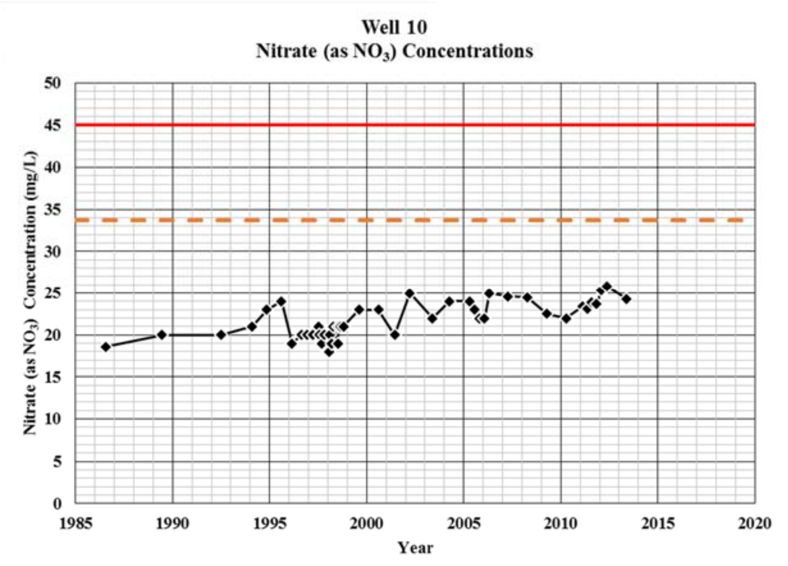
Arsenic

Since 1995, concentrations of arsenic have remained stable with a slight decreasing trend. Concentrations ranged between 5 and 7 µg/L from 1995 through 2013. The most recent concentration of arsenic was reported at 5.5 µg/L in 2013.



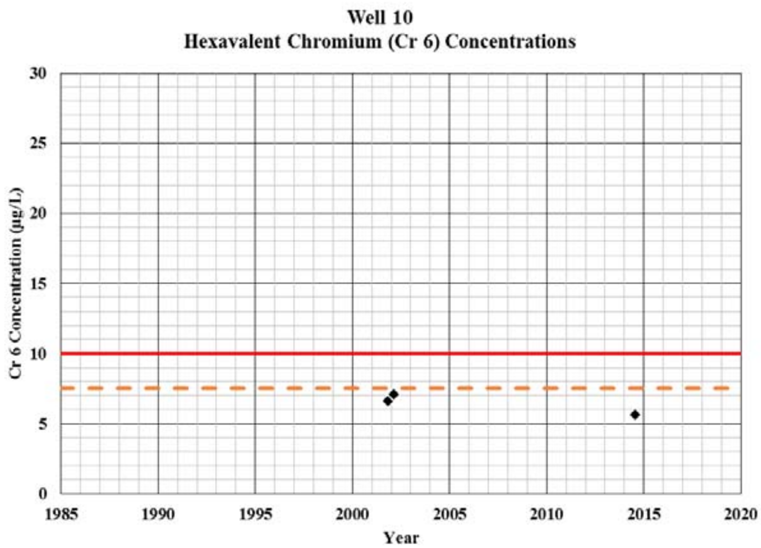
Nitrate (as NO_3)

Concentrations have slightly increased over the period of record, with values ranging between 18 mg/L to 26 mg/L. The most recent nitrate concentration was 24.3 mg/L in 2013.



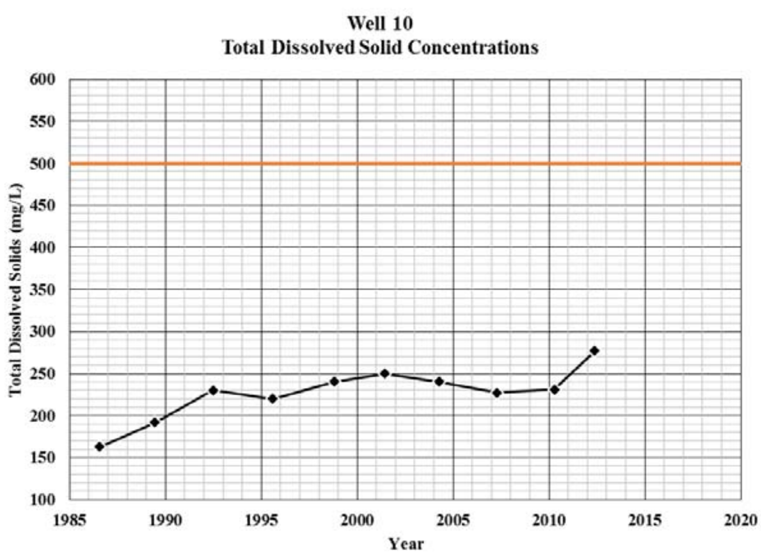
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration at 5.6 µg/L recorded in 2014.



Total Dissolved Solids

TDS concentrations have increased over the period of record at a rate of 4 mg/L per year, from 163 mg/L in 1986 to 277 mg/L in 2012.



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10.5 Well 13 (Active)

Well Location and Construction

Well 13 is located on the eastside of the intersection of East Main and Canal Drive, as shown in Figure 1. Well 13 was constructed by the reverse rotary drilling method in 1950, presently making the well 66 years old. The well was drilled to a depth of 430 feet.

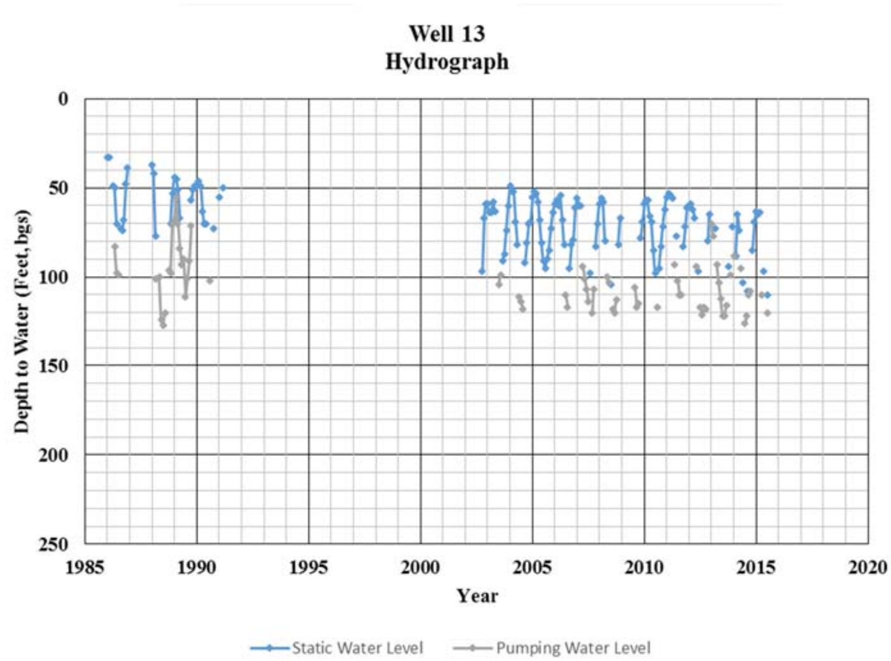
A 32-inch diameter conductor casing and sanitary seal extend from the ground surface to 80 feet. A 16-inch diameter steel well casing extends from ground surface to a depth of 150 feet with perforations starting at 132 feet to an unknown depth. A 16-inch diameter steel casing that extends from a depth of 150 feet to 432 feet.

Well Equipment and Production

Well 13 is equipped with a 100 horsepower motor and a Bryon Jackson vertical turbine oil-lubricated pump set to a depth of 180 feet. The well is reported to be producing an average of 908 gpm to the system with a specific capacity of approximately 40 gpm/foot of drawdown. In 2014, Well 13 produced 250,766,000 gallons of groundwater, approximately 4% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 13 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 63 feet (January 2015). Spring static water levels have declined by 30 feet from January 1986 to January 2015 at a rate of approximately one foot per year.

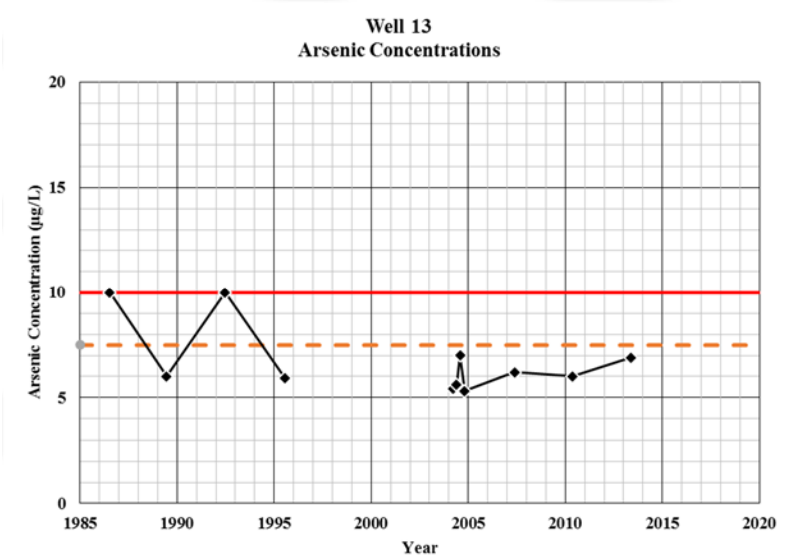


Water Quality

Water quality records indicate that the water produced from Well 13 currently meets all DDW primary and secondary drinking water requirements. Well 13 is currently active and provides untreated water to the system.

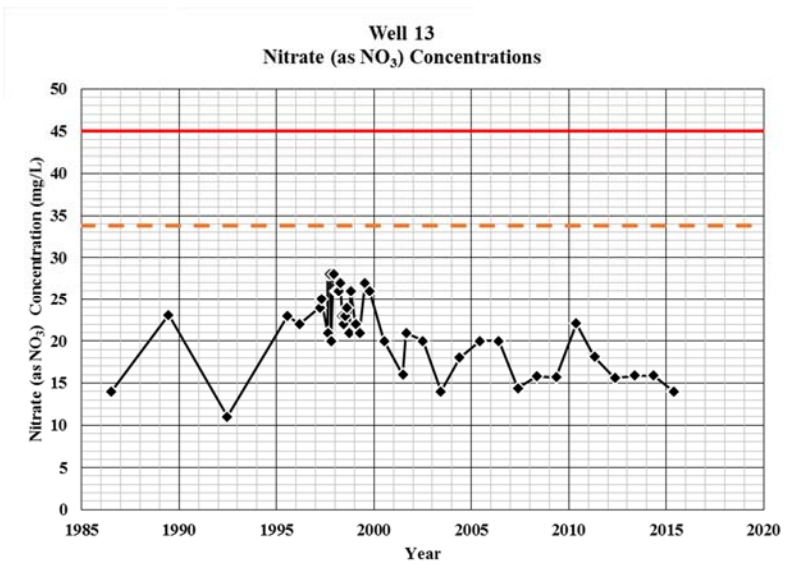
Arsenic

Historic arsenic data indicate stable concentrations between 5 and 7 µg/L. The most recent concentration was reported at 6.9 µg/L in 2013.



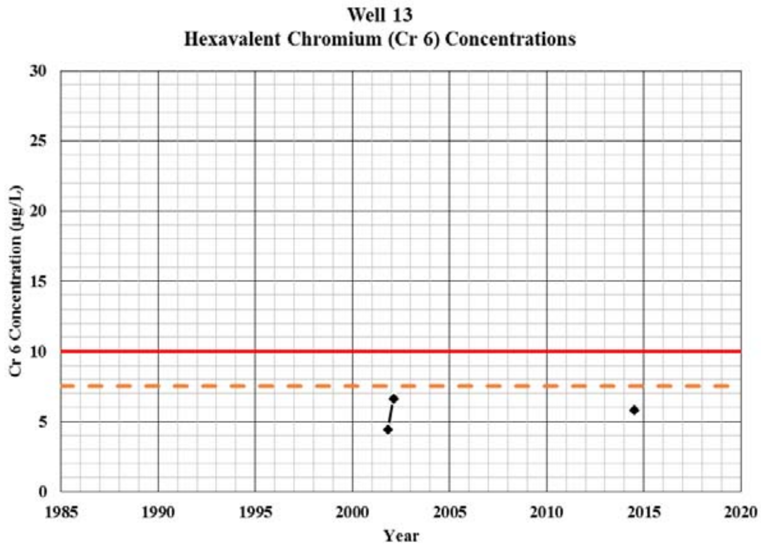
Nitrate (as NO_3)

Concentrations have ranged between 11 and 28 mg/L. The most recent concentration was reported at 14 mg/L in 2015.



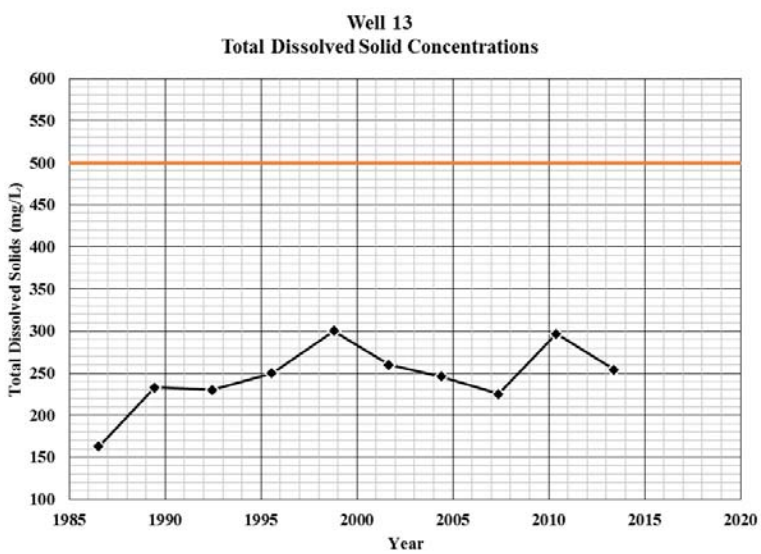
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration of 5.8 µg/L recorded in 2014.



Total Dissolved Solids

TDS concentrations have increased over the period of record at a rate of approximately 3 mg/L per year from 163 mg/L in 1986 to 254 mg/L in 2013.



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10.6 Well 14 (Active)

Well Location and Construction

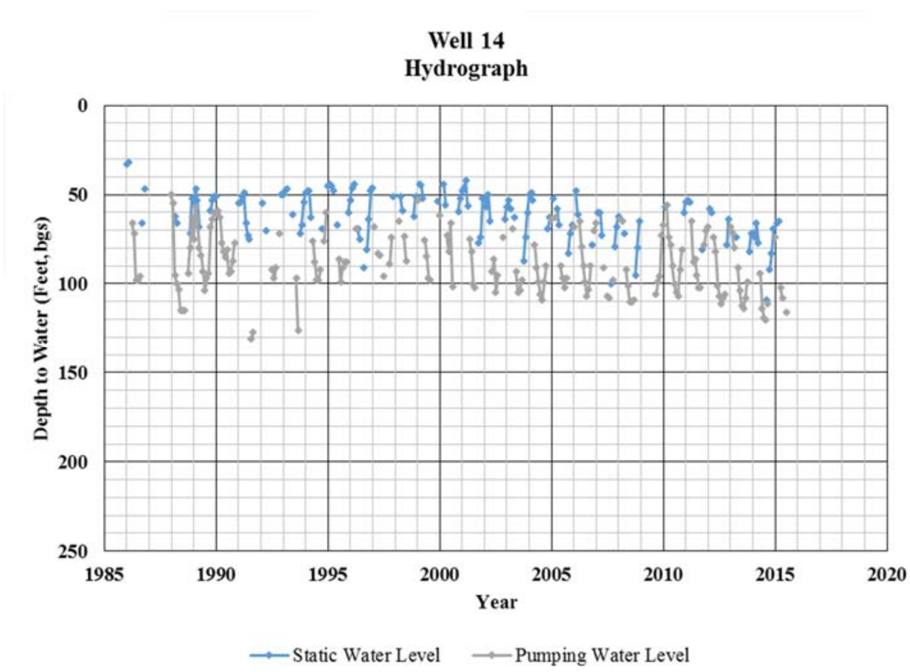
Well 14 is located at 2015 E. Canal Drive, as shown in Figure 1. Well 14 was constructed by the cable tool drilling method in 1955, presently making this well 61 years old. The well was drilled to a depth of 265 feet. A cement grout sanitary seal was placed from the ground surface to a depth of 145 feet. The well structure consists of an 18-inch diameter casing from the ground surface to a depth of 92 feet, a 12-inch diameter casing with machine cut perforations from 140 to 240 feet, and a 10-inch diameter casing with machine cut perforations from 160 to 260 feet. The remaining five feet of the well is uncased and open borehole.

Well Equipment and Production

Well 14 is equipped with a 50 horsepower motor and a vertical turbine oil-lubricated pump set to a depth of 180 feet. The well is reported to produce an average of 539 gpm to the system with a specific capacity of approximately 13 gpm/foot of drawdown. In 2014, Well 14 produced approximately 145,585,000 gallons of groundwater, approximately 2% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 14 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 65 feet (March 2015). Spring static water levels have declined by 33 feet from February 1986 to March 2015 at a rate of approximately one foot per year.

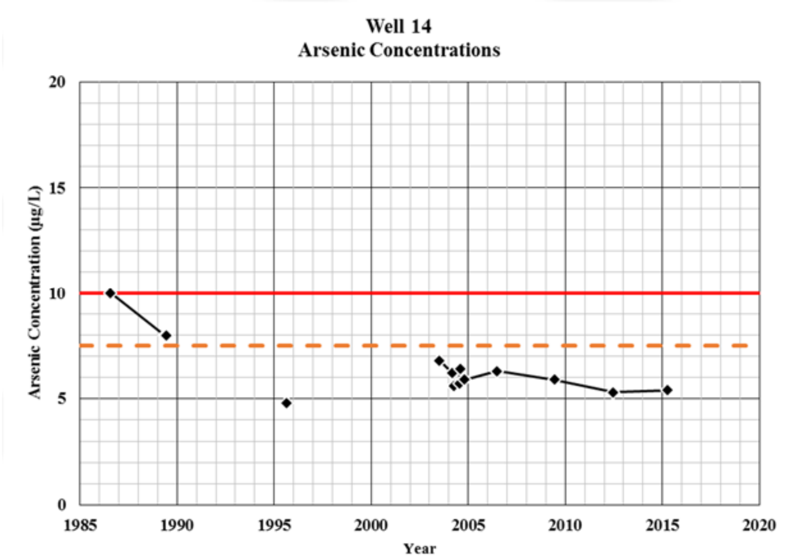


Water Quality

Water quality records indicate that the water produced from Well 14 currently meets all DDW primary and secondary drinking water requirements. Well 14 is currently active and provides untreated water to the system.

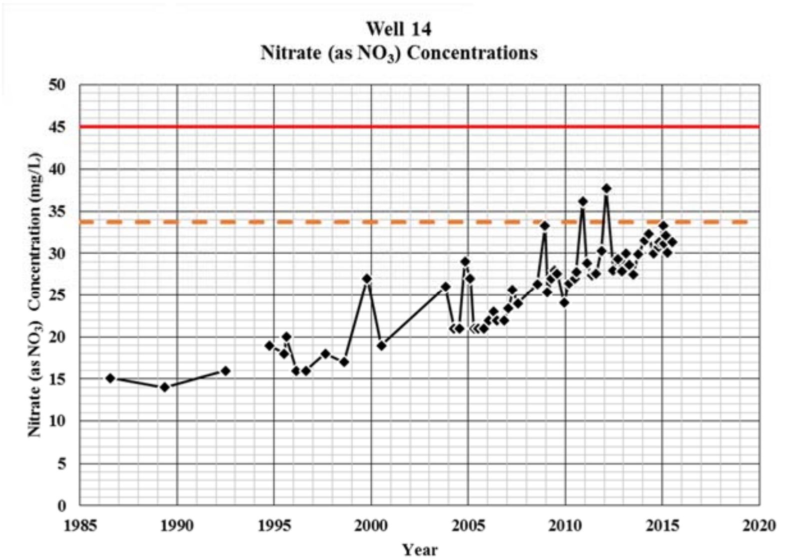
Arsenic

Historic data indicate stable concentrations of arsenic, with concentrations between 4.8 and 6.8 µg/L since 1995. The most recent concentration was reported at 5.4 µg/L in 2015.



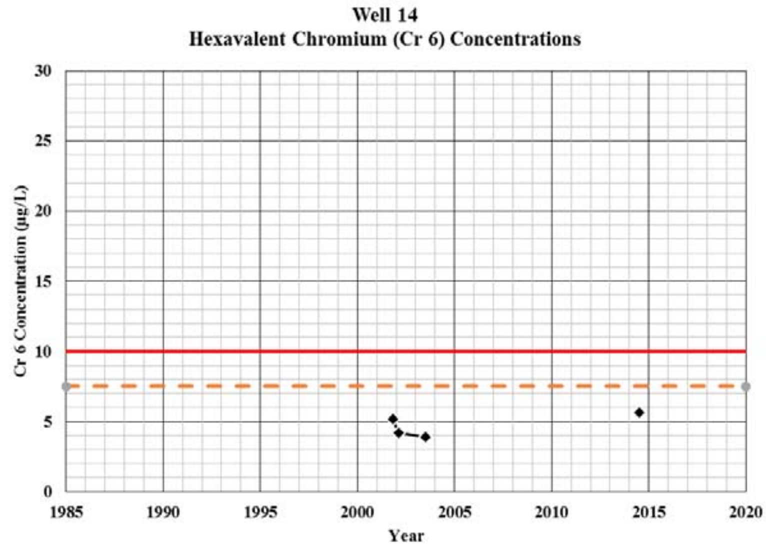
Nitrate (as NO_3)

Concentrations have increased over the period of record from 14 mg/L in 1986 to 33 mg/L in early 2015. The most recent nitrate concentration was reported in 2015 to be 31.3 mg/L. Temporary spikes in nitrate concentrations are indicative of water moving from the shallow aquifers down into deeper aquifers when this well is idle.



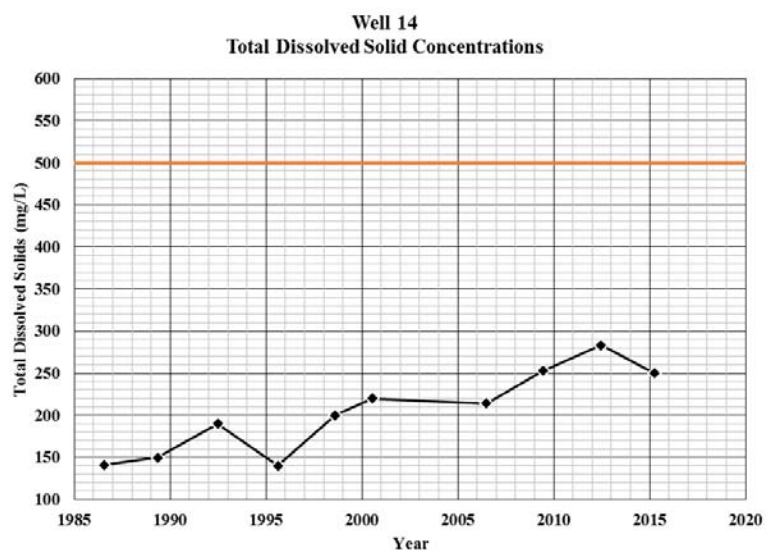
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration of 5.6 µg/L recorded in 2014.



Total Dissolved Solids

TDS concentrations have increased over the period of record at a rate of approximately 4 mg/L per year, from 141 mg/L in 1986 to 250 mg/L in 2015.



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10.7 Well 15 (Active)

Well Location and Construction

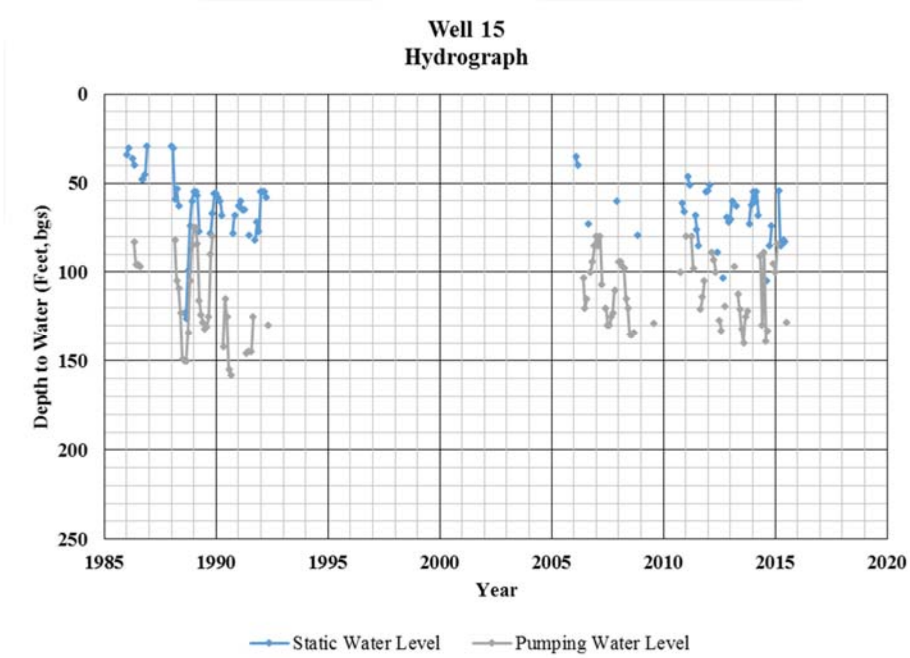
Well 15 is located at 1400 W. Main Street, as shown in Figure 1. Well 15 was constructed by the cable tool drilling method in 1956, presently making this well 60 years old. The well was drilled to a depth of 424 feet. A 20-inch diameter conductor casing extends from ground surface to a depth of 92 feet. A sanitary seal was placed to a depth of 92 feet, between the 20-inch diameter conductor casing and the 16-inch diameter steel well casing. The well structure consists of a16-inch diameter well casing from ground surface to a depth of 180 feet, a 14-inch diameter well casing from 180 to 280 feet, a 12-inch diameter well casing from 280 to 380 feet, and a10-inch diameter casing from 380 feet to 424 feet. The well is perforated from 180 to 424 feet with unknown slot size.

Well Equipment and Production

Well 15 is equipped with a 100 horsepower U.S. Motor and a vertical turbine oil-lubricated pump. The well is reported to produce an average 1,169 gpm to the system with a specific capacity of approximately 26 gpm/foot of drawdown. In 2014, Well 15 produced approximately 244,515,000 gallons of groundwater, approximately 4% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 15 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 54 feet (March 2015). Spring static water levels have declined by 24 feet from February 1986 to March 2015 at a rate of approximately one foot per year.

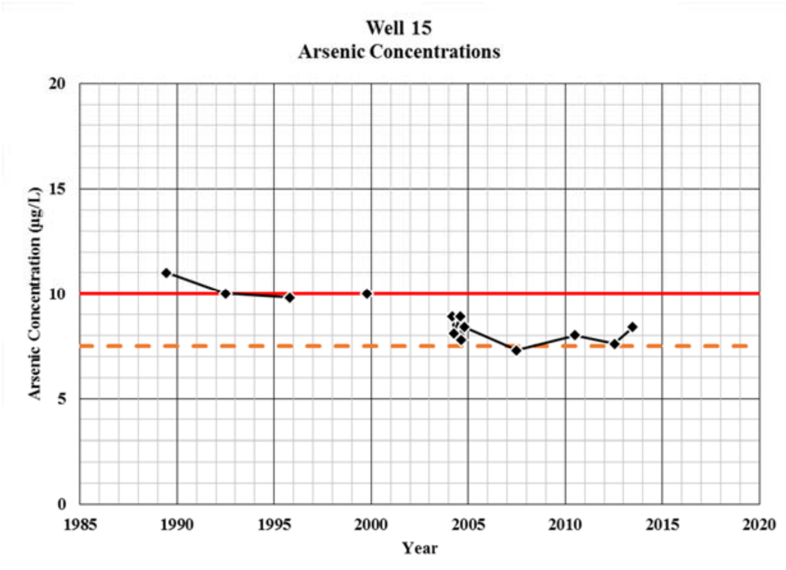


Water Quality

Water quality records indicate that the water produced from Well 15 currently meets all DDW primary and secondary drinking water requirements. Well 15 is currently active and provides untreated water to the system.

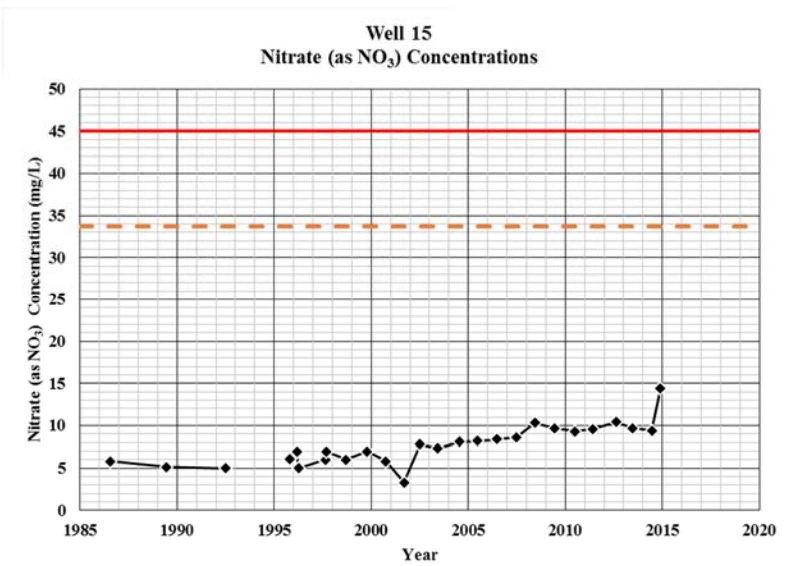
Arsenic

Historic arsenic data indicate concentrations were above the current MCL prior to 2000. Since 2000, arsenic concentrations ranged between 7 and 9 µg/L. The most recent concentration was reported at 8.4 µg/L in 2013.



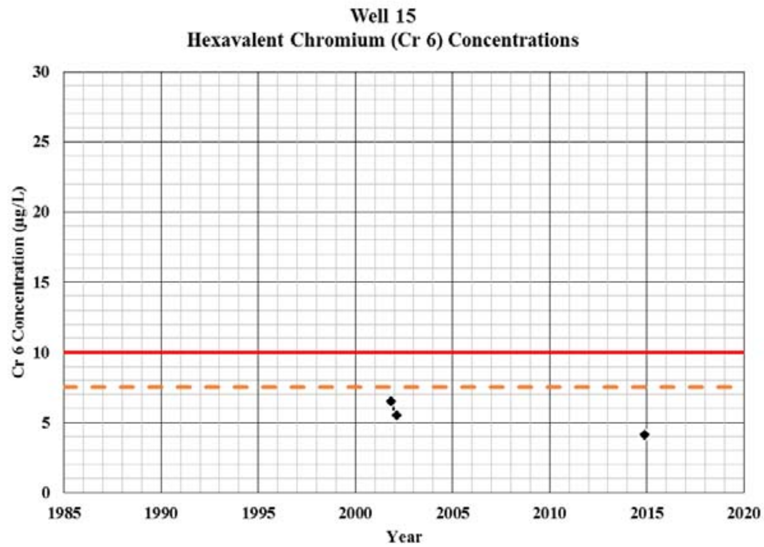
Nitrate (as NO_3)

Concentrations have remained below the MCL, but the data suggest a slightly increasing trend. The most recent reported concentration was 14.4 mg/L in late 2014.



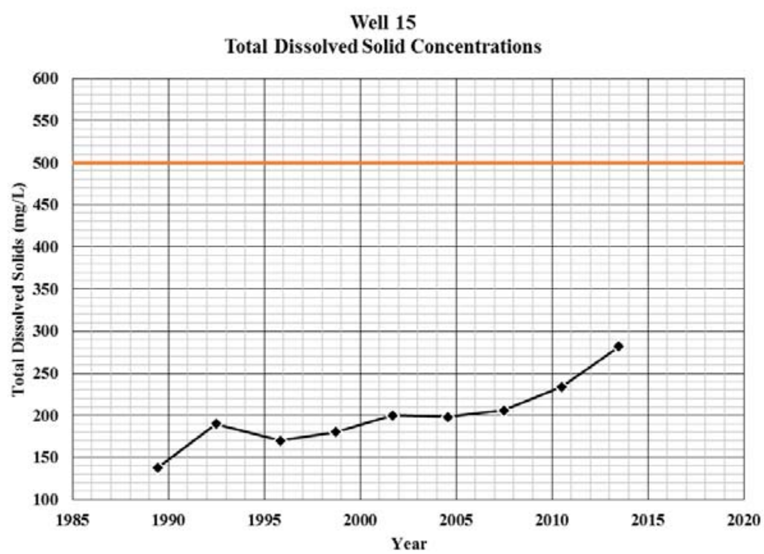
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration of 4.1 µg/L recorded in 2014.



Total Dissolved Solids

TDS concentrations have increased at a rate of 6 mg/L per year over the period of record from 138 mg/L in 1989 to 282 mg/L in 2013.



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10.8 Well 19 (Active)

Well Construction and Location

Well 19 is located at 600 Pedras Road at Donnely Park, as shown in Figure 1. Well 19 was constructed by the cable tool drilling method in 1965, presently making this well 51 years old.

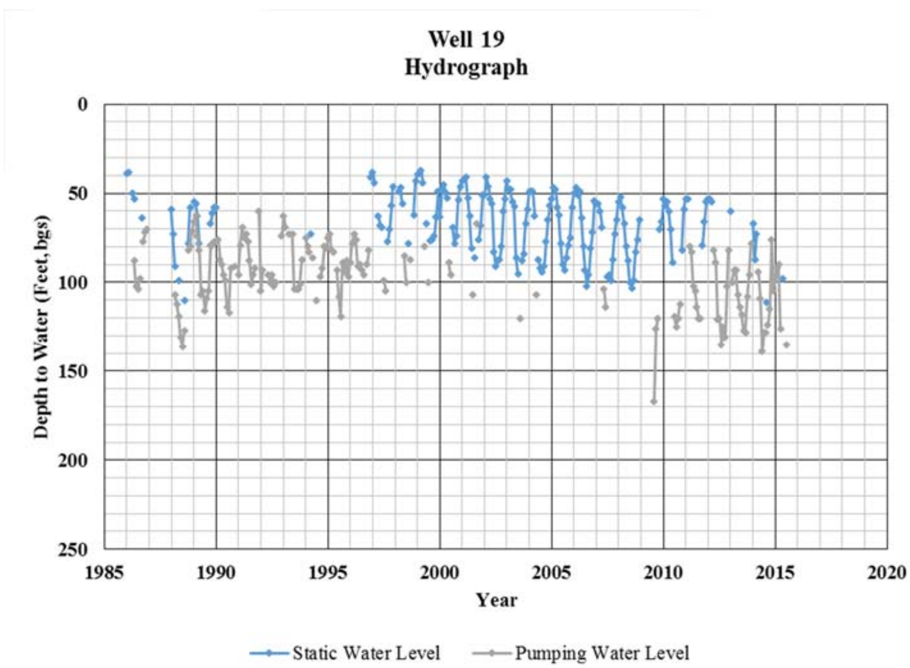
The well was drilled to a depth of 442 feet. A 20-inch conductor casing extends from ground surface to a depth of 84 feet. An annular seal was placed to a depth of 65 feet. The well structure consists of a 16-inch diameter steel casing from the ground surface to a depth of 172 feet, a 14-inch diameter steel casing from 172 to 184 feet, and a 12-inch diameter steel casing from 268 to 368 feet. The remaining 74 feet of the well is uncased and open borehole. The well is perforated from 172 to 368 feet, with an unknown slot size.

Well Equipment and Production

Well 19 is equipped with a 100 horsepower electric U.S. Motor and a vertical turbine oil-lubricated pump. The well is reported to produce an average 980 gpm to the system with a specific capacity of approximately 26 gpm/foot of drawdown. In 2014, Well 19 produced approximately 359,628,000 gallons of groundwater to the system, approximately 5% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 19 since 1986 and include both static and pumping water level measurements. From 1986 to 2012, spring groundwater levels declined by 24 feet at a rate of approximately one foot per year. From 2012 to 2014, spring groundwater levels declined by 34 feet at an increased rate of approximately one foot per year.

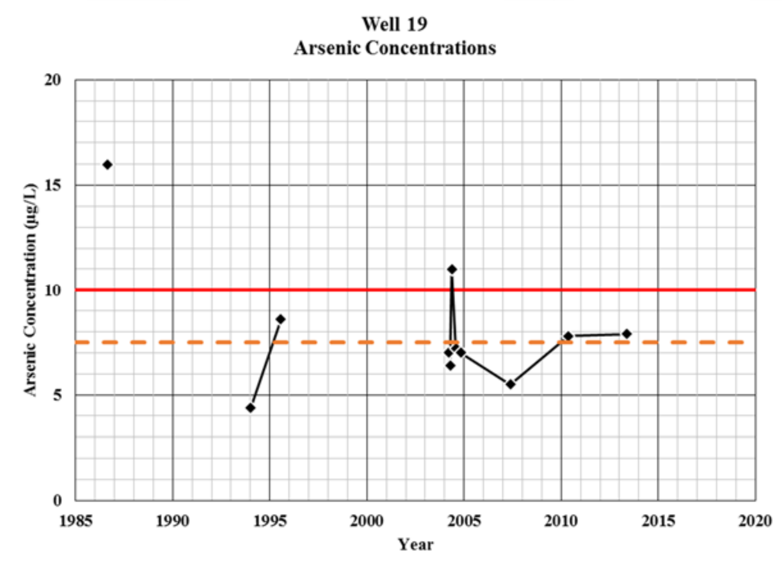


Water Quality

Water quality records indicate that the water produced from Well 19 currently meets all DDW primary and secondary drinking water requirements. Well 19 is currently active and provides untreated water to the system.

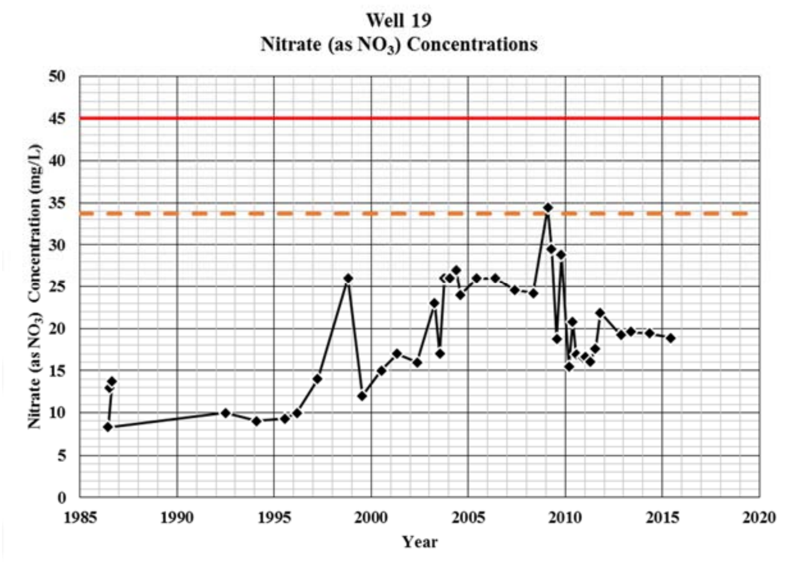
Arsenic

Historic arsenic data indicate that in May of 2004, the arsenic concentration spiked above the MCL; however, this appears to be an anomaly as samples collected one month prior and three months afterward indicated concentrations of 6.4 and 7.2 µg/L, respectively. Arsenic concentrations have remained below the MCL, with the latest concentration of 7.9 µg/L reported in 2013.



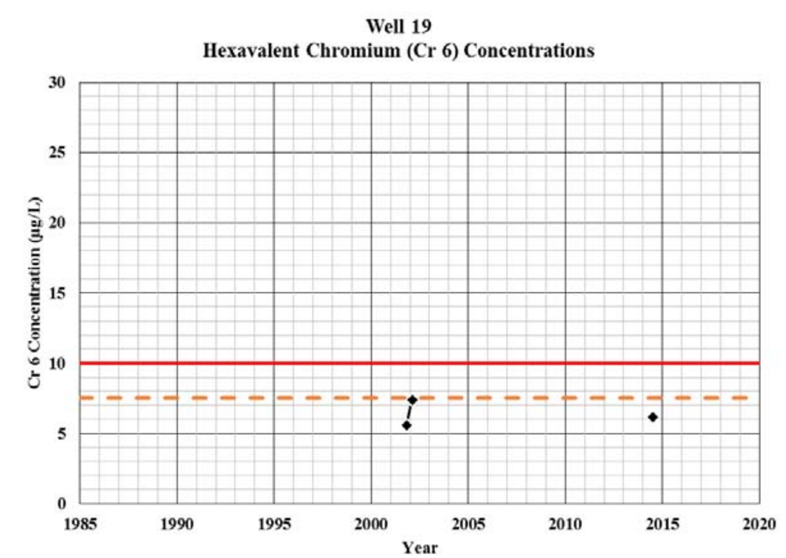
Nitrate (as NO_3)

Nitrate concentrations have generally increased over the period of record. In 2009, the concentration spiked to 34.4 mg/L but subsequently decreased in 2010. Since 2010, concentrations have ranged between 15 and 22 mg/L. Temporary spikes indicate that when this well is idle, water moves from shallow aquifers down into the deeper aquifers. The decrease, which started in 2008, is likely related to more continuous use, which prevents the inter-aquifer movement of water.



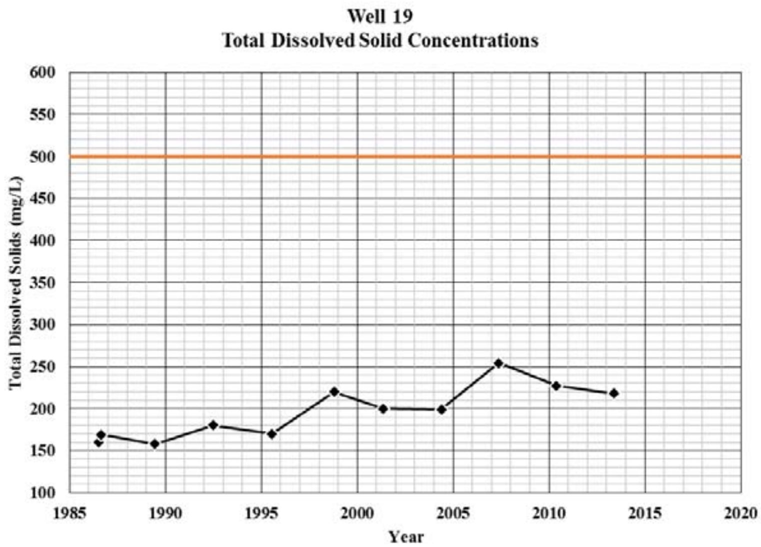
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration of 6.2 µg/L recorded in 2014.



Total Dissolved Solids

The concentration of TDS has increased at a rate of approximately 2 mg/L per year over the period of record, from 160 mg/L in 1986 to 218 mg/L in 2013.


Well 19
Total Dissolved Solid Concentrations
Total Dissolved Solids (mg/L)
600
550
500
450
400
350
300
250
200
150
100
1985
1990
1995
2000
2005
2010
2015
2020
Year

10.9 Well 20 (Active)

Well Location and Construction

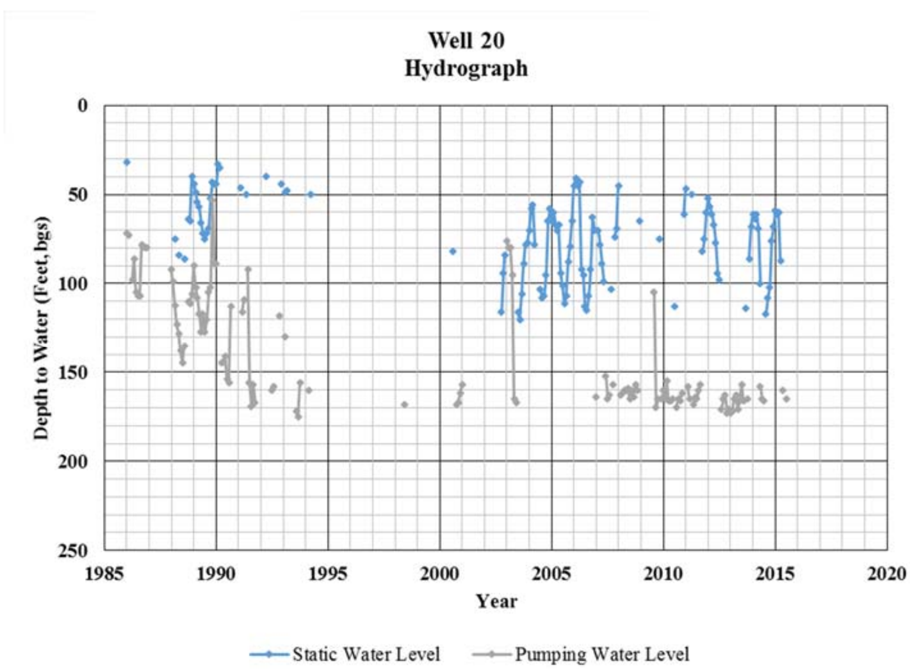
Well 20 is located at 1200 W. Monte Vista Ave, as shown in Figure 1. Well 20 was constructed using the reverse rotary drilling method in 1978, presently making this well 38 years old. A test hole was drilled to a depth of 500 feet, with a final borehole depth of 380 feet and the well casing set at a depth of 360 feet. The test hole was sealed or filled with an unspecified material. A 30-inch conductor casing and an annular seal were placed from the ground surface to a depth of 90 feet. The well structure consists of a 16-inch outside diameter well casing with 5/16-inch wall thickness from the ground surface to a depth of 360 feet, inside a 26-inch diameter borehole. The well is screened (reported to be Johnson screen) from 160 to 180 feet and 310 to 350 feet with 0.080-inch slot size. The gravel envelope extends from the total depth of the well (380 feet) to ground surface.

Well Equipment and Production

Well 20 is equipped with a 100 horsepower U.S. Motor and a vertical turbine oil-lubricated pump set to a depth of 210 feet. The well is reported to produce an average 836 gpm to the system with a specific capacity of approximately 11 gpm/foot of drawdown. In 2014, Well 20 produced approximately 107,032,000 gallons of groundwater, approximately 2% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 20 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 59 feet (January 2015). Spring static water levels have declined by 27 feet from January 1986 to January 2015 at a rate of approximately one foot per year.

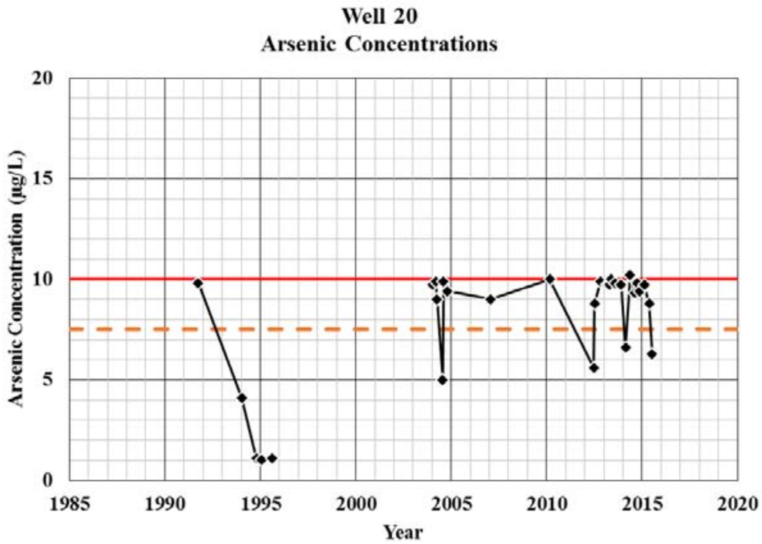


Water Quality

Water quality records indicate that the water produced from Well 20 currently meets all DDW primary and secondary drinking water requirements. Well 20 is currently active and provides untreated water to the system.

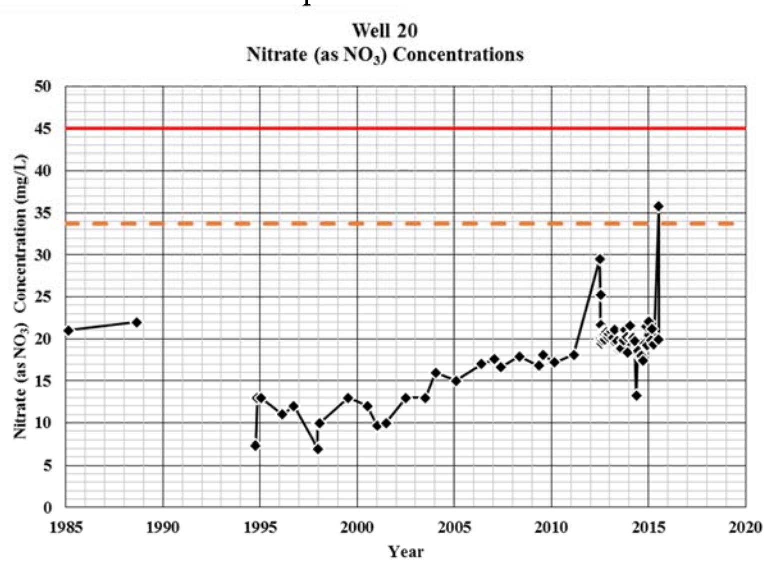
Arsenic

Historic arsenic concentrations indicate a wide range of values between 1.0 µg/L to 10.2 µg/L. Arsenic was previously close to or at the MCL; however, the most recent concentration was reported at 6.3 µg/L on July 13, 2015.



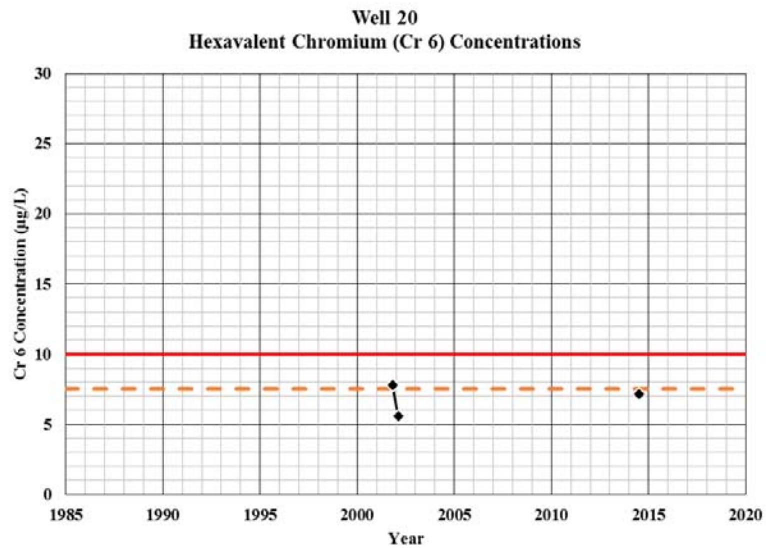
Nitrate (as NO_3)

Concentrations have gradually increased over the period of record from 7.4 mg/L in 1994 to 20 mg/L in 2015 but have remained below the MCL. Spikes in nitrate concentrations have an inverse relationship with decreased arsenic concentrations, suggesting inter-aquifer movement of groundwater when the well is idle. Implementing a strategic pumping program to pump this well could balance the two constituents and help reduce arsenic concentrations.



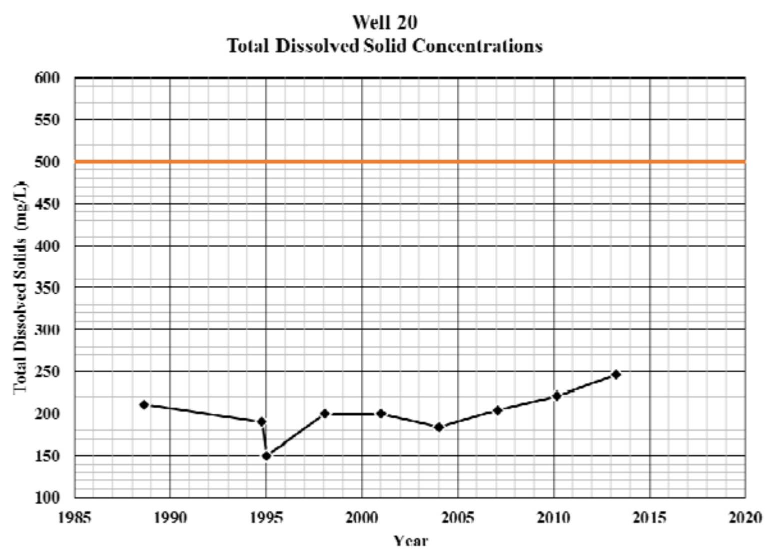
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration of 7.1 µg/L recorded in 2014.



Total Dissolved Solids

TDS concentrations over the period of record indicate a slight increasing trend but are below the Recommended Limit, with the latest TDS concentration of 246 mg/L recorded in 2013.



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10.10 Well 22 (Active)

Well Construction

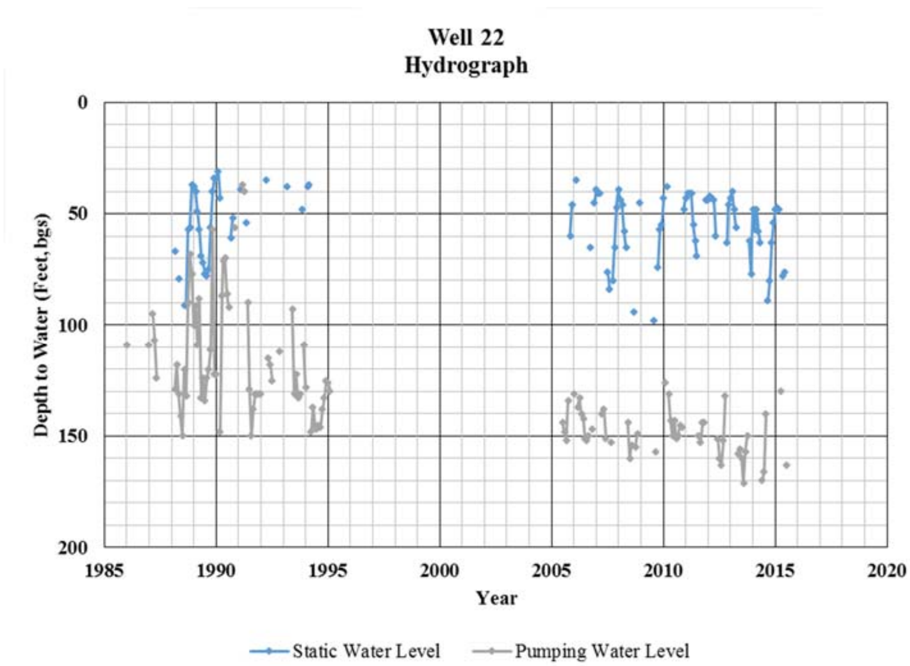
Well 22 is located at 1605 Linden Lane, as shown in Figure 1. Well 22 was constructed by the reverse rotary method in 1980, presently making this well 36 years old. A test hole was drilled to a depth of 462 feet, and reamed to 28-inches in diameter to a depth of 310 feet. The test hole was sealed or filled with an unspecified material. A 30-inch outside diameter conductor casing and an annular seal were placed from the ground surface to a depth of 100 feet. The well structure consists of a 16-inch outside diameter with 5/16-inch wall thickness well casing from the ground surface to 310 feet, with louvered well screen 150 to 300 feet with an unknown slot size.

Well Equipment/Production

Well 22 is equipped with a 150 horsepower U.S. Motor and a vertical turbine oil-lubricated pump set to a depth of 200 feet. The well is reported to produce an average 2,305 gpm to the system with a specific capacity of approximately 27 gpm/foot of drawdown. In 2014, Well 22 produced approximately 62,381,100 gallons of groundwater, approximately 1% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 22 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 48 feet (March 2015). Spring static water levels have declined by 19 feet from March 1986 to March 2015 at a rate of approximately 0.7 feet per year.

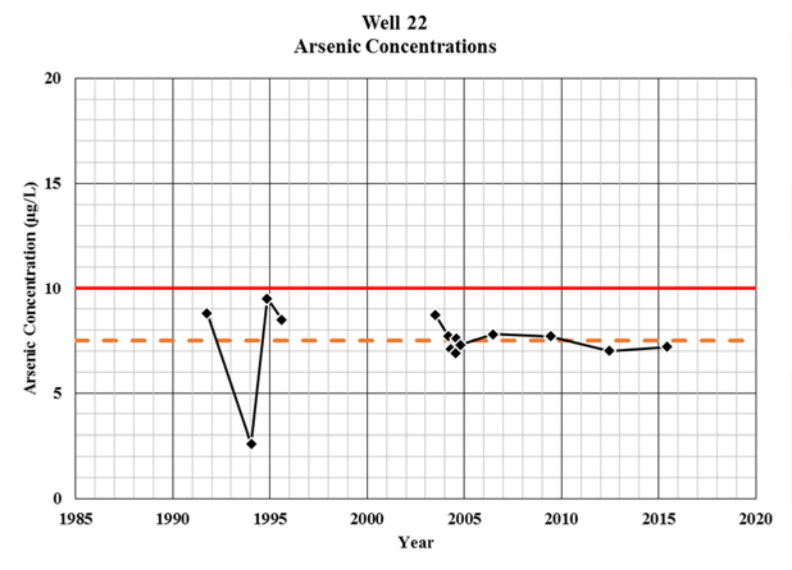


Water Quality

Water quality records indicate that the water produced from Well 22 currently meets all DDW primary and secondary drinking water requirements. Well 22 is currently active and provides untreated water to the system.

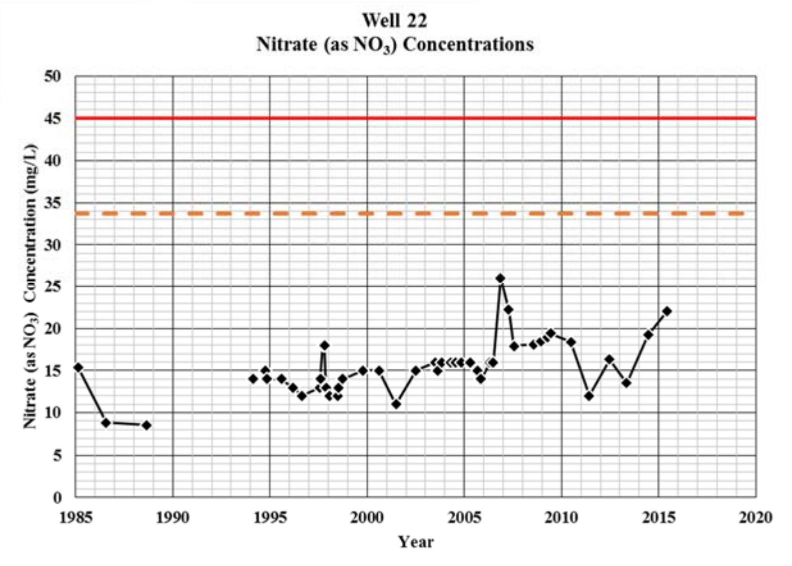
Arsenic

From 1991 through 1995, concentrations of arsenic fluctuated between 2.6 to 9.5 µg/L. Since 1995, arsenic has remained relatively stable with a slight downward trend from 8.7 µg/L (2003) to 7.2 µg/L (2015).



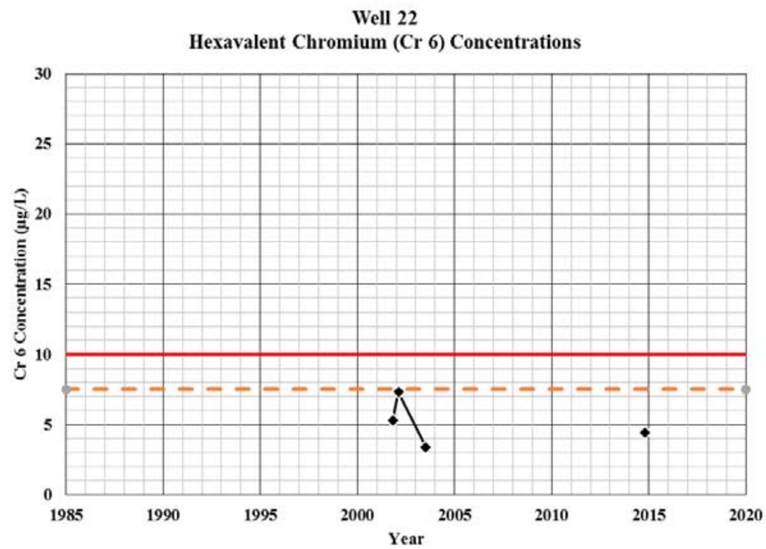
Nitrate (as NO_3)

Concentrations have remained below the MCL, but exhibit a slight increasing trend with a reported value of 22.1 mg/L in 2015.



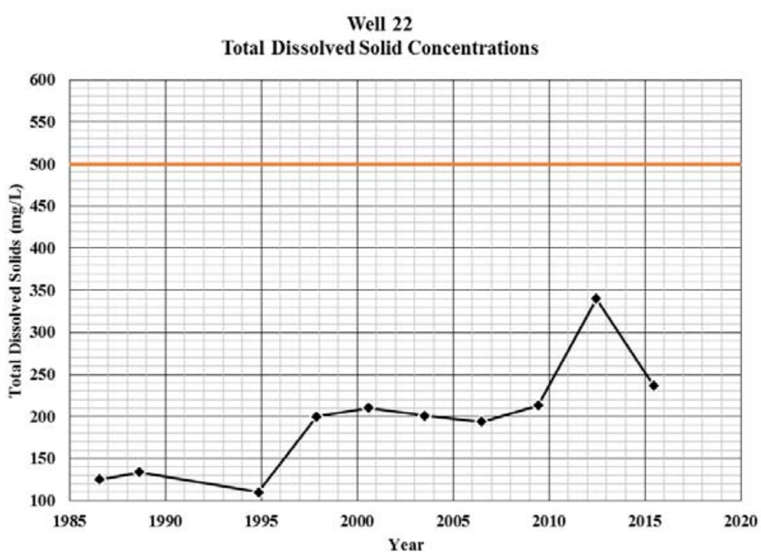
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration of 4.4 µg/L recorded in 2014.



Total Dissolved Solids

TDS concentrations indicate a gradually increasing trend of approximately four mg/L per year over the period of record (1988 to 2015), with the most recent concentration of 237 mg/L reported in 2015.



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10.11 Well 24 (Inactive)

Well Location and Construction

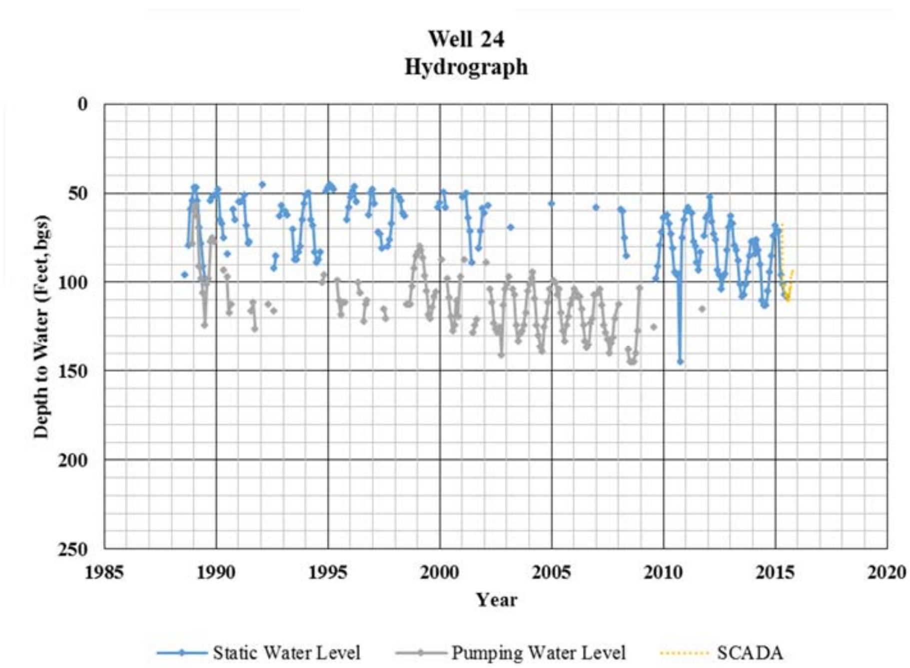
Well 24 is located at 1900 N. Quincy Road, as shown in Figure 1. Well 24 was constructed by the reverse rotary drilling method in 1988, presently making this well 28 years old. A test hole was drilled to a depth of 510 feet and the reamed to 28-inches in diameter to a depth of 400 feet. The test hole was sealed or filled with an unspecified material. An unknown diameter conductor casing and a sanitary seal were placed from the ground surface to a depth of 50 feet. The well structure consists of an 18-inch diameter well casing with ¼-inch wall thickness from the ground surface to a depth of 400 feet. The well screen is “Ful-Flo” louvered pattern and is screened from 140 to 250 feet and 290 to 400 feet.

Well Equipment and Production

Well 24 is equipped with a Byron Jackson 150 horsepower submersible motor and pump set to a depth of 216 feet. The well is reported to produce an average 1,272 gpm to the system. The well has not operated since 2009.

Groundwater Levels

Groundwater levels have been measured in Well 24 since 1986 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 68 feet (January 2015). Spring static water levels have declined by 21 feet from January 1988 to January 2015 at a rate of approximately 0.8 feet per year.

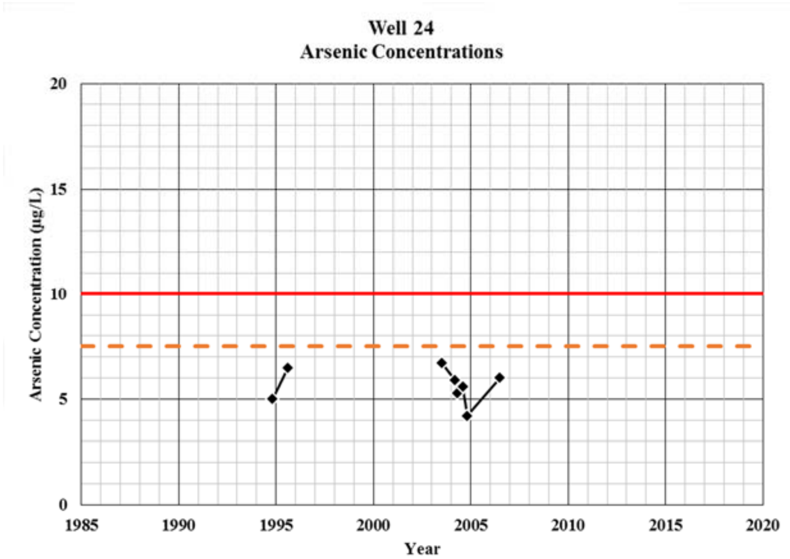


Water Quality

Water quality records indicate that the water produced from Well 24 meets all DDW primary and secondary drinking water requirements, with the exception for nitrate (as NO_3). Well 24 is currently inactive and does not provide water to the system. Well 24 has been offline since 2009 due to elevated nitrate concentrations above the MCL.

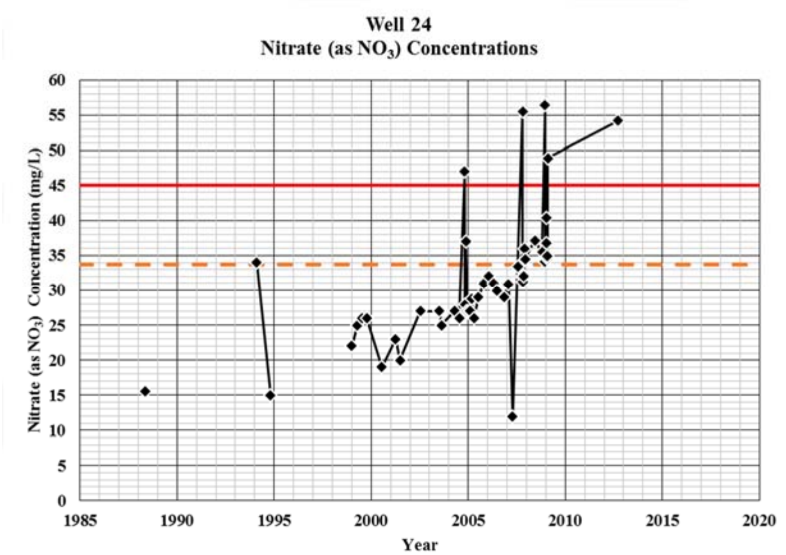
Arsenic

Arsenic concentrations have ranged between 4.2 and 6.7 µg/L, with the most recent concentration of 6 µg/L reported in 2006.



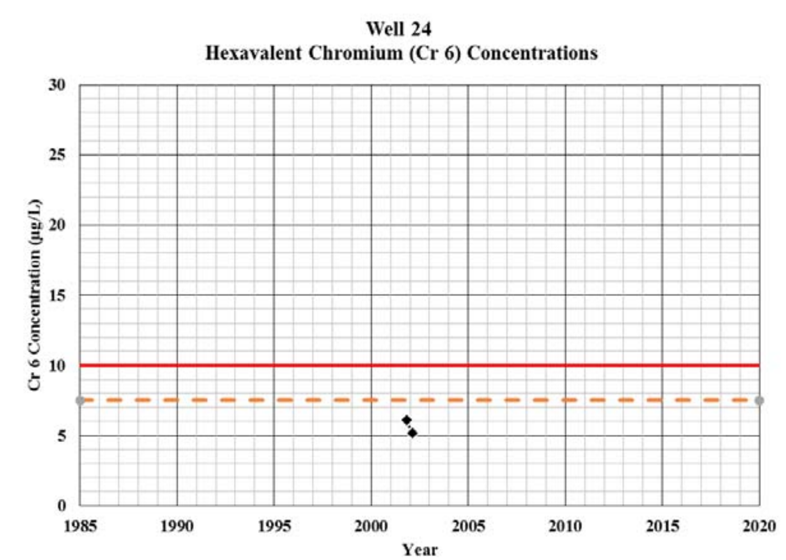
Nitrate (as NO_3)

Nitrate concentrations have increased over the period of record, with multiple spikes above the MCL. The highest concentration of 56.4 mg/L was reported in 2009. The most recent concentration of 54.2 mg/L was reported in 2012. Nitrate concentrations temporarily spike indicating that when this well is idle, water moves from the shallow aquifers down into the deeper aquifers. Well 24 is currently acting as a conduit allowing poorer quality shallow groundwater to migrate to deeper aquifers at this site, and may also be causing regional contamination of the deeper aquifers beneath the City.



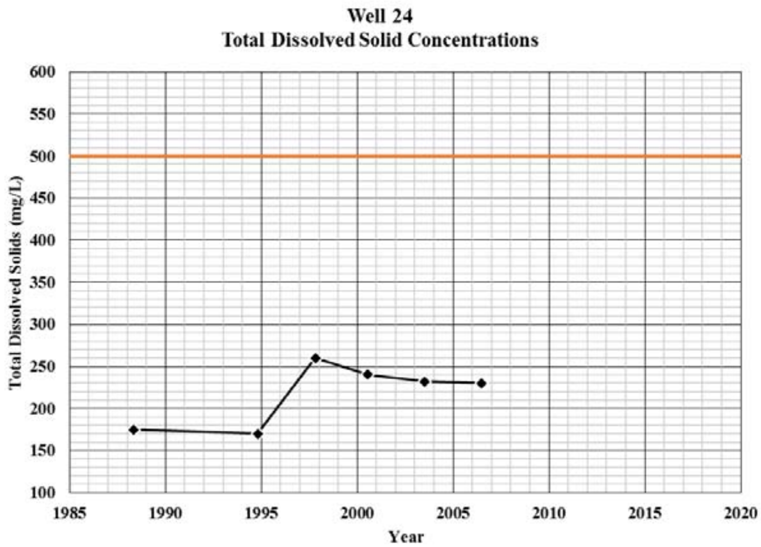
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL with the most recent concentration of 5.2 µg/L reported in 2002.



Total Dissolved Solids

TDS concentrations have increased at a rate of 3 mg/L per year, from 175 mg/L in 1988 to 230 mg/L in 2006.



10.12 Well 27 (Active)

Well Location and Construction

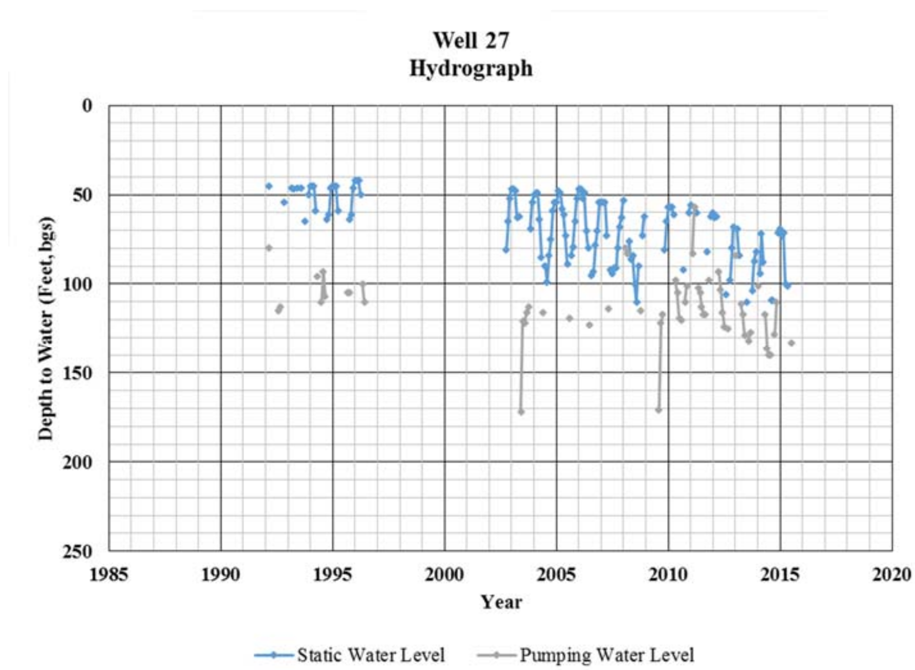
Well 27 is located at the southwest corner of 601 E. Christoffersen Parkway, as shown in Figure 1. Well 27 was constructed by the reverse rotary drilling method in 1992, presently making this well 24 years old. A 28-inch diameter conductor casing was cemented in place to a depth of 115 feet. The well structure consists of a 16-inch diameter with ¼-inch wall thickness well casing from the ground surface to a depth of 400 feet inside a 25-inch diameter borehole. The well screen consists of stainless steel (unknown screen pattern) from a depth of 130 to 230 feet and 290 to 390 feet. An unspecified gravel envelope was placed from 405 feet to ground surface.

Well Equipment and Production

Well 27 is equipped with a 150 horsepower motor and a Byron Jackson vertical turbine oil-lubricated pump set to a depth of 165 feet. The well is reported to produce an average 1,565 gpm to the system with a specific capacity of approximately 50 gpm/foot of drawdown. In 2014, Well 27 produced approximately 543,291,000 gallons of groundwater, approximately 8% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 27 since 1992 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 69 feet (January 2015). Spring static water levels have declined by 24 feet from January 1992 to March 2015 at a rate of approximately 1 foot per year.

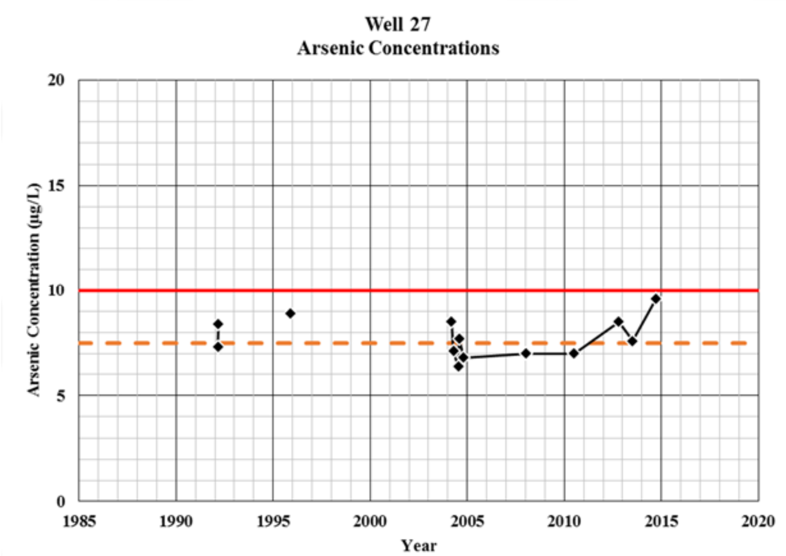


Water Quality

Water quality records indicate that the water produced from Well 27 currently meets all DDW primary and secondary drinking water requirements. Well 27 is currently active and provides untreated water to the system.

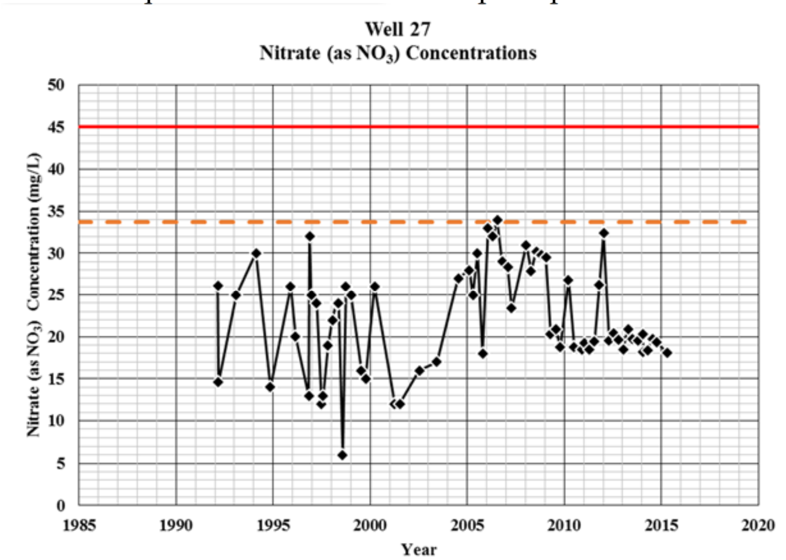
Arsenic

Historic arsenic concentrations have remained below the MCL, but are increasing toward the MCL (6.4 µg/L in 2004 and 9.6 µg/L in 2014). Concentrations of arsenic exhibit an inverse relationship with nitrate concentrations; low concentrations of arsenic occur concurrently with high concentrations of nitrate when the well is idle. If concentrations increase, implementing a strategic pumping program may improve water quality.



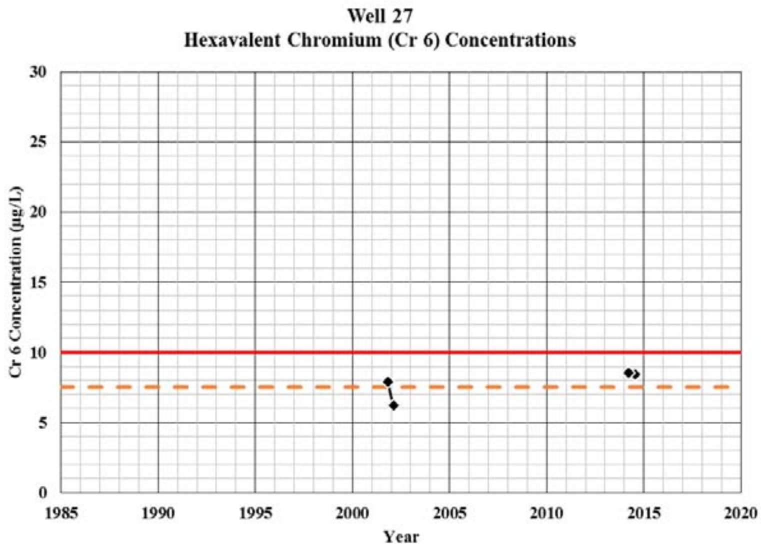
Nitrate (as NO_3)

Nitrate concentrations have remained below the MCL, but have largely fluctuated over the period of record, ranging from 5.5 to 30 mg/L. The most recent concentration of 18.1 mg/L was reported in 2015. Nitrate concentrations temporarily spike upward indicating that when this well is idle, water moves from shallow aquifers downward into deeper aquifers.



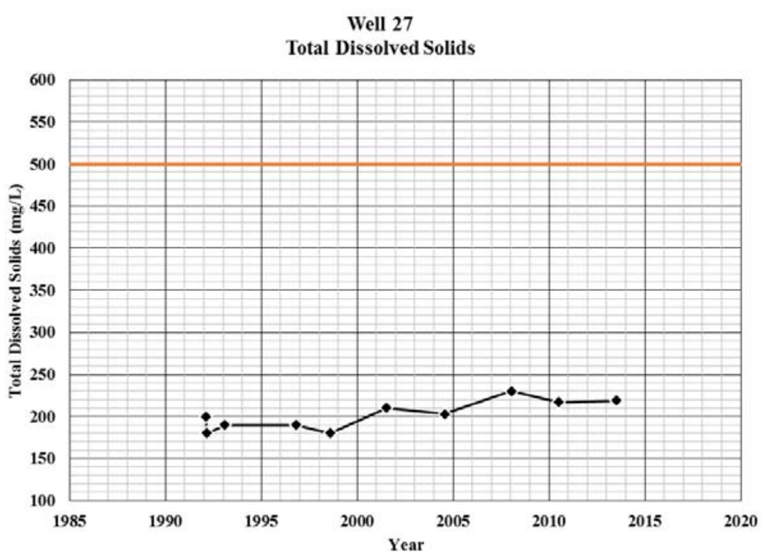
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 8.5 µg/L reported in 2014.



Total Dissolved Solids

TDS concentrations have increased over the period of record at a rate of approximately 2 mg/L per year from 180 mg/L to 219 mg/L. The most recent TDS concentration reported was 219 mg/L in 2013.



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10.16 Well 28 (Inactive)

Well Location and Construction

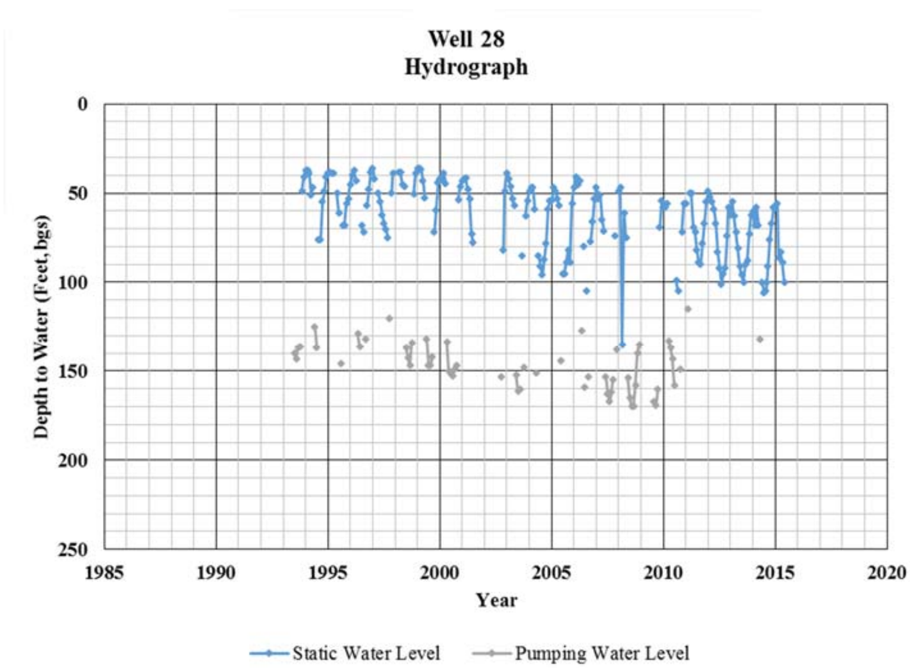
Well 28 is located at 2080 W. Tuolumne Road, as shown in Figure 1. Well 28 was constructed by the reverse rotary drilling method in 1992, presently making this well 24 years old. A 30-inch outside diameter conductor casing was cemented in place to a depth of 90 feet. The well structure consists of 16.625-inch outside diameter with 5/16-inch wall thickness well casing to a depth of 405 feet. The well screen pattern and interval were not specified in the records, but likely extends from approximately 200 feet to 395 feet. The annular space is filled with a gravel envelope (Heart of Texas) from 405 feet to 192 feet, a fine sand transition seal from 192 to 185 feet, and a sand/cement annular seal from 185 feet to the ground surface.

Well Equipment and Production

Well 28 is equipped with a 175 horsepower motor and a Worthington pump set to a depth of 200 feet. The well is reported to produce an average 1,533 gpm to the system with a specific capacity of approximately 18 gpm/foot of drawdown. In 2014, Well 28 produced approximately 17,443,000 gallons of groundwater, less than 1% of the total well field production. In 2011, production in Well 28 significantly dropped.

Groundwater Levels

Groundwater levels have been measured in Well 28 since 1993 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 56 feet (February 2015). Spring static water levels have declined by 19 feet from February 1994 to February 2015 at a rate of approximately one foot per year.

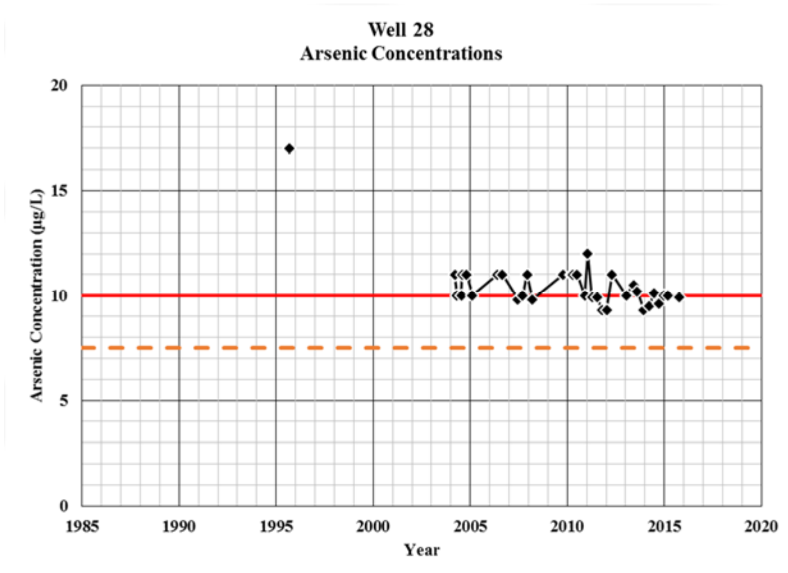


Water Quality

Water quality records indicate that the water produced from Well 28 meets all DDW primary and secondary drinking water requirements, with the exception of arsenic. Well 28 is currently inactive and does not provide water to the system due to the elevated arsenic concentrations.

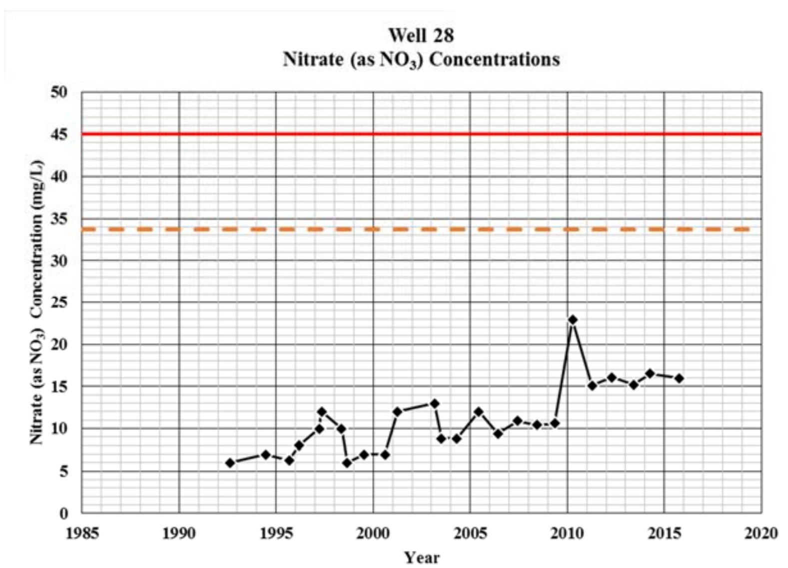
Arsenic

Arsenic has historically exceeded the MCL, with concentrations ranging from 9.3 to 12 µg/L. The most recent arsenic concentration was reported at 9.9 µg/L in 2015.



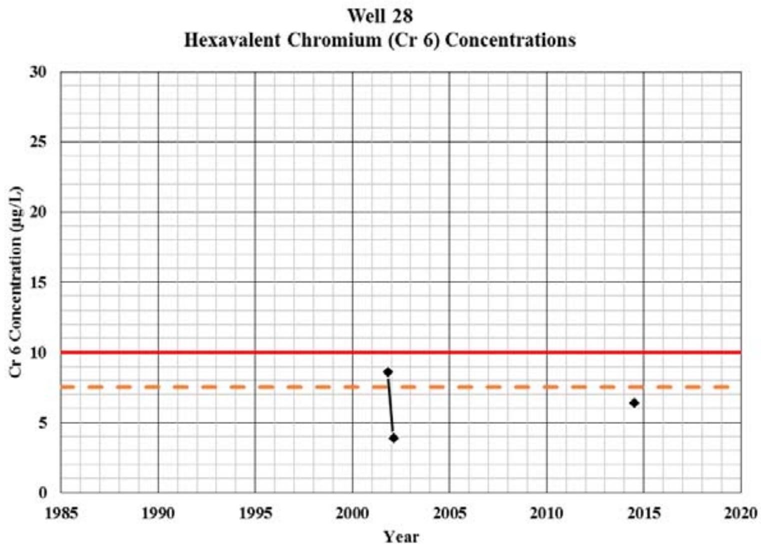
Nitrate (as NO_3)

Nitrate concentrations have remained below the MCL, but exhibit an increasing trend from 6 mg/L in 1992 to 16 mg/L in 2015. In 2010, concentrations spiked to 23 mg/L. It appears that starting in March 2011, the well has only operated for very short durations.



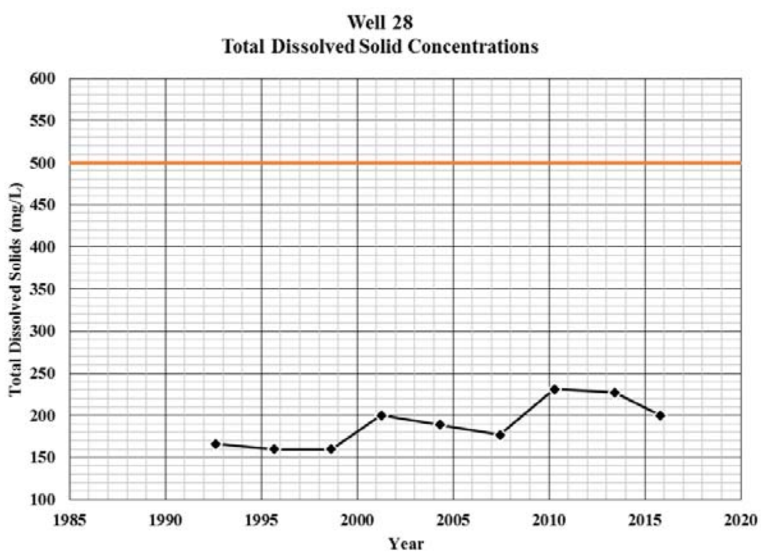
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 6.4 µg/L reported in 2014.



Total Dissolved Solids

TDS concentrations have increased slightly over the period of record, ranging from 160 to 230 mg/L, with the most recent concentration of 200 mg/L reported in 2015.



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10.17 Well 29 (Active)

Well Location and Construction

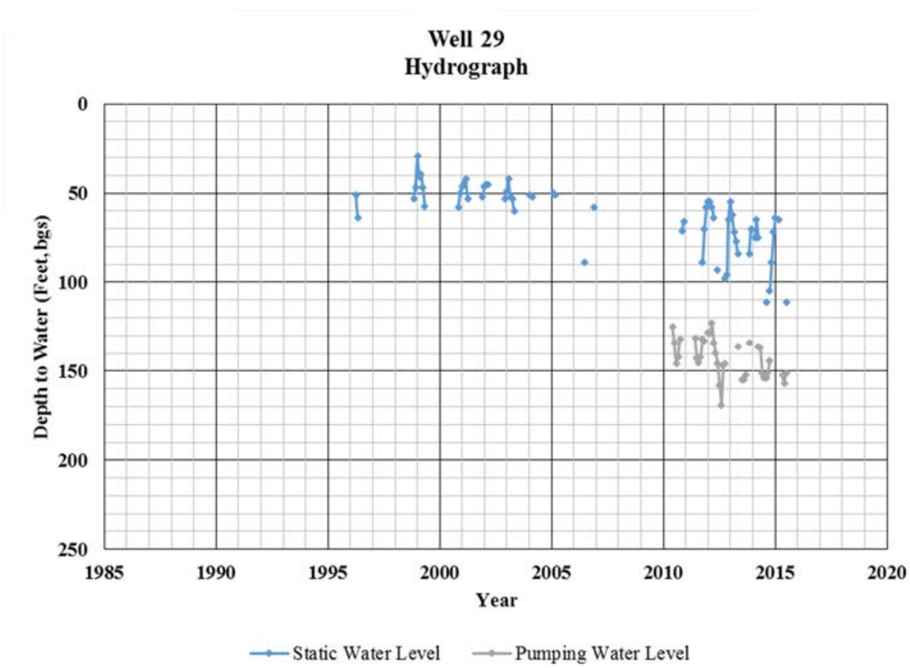
Well 29 is located at 201 E. Hawkeye Avenue, as shown in Figure 1. Well 29 was constructed by the reverse rotary drilling method in 1995, presently making this well 21 years old. A 32-inch outside conductor casing and a sanitary seal were placed to a depth of 50 feet. A 32-inch diameter borehole was drilled to a depth of 608 feet. The well structure consists of an 18.625-inch outside diameter with 5/16-inch wall thickness well casing to a depth of 472 feet and well screen with a 0.050-inch slot size from 204 to 324 feet, 348 to 388 feet, and 417 to 457 feet. The annular space is filled with Colorado Silica 6 x 20 gravel envelope from the total borehole depth to 190 feet. A cement grout sanitary seal was placed from 190 feet to the ground surface.

Well Equipment and Production

Well 29 is equipped with a 125 horsepower motor and a Fairbanks Morse vertical turbine oil-lubricated pump set to a depth of 220 feet. The well is reported to produce an average 1,240 gpm to the system, with a specific capacity of approximately 26 gpm/foot of drawdown. In 2014, Well 29 produced approximately 206,865,000 gallons of groundwater, approximately 3% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 29 since 1996 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 65 feet (March 2015). Spring static water levels have declined by 14 feet from March 1996 to March 2015 at a rate of approximately 0.7 feet per year.

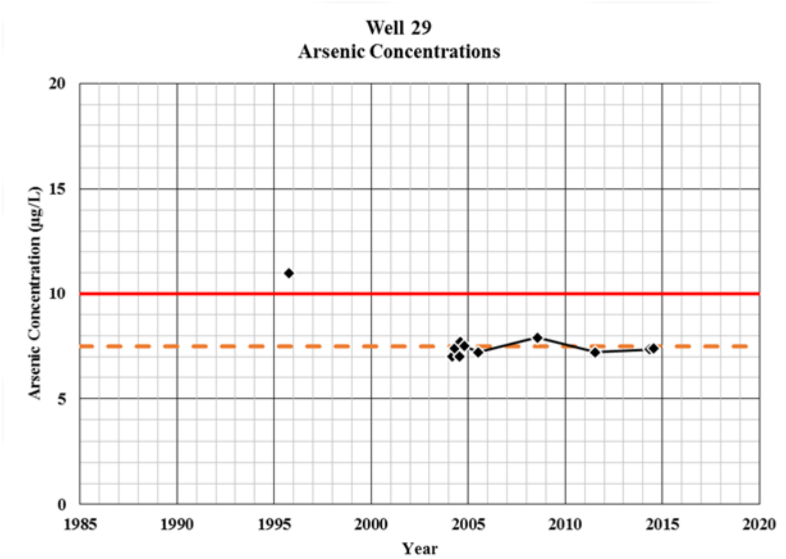


Water Quality

Water quality records indicate that the water produced from Well 29 currently meets all DDW primary and secondary drinking water requirements. Well 29 is currently active and provides untreated water to the system.

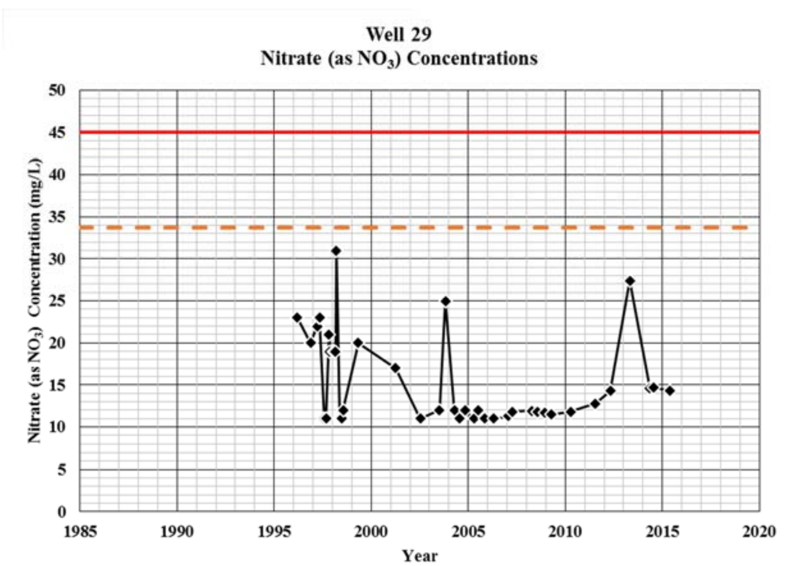
Arsenic

Historic arsenic concentrations have remained below the MCL since 2004, ranging from 7 to 7.8 µg/L, with the latest arsenic concentration of 7.4 µg/L recorded in 2014.



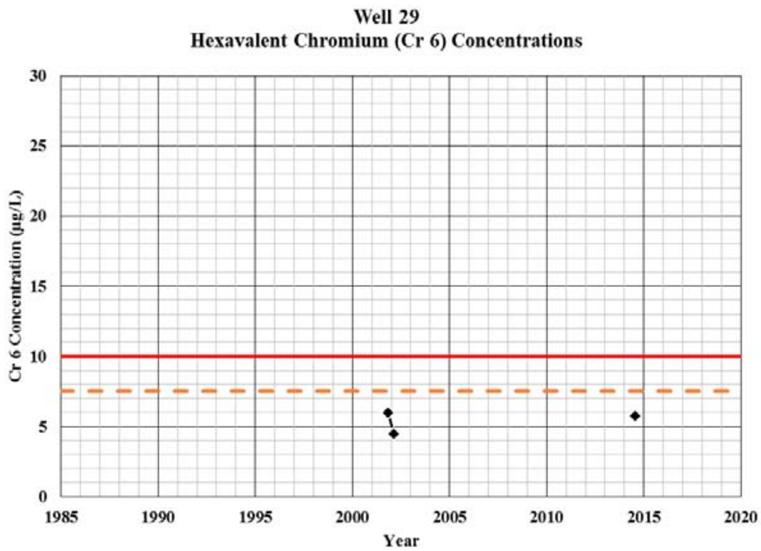
Nitrate (as NO_3)

Nitrate concentrations have remained below the MCL ranging from 11 to 31 mg/L, with the latest concentration of 14.3 mg/L reported in 2015. Nitrate concentrations temporarily spike upward indicating that when this well is idle, water moves from shallow aquifers downward into deeper aquifers.



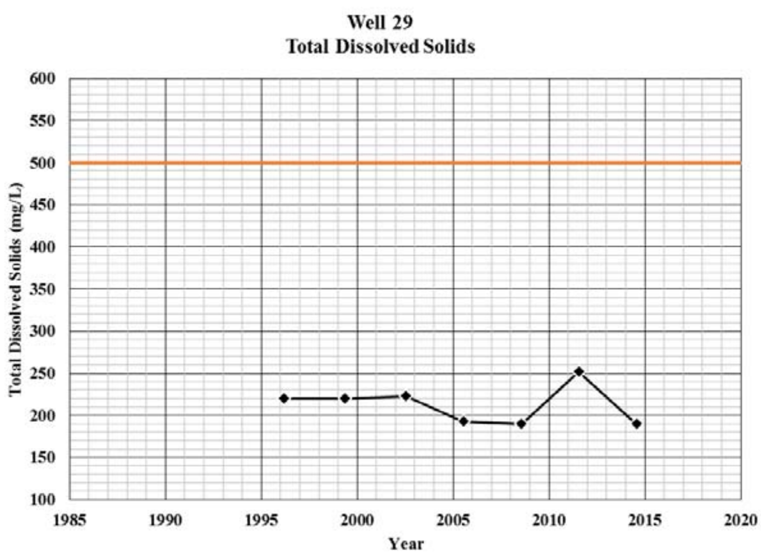
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 5.7 µg/L reported in 2014.



Total Dissolved Solids

TDS concentrations have ranged from 190 to 252 mg/L, with the most recent TDS concentration reported at 190 mg/L in 2015.



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10.18 Well 30 (Active)

Well Location and Construction

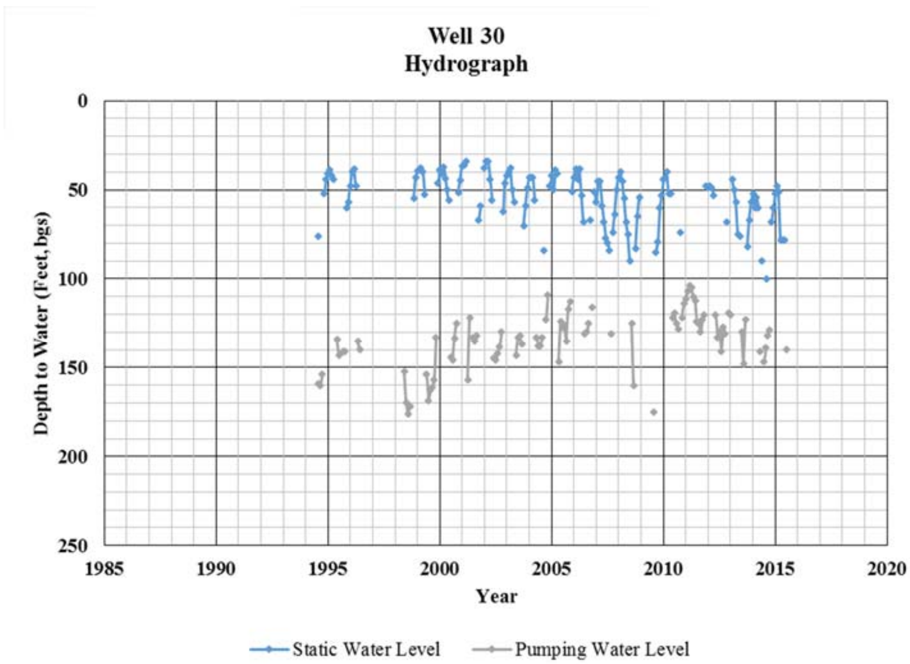
Well 30 is located at the southeast corner of 991 S. Orange Street, as shown in Figure 1. Well 30 was constructed by the reverse rotary drilling method in 1993, presently making this well 23 years old. A 34-inch diameter conductor casing and sanitary seal were placed to a depth of 50 feet. A 31-inch diameter borehole was drilled to a depth of 425 feet. The well structure consists of an 18.625-inch outside diameter with 5/16-inch wall thickness steel casing with a single perforated interval (unspecified screen pattern) with 0.050-inch slot size from 215 to 415 feet. The annular space is filled with a graded gravel envelope (6 x 20) from the total borehole depth to 190 feet, a bentonite seal from 185 to 190 feet and a sand cement annular seal from 190 feet to the ground surface. A two-inch sounding pipe enters the casing at a depth of 240 feet and a three-inch gravel fill pipe was placed to a depth of 195 feet.

Well Equipment and Production

Well 30 is equipped with a 150 horsepower motor and a Bryon Jackson vertical turbine oil-lubricated pump set to a depth of 195 feet. The well is reported to produce an average 1,013 gpm to the system, with a specific capacity of approximately 16 gpm/foot of drawdown. In 2014, Well 30 produced approximately 150,807,000 gallons of groundwater, approximately 2% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 30 since 1994 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 48 feet (February 2015). Spring static water levels have declined by 9 feet from February 1995 to February 2015 at a rate of approximately 0.5 feet per year.

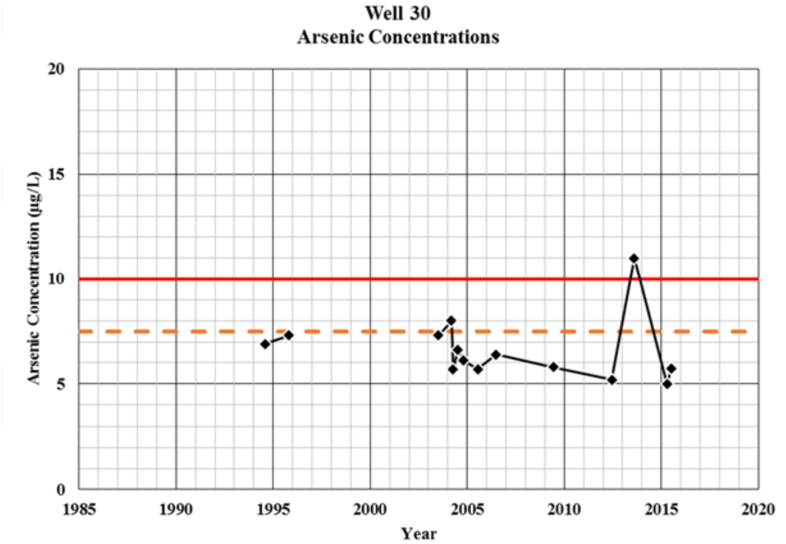


Water Quality

Water quality records indicate that the water produced from Well 30 meets all DDW primary and secondary drinking water requirements. Well 30 is currently active and provides untreated water to the system.

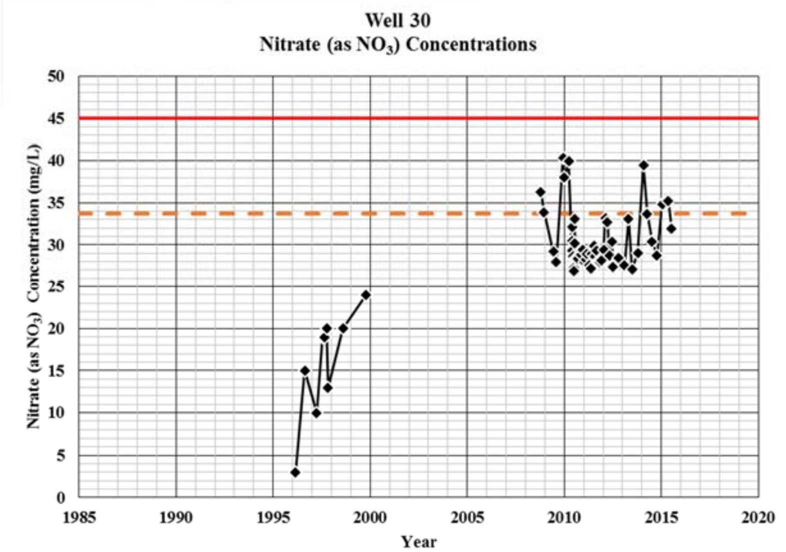
Arsenic

Historic arsenic concentrations have remained below the MCL, with an exception of an anomalous value of 11 µg/L in 2013. Excluding the anomalous value, arsenic concentrations have ranged between 5 to 8 µg/L, with the most recent concentration of 5.7 µg/L reported in 2015.



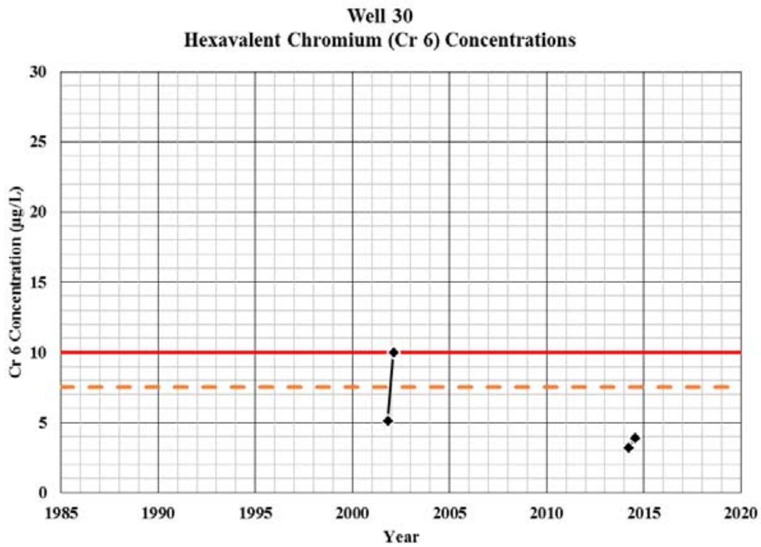
Nitrate (as NO_3)

Nitrate concentrations have remained below the MCL; however, concentrations have increased over the period of record from 3 mg/L up to a maximum of 40.3 mg/L in 2009. The most recent reported concentration was 31.9 mg/L in 2015.



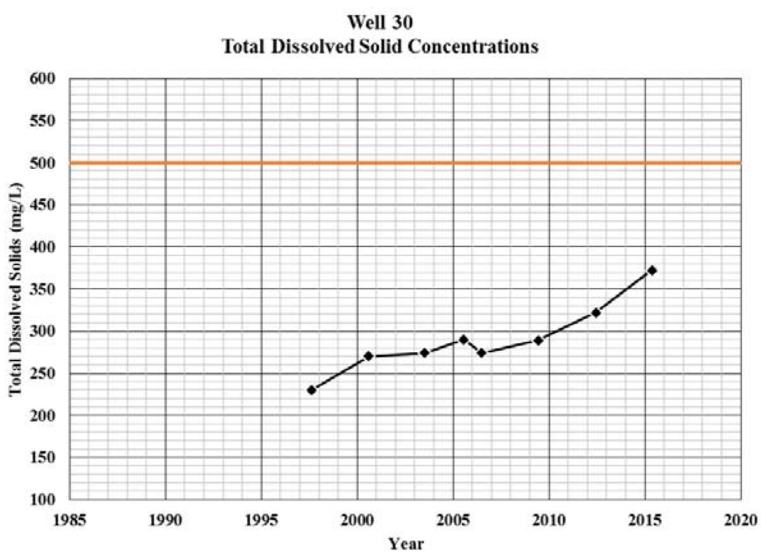
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 3.9 µg/L reported in 2014; however, in 2002, Cr^{6+} was reported at 10 µg/L.



Total Dissolved Solids

TDS concentrations have increased at a rate of approximately 8 mg/L per year over the period of record from 230 to 372 mg/L. The most recent TDS concentration was 370 mg/L reported in 2015.



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10.19 Well 31 (Stand-by)

Well Location and Construction

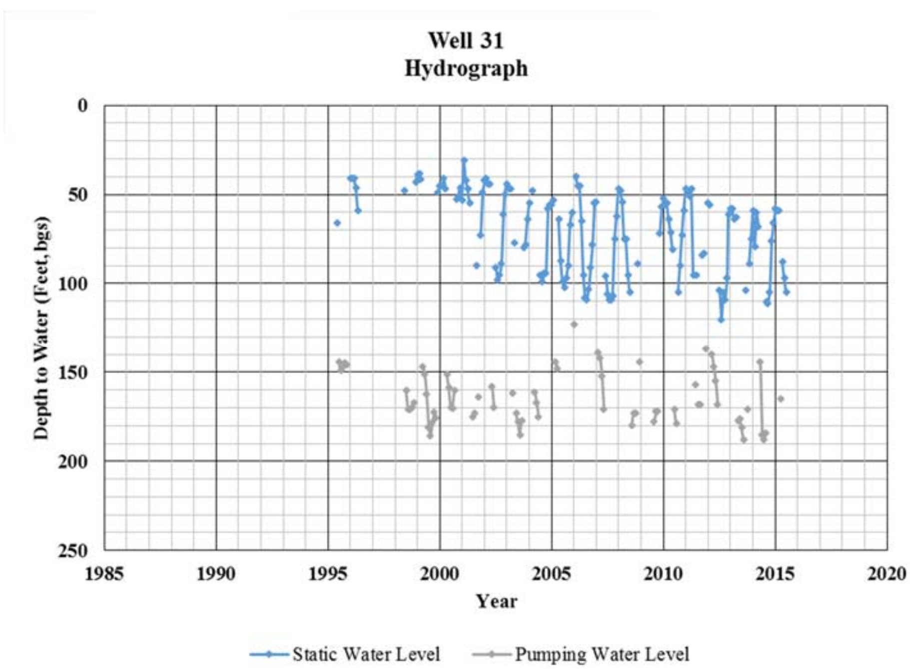
Well 31 is located at 3951 N. Walnut Road, in the south-eastern portion of the Turlock Junior High School, as shown in Figure 1. Well 31 was constructed by the reverse rotary drilling method in 1993, presently making this well 23 years old. A 33-inch diameter conductor casing and a sanitary seal extend from the ground surface to a depth of 50 feet. A 30-inch diameter borehole was drilled to a total depth of 403 feet. An 18.625-inch outside diameter well casing with 5/16-inch wall thickness extends from the ground surface to a depth of 400 feet. Louvered well screen with 0.070-inch slot size extends from 200 to 260 feet and 300 to 390 feet. A 4 x 16 graded gravel envelope was placed from 403 to 180 feet, with a bentonite seal from 190 to 180 feet, and a cement annular seal from 180 feet to the ground surface. A two-inch sounding pipe enters the well structure at a depth of 200 feet and a three-inch gravel fill pipe was installed to an unknown depth.

Well Equipment and Production

Well 31 is equipped with a 150 horsepower motor and a Peerless vertical turbine oil-lubricated pump set to a depth of 205 feet. The well is reported to produce an average 2,167 gpm to the system, with a specific capacity of approximately 36 gpm/foot of drawdown. In 2014, Well 31 produced approximately 289,436,000 gallons of groundwater, approximately 4% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 31 since 1995 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 59 feet (March 2015). Spring static water levels have declined by 18 feet from March 1996 to March 2015 at a rate of approximately one foot per year.

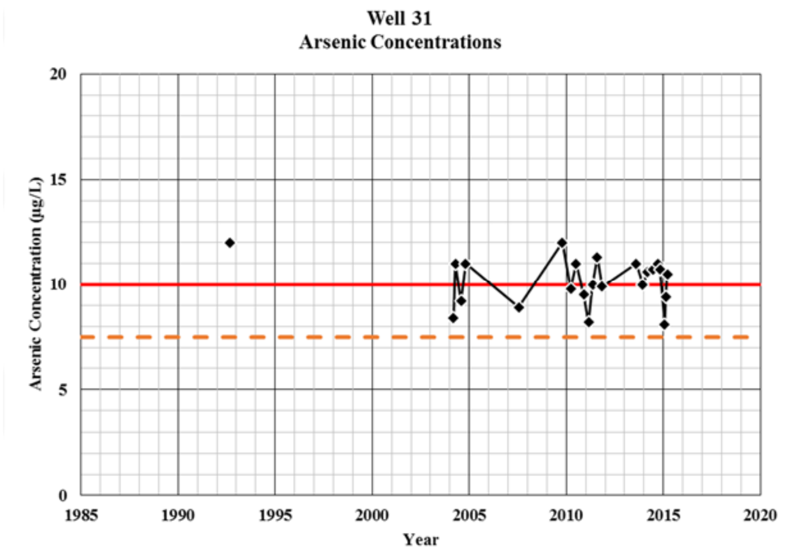


Water Quality

Water quality records indicate that the water produced from Well 31 meets all of the DDW primary and secondary drinking water requirements with the exception of arsenic. Well 31 is currently inactive and does not provide water to the system due to elevated concentrations of arsenic.

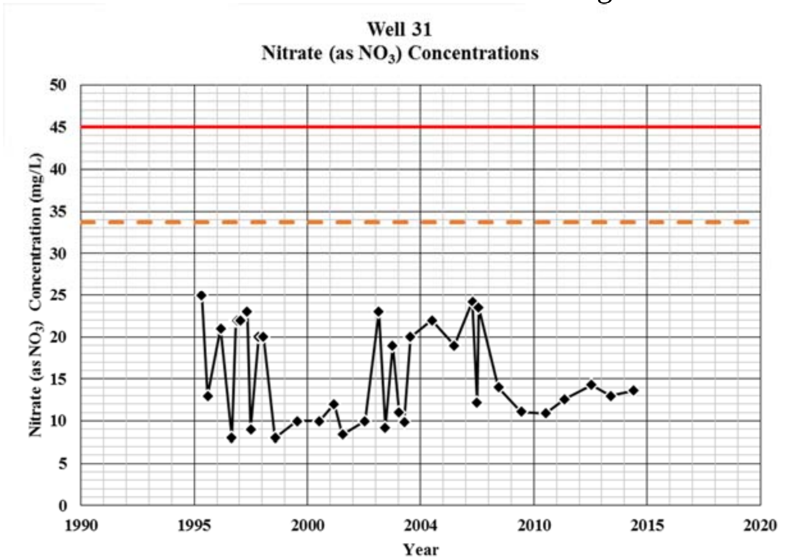
Arsenic

Arsenic concentrations have averaged 10.2 µg/L, exceeding the current MCL. Concentrations have ranged from 8 µg/L to 12 µg/L, with the most recent concentration of 10.5 µg/L reported in 2015.



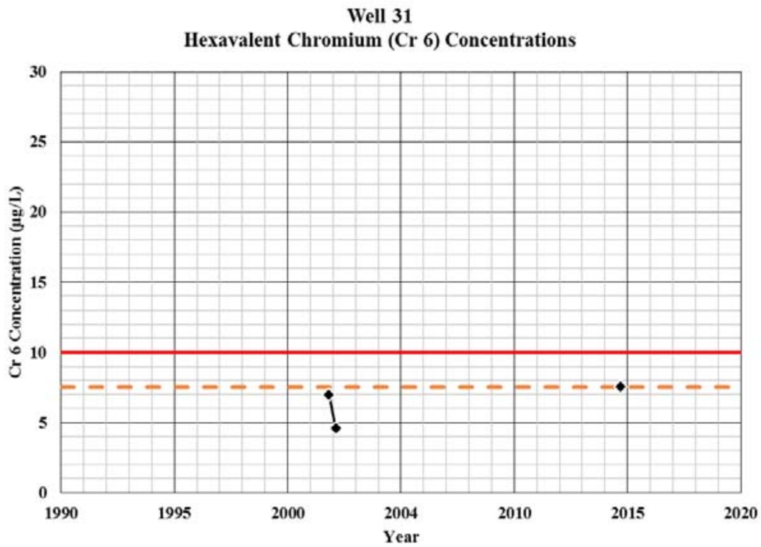
Nitrate (as NO_3)

Nitrate concentrations have remained below the MCL, ranging from 8 mg/L to 25 mg/L, with a relatively stable trend. The most recent concentration of 13.6 mg/L was recorded in 2014.



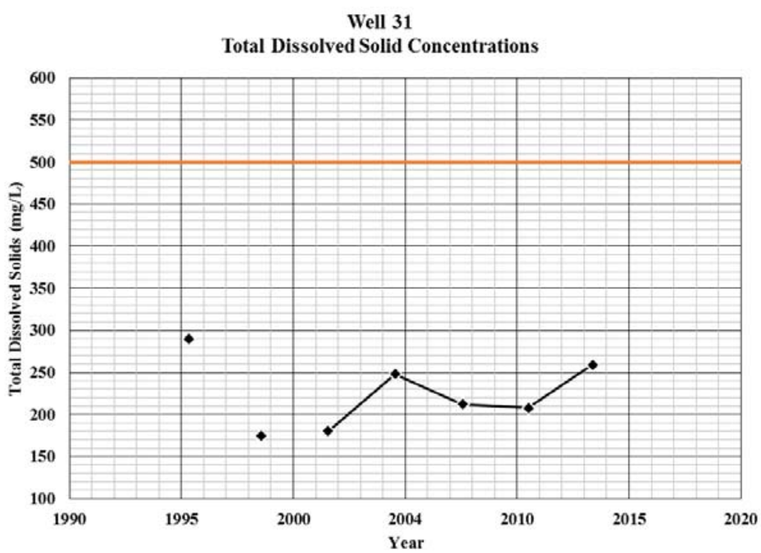
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 7.5 µg/L reported in 2014.



Total Dissolved Solids

TDS concentrations have ranged between 175 to 290 mg/L, with the most recent concentration of 259 mg/L reported in 2013.



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10.20 Well 32 (Stand-by)

Well Construction and Location

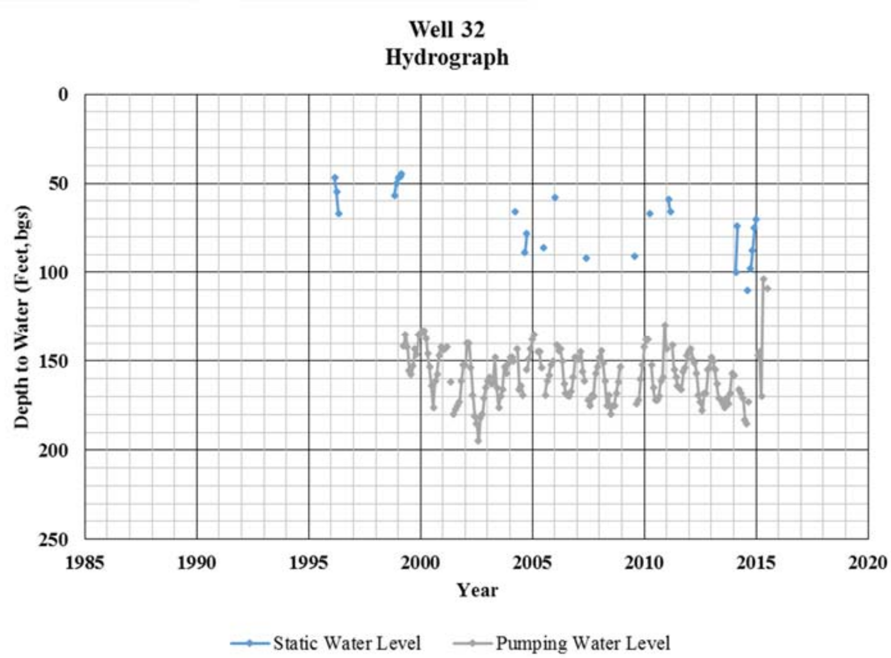
Well 32 is located at 1623 Alex Way, as shown in Figure 1. Well 32 was constructed by the reverse rotary drilling method in 1995, presently making this well 21 years old. A 32-inch diameter conductor casing and a cement sanitary seal were placed to a depth of 50 feet. Initially, an 18-inch diameter pilot borehole was drilled to a depth of 600 feet. The pilot hole was reamed to a depth of 525 feet with a diameter of 32-inches. The well structure consists of an 18.625-inch outside diameter with a 5/16-inch wall thickness well casing and screen assembly, with perforated intervals from 195 to 310 feet, 324 to 400 feet, and 470 to 515 feet (unknown pattern) with a well screen opening of 0.050-inch slot size. The annular space is filled with a Colorado Silica gravel envelope (6 x 20 gradation) from 525 to 185 feet, followed by a sand/cement grout annular seal from 185 feet to the ground surface. The original pilot hole was backfilled with Colorado Silica from a depth of 600 to 525 feet.

Well Equipment and Production

Well 32 is equipped with a 150 horsepower motor and a Peabody Floway submersible pump set to a depth of 240 feet. The well is reported to produce an average 1,580 gpm to the system, with a specific capacity of approximately 19 gpm/foot of drawdown. In 2014, Well 32 produced approximately 585,423,800 gallons of groundwater, about 9% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 32 since 1995 and include both static and pumping water level measurements, with the majority of the groundwater measurements reflecting pumping water levels. Limited static water level measurements, which are also likely influenced by recent pumping, reduce the ability to identify longer-term trends. The most recent spring high static groundwater level measurement was 70 feet (January 2015). Spring static water levels have declined by approximately 23 feet from January 1996 to March 2015 at a rate of approximately 1.2 feet per year.

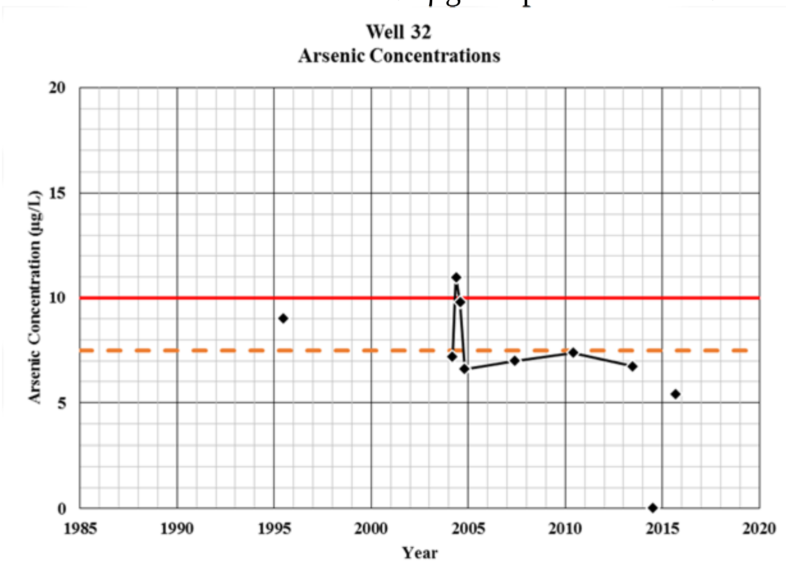


Water Quality

Water quality records indicate that the water produced from Well 32 nearly meets all DDW primary and secondary drinking water requirements, with the exception of nitrate (as NO_3). Well 32 is currently active, but is currently on stand-by status due to the elevated concentrations of nitrate that are near or in exceedance of the MCL.

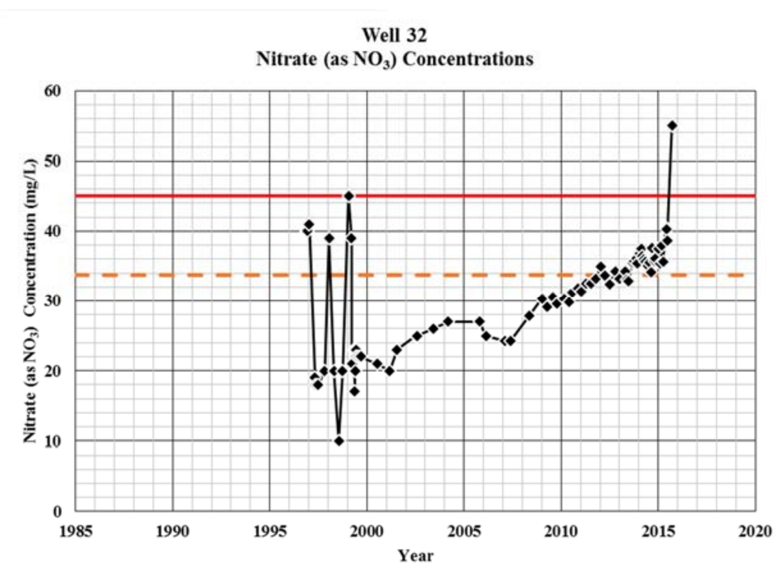
Arsenic

Historic arsenic concentrations have remained below the MCL, with an exception in 2004 where concentrations spiked to 11 µg/L. Arsenic concentrations have ranged from non-detectable to 11 µg/L, with the most recent concentration of 5.4 µg/L reported in 2015.



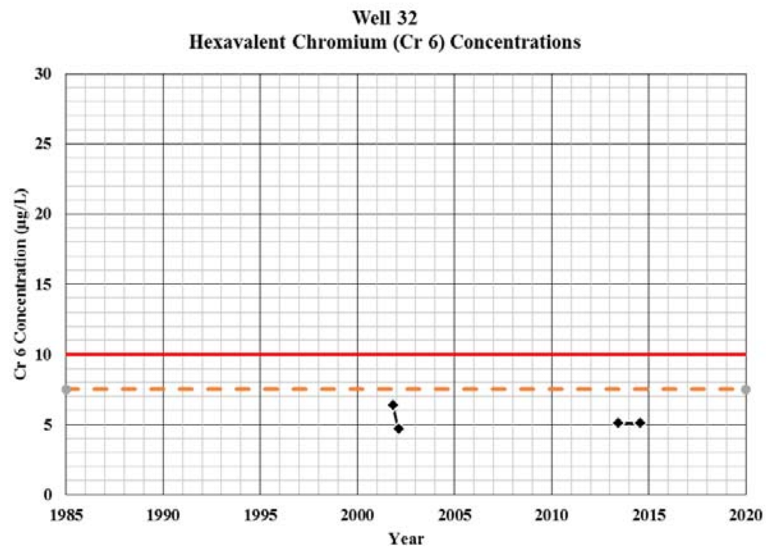
Nitrate (as NO_3)

Between 1996 and 2000, nitrate (as NO_3) concentrations fluctuated between 10 mg/L and 45 mg/L. From 2000 to 2015, concentrations became more stable, but increased toward the MCL, with the most recent concentration of 55 mg/L reported in 2015. Temporary spikes in nitrate concentrations indicate that when this well is idle, groundwater moves from shallow aquifers downward into the deeper aquifers.



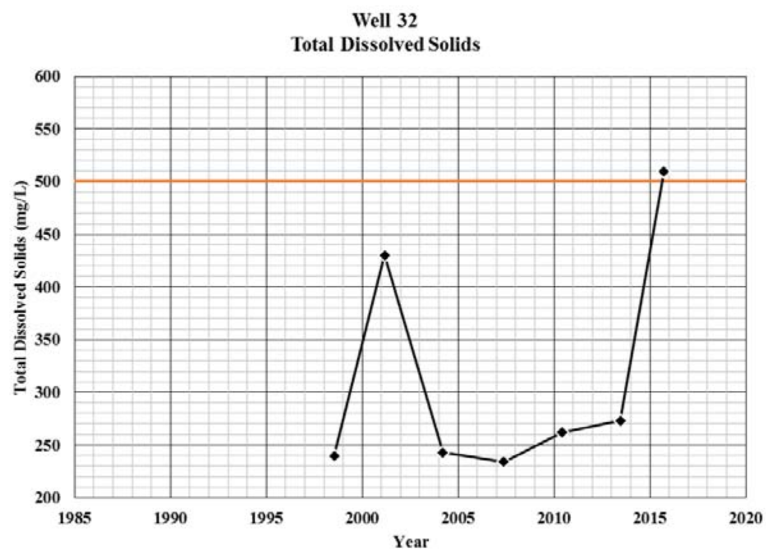
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 5.1 µg/L reported in 2014.



Total Dissolved Solids

TDS concentrations have generally been low, but have fluctuated between 230 to 430 mg/L. The most recent concentration of 510 mg/L was reported in 2015, a significant increase from the 2013 reported concentration of 273 mg/L. Elevated concentrations are likely a result of downward migration of shallow groundwater when this well is idle.



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10.21 Well 33 (Active)

Well Location and Construction

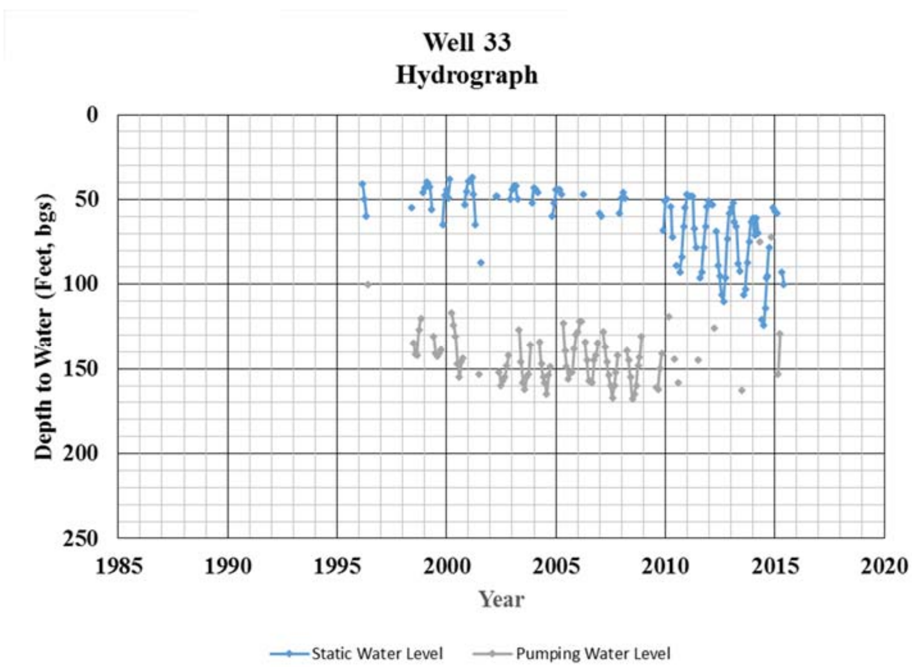
Well 33 is located at 500 S. Berkeley Avenue on the southwest corner of Sunnyview Park as shown in Figure 1. Well 33 was constructed by the reverse rotary drilling method in 1995, presently making this well 21 years old. An 18-inch diameter pilot borehole was drilled to a depth of 610 feet. A 32-inch diameter conductor casing and a cement sanitary seal were placed to a depth of 50 feet. The pilot hole was reamed to a diameter of 30-inches to a depth of 450 feet. The well structure consists of an 18.625-inch outside diameter with 5/16-inch wall thickness to a depth of 450 feet, with perforated screen intervals (unspecified screen pattern) with 0.070-inch slot size from 150 to 170 feet, 185 to 200 feet, 220 to 236 feet, 250 to 260 feet, 275 to 336 feet, 350 to 370 feet, and 424 to 440 feet. The annular space, including the 18-inch pilot hole, was filled with a graded gravel envelope (4 x 20 Colorado Silica) from the total depth to a depth of 140 feet, followed by a cement annular seal from 140 feet to the ground surface.

Well Equipment/Production

Well 33 is equipped with a 200 horsepower motor and a Floway vertical turbine oil-lubricated pump set to a depth of 180 feet. The well is reported to produce an average 2,200 gpm to the system, with a specific capacity of approximately 76 gpm/foot of drawdown. In 2014, Well 33 produced approximately 378,014,000 gallons of groundwater, approximately 6% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 33 since 1996 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 58 feet (February 2015). Spring static water levels have declined by approximately 17 feet from March 1996 to February 2015 at a rate of approximately 1 foot per year.

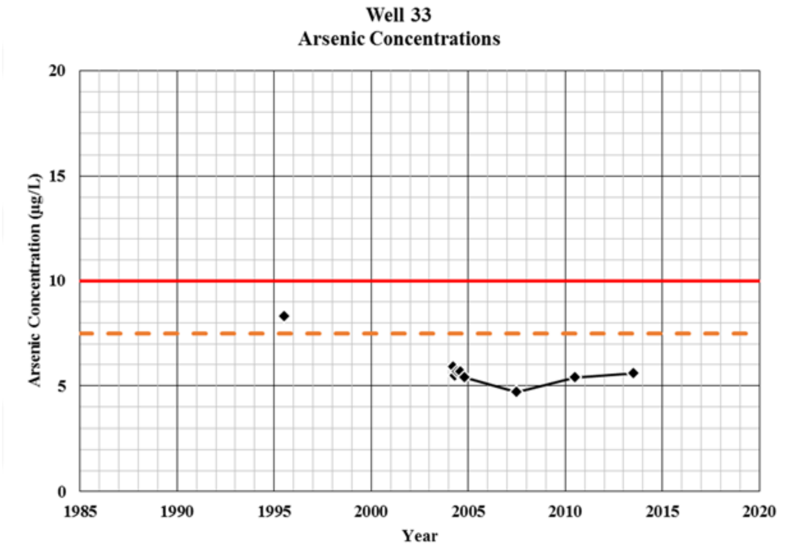


Water Quality

Water quality records indicate that the water produced from Well 33 meets all DDW primary and secondary drinking water requirements. Well 33 is currently active and provides untreated water to the system.

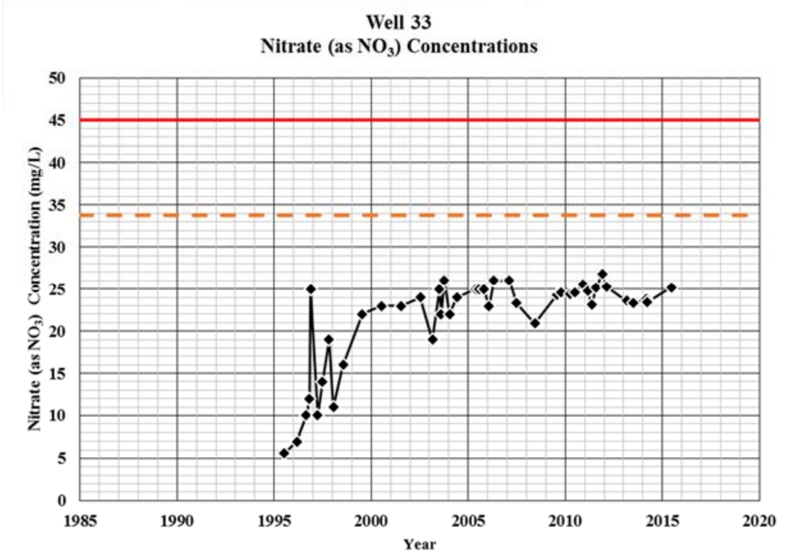
Arsenic

Historic arsenic concentrations appear to be stable and have remained below the MCL, ranging between 4.8 to 8.3 µg/L. The most recent concentration of 5.6 µg/L was reported in 2015.



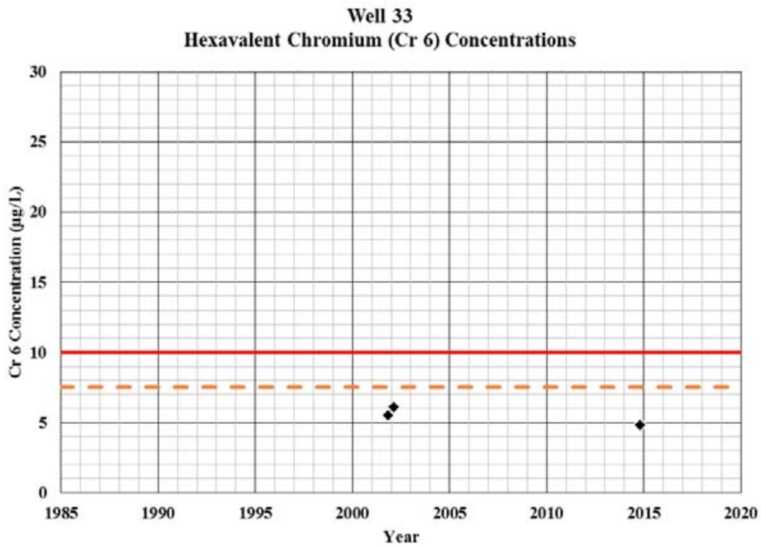
Nitrate (as NO3)

Nitrate concentrations have ranged from 5.5 to 26.8 mg/L. The overall trend suggests that from 1995 through 2000, concentrations increased at a rate of approximately 3.5 mg/L per year. From 2000 through 2015, the rate of increase reduced to less than 0.5 mg/L and appears to be relatively stable. The most recent concentration of 25.2 mg/L was reported in 2015.



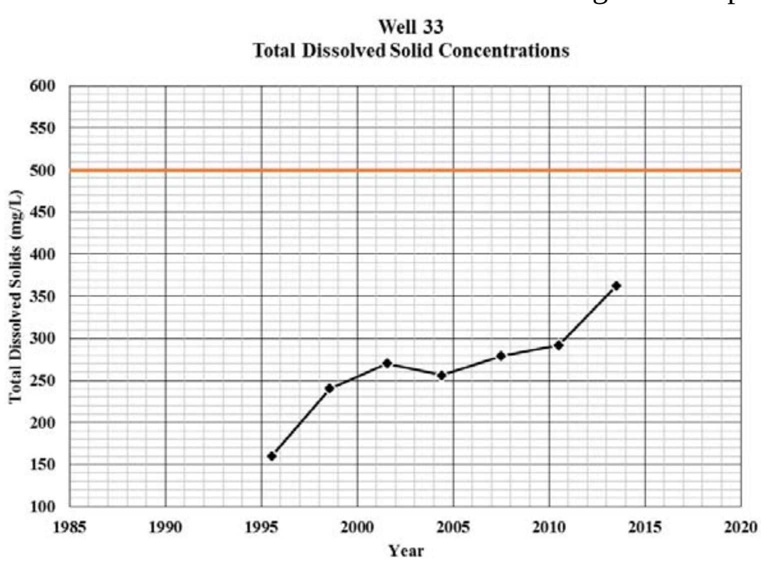
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 4.8 µg/L reported in 2014.



Total Dissolved Solids

TDS concentrations are below the Recommended Limit of 500 mg/L. However, the concentration has been increasing over the period of record at a rate of approximately 10 mg/L per year. If this trend continues, water produced from Well 33 could exceed the Recommended Limit in approximately 14 years. The most recent concentration of 362 mg/L was reported in 2013.



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10.22 Well 34 (Active)

Well Construction

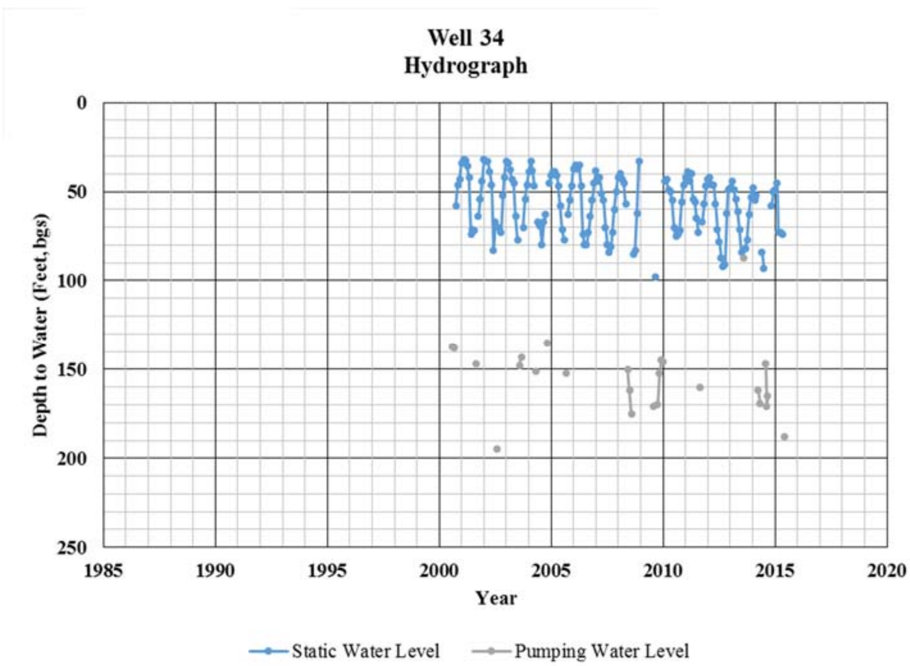
Well 34 is located at 6000 Dianne Drive as shown in Figure 1. Well 34 was constructed by the reverse rotary method in 1999, presently making this well 17 years old. A pilot borehole was drilled to a depth of 602 feet. A 32-inch diameter conductor casing and cement sanitary seal were placed to a depth of 50 feet. The pilot hole was reamed to a diameter of 30-inches to a depth of 430 feet. The well structure consists of an 18.625-inch outside diameter well casing with 5/16-inch wall thickness to a depth of 430 feet, with perforated screen intervals (unspecified screen pattern) with 0.040-inch slot size from 305 to 410. The annular space was filled with a graded gravel envelope (8 x 30) from the total depth to 295 feet, followed by a cement annular seal from 295 feet to the ground surface.

Well Equipment and Production

Well 34 is equipped with a 125 horsepower G.E. motor and a vertical turbine oil-lubricated pump set to a depth of 230 feet. The well is reported to produce an average 997 gpm to the system, with a specific capacity of approximately 9 gpm/foot of drawdown. In 2014, Well 34 produced approximately 281,757,000 gallons of groundwater, approximately 4% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 34 since 2000 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 45 feet (February 2015). Spring static water levels have declined by approximately 13 feet from February 2001 to February 2015 at a rate of approximately 1 foot per year.

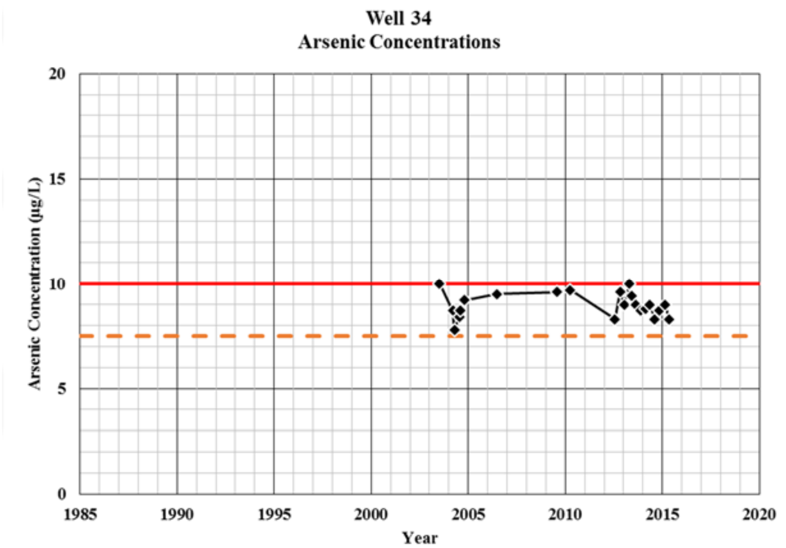


Water Quality

Water quality records indicate that the water produced from Well 34 meets all DDW primary and secondary drinking water requirements. Well 34 is currently active and provides untreated water to the system.

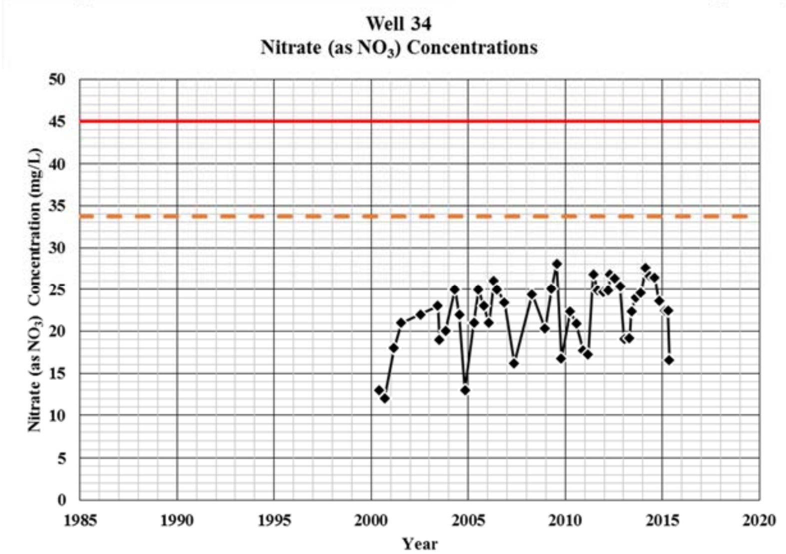
Arsenic

Historic arsenic concentrations have been at or below the MCL, ranging from 7.8 to 10 µg/L. The overall trend appears to be relatively stable, with the most recent concentration of 8.3 µg/L reported in 2015.



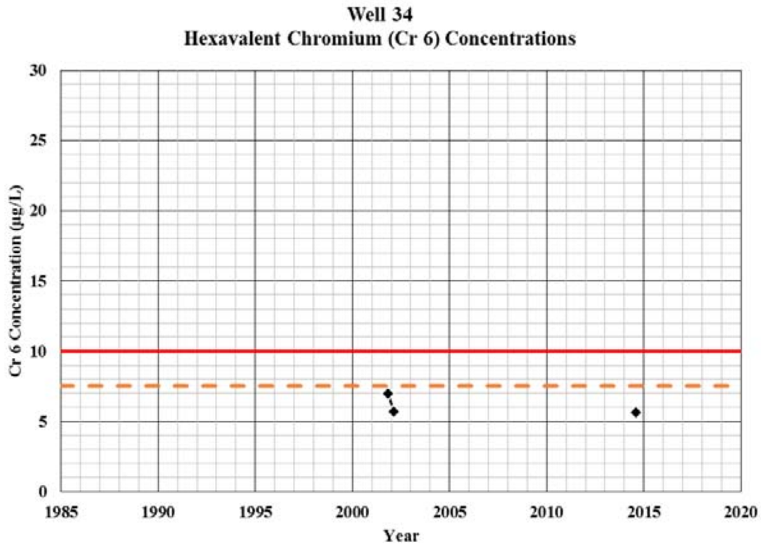
Nitrate (as NO_3)

Nitrate concentrations have remained below the MCL, but indicate an overall increasing trend. Concentrations appear to fluctuate throughout the year, but do not appear to be correlated with the time of year (i.e. spring/summer, fall/winter). Over the period of record, concentrations have ranged from 12 to 28 mg/L, with the most recent concentration of 22.5 mg/L reported in 2015.



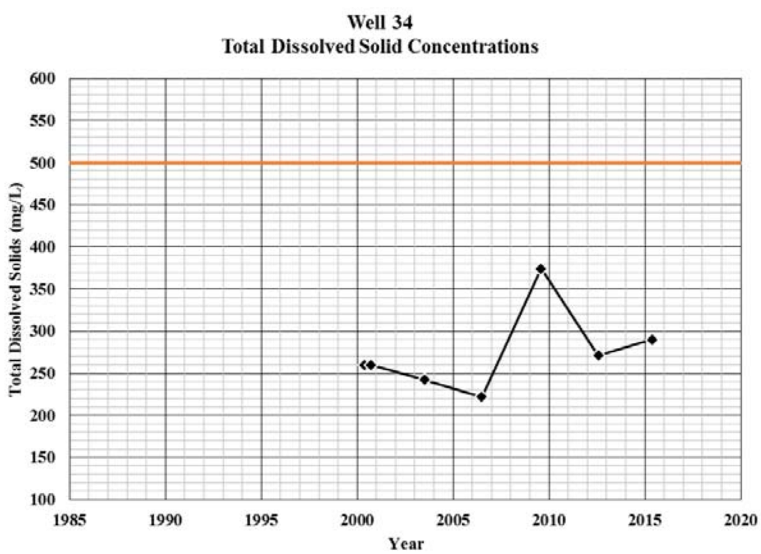
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 5.6 µg/L reported in 2014.



Total Dissolved Solids

Concentrations of TDS have increased at a rate of 2 mg/L per year over the period of record from 220 to 372 mg/L. The most recent TDS concentration was 290 mg/L reported in 2015, below the Recommended Limit for potable supply.



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10.23 Well 35 (Active)

Well Construction

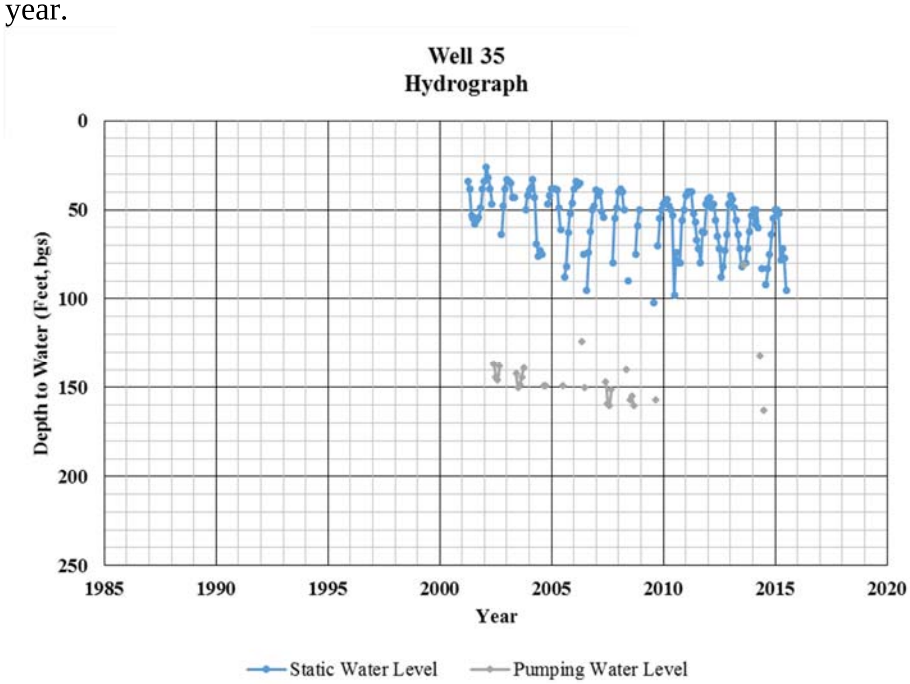
Well 35 is located at 3089 North Tegner Road as shown in Figure 1. Well 35 was constructed by the reverse rotary drilling method in 1999, presently making this well 17 years old. A pilot hole was drilled to a total depth of 600 feet. A 32-inch diameter conductor casing and cement sanitary seal were placed from the ground surface to a depth of 50 feet. The pilot hole was reamed to a diameter of 30-inches to a depth of 495 feet. The well structure consists of an 18.625-inch outside diameter well casing with a wall thickness of 5/16-inches to a depth of 495 feet, with a single perforated interval (unspecified screen pattern) and unknown slot size from 205 to 485 feet. The annular space was filled with a graded gravel envelope (5/16 x 16) from the total depth to 185 feet, followed by a cement annular seal from 185 feet to the ground surface. The pilot hole below a depth of 495 is filled with an unspecified material.

Well Equipment and Production

Well 35 is equipped with a 250 horsepower motor with a Sterling-Peerless vertical turbine water-lubricated pump set to a depth of 200 feet. The well is reported to produce an average of 1,665 gpm to the system, with a specific capacity of approximately 24 gpm/ft of drawdown. In 2014, Well 35 produced approximately 62,905,000 gallons of groundwater, approximately 1% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 35 since 2001 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 50 feet (February 2015). Spring static water levels have declined by approximately 16 feet from April 2001 to February 2015 at a rate of approximately just over one foot per year.

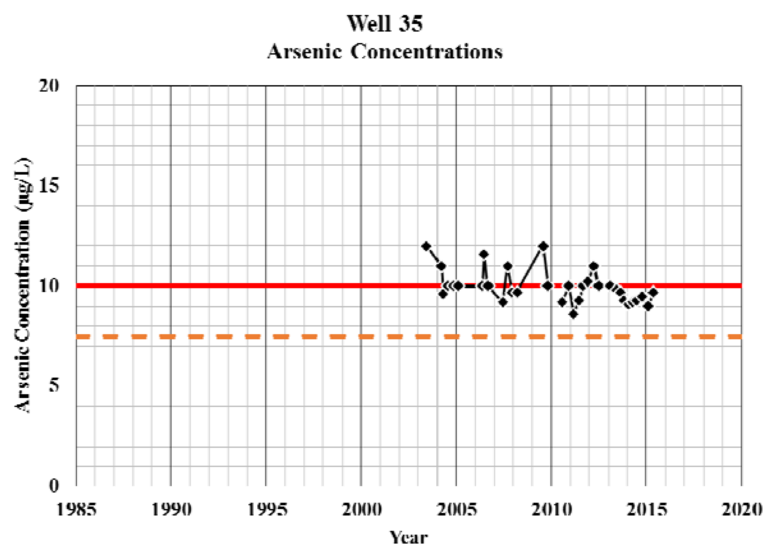


Water Quality

Water quality records indicate that the water produced from Well 35 meets all DDW primary and secondary drinking water requirements. Well 35 is currently active and provides untreated water to the system.

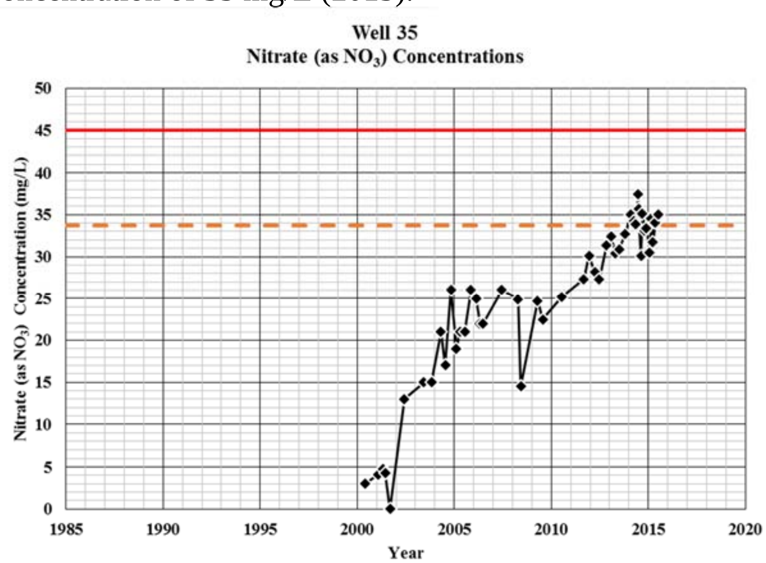
Arsenic

Concentrations of arsenic have fluctuated over the period of record, often exceeding the current MCL. Concentrations have ranged from 8.6 to 12 µg/L; however, since 2013, arsenic concentrations have remained below the MCL with the latest concentration of 9.7 µg/L reported in 2015.



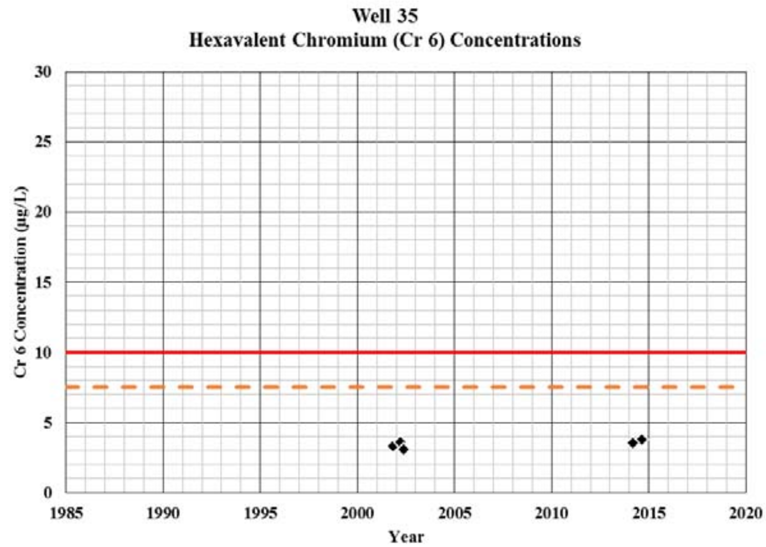
Nitrate (as NO_3)

Concentrations of nitrate over the period of record indicate seasonal fluctuations as well as an overall increasing trend. Concentrations have increased approximately 2 mg/L per year from 3 mg/L (2001) to a concentration of 35 mg/L (2015).



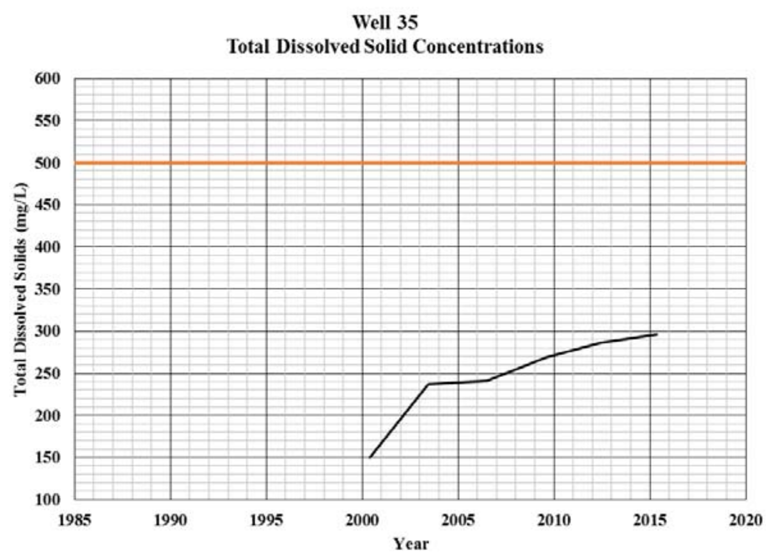
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 5.6 µg/L reported in 2014. Between 2002 and 2014, the concentrations appear to be stable; however, there are limited data between the two sampling years.



Total Dissolved Solids

Concentrations of TDS have ranged from 150 to 296 mg/L over the period of record and indicate an overall increasing trend at a rate of 10 mg/L per year. The most recent TDS concentration was 296 mg/L reported in 2015, below the Recommended Limit for potable supply.



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10.24 Well 36 (Active)

Well Location and Construction

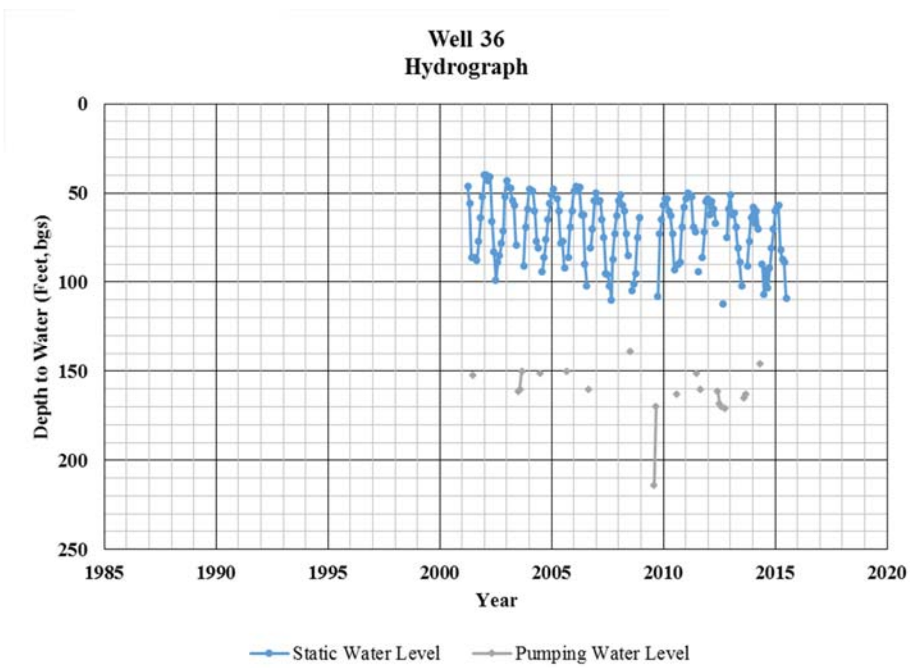
Well 36 is located at 1350 Fulkerth Road on the northeast corner of Summerfaire Park as shown in Figure 1. Well 35 was constructed by the reverse rotary drilling method in 2000, presently making this well 16 years old. A 32-inch diameter conductor casing and cement sanitary seal were placed from the ground surface to a depth of 51 feet. A 30-inch diameter borehole was drilled to a total depth of 585 feet. The well structure consists of an 18.625-inch outside diameter well casing with a wall thickness of 5/16-inches to a depth of 580 feet, with perforated intervals (unspecified screen pattern) of 0.070-inch slot size from 290 to 335 feet, 365 to 385 feet, 395 to 405 feet, 415 to 440 feet, 450 to 460 feet, 510 to 535 feet, and 545 to 570 feet. The annular space is filled with a gravel envelope (unspecified gradation) from the total depth to 270 feet, followed by a cement annular seal from 270 feet to the ground surface.

Well Equipment and Production

Well 36 is equipped with a 200 horsepower motor and a Fairbanks Morris oil-lubricated pump set to a depth of 250 feet. The well is reported to produce an average of 2,013 gpm to the system, with a specific capacity of approximately 54 gpm/foot of drawdown. In 2014, Well 35 produced approximately 18,394,000 gallons of groundwater, less than 1% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 36 since 2001 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 57 feet (March 2015). Spring static water levels have declined by approximately 11 feet from April 2001 to March 2015 at a rate of approximately just under one foot per year.

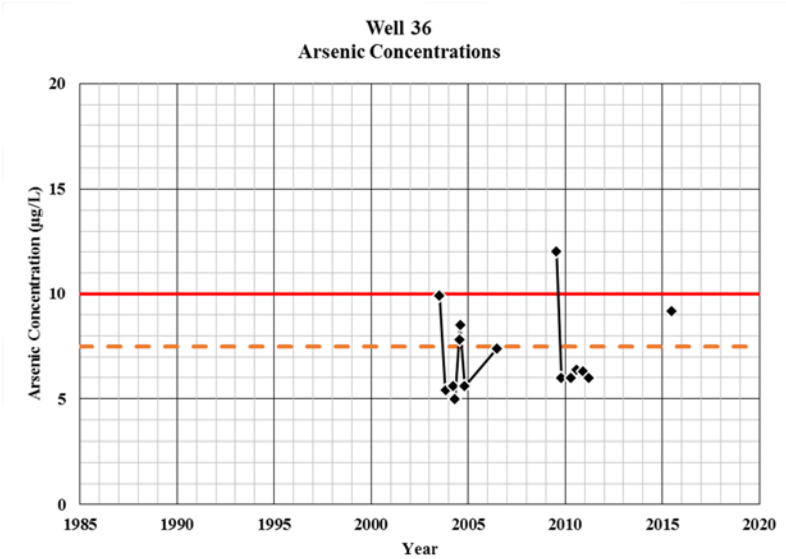


Water Quality

Water quality records indicate that the water produced from Well 36 meets all DDW primary and secondary drinking water requirements. Well 36 is currently active and provides untreated water to the system.

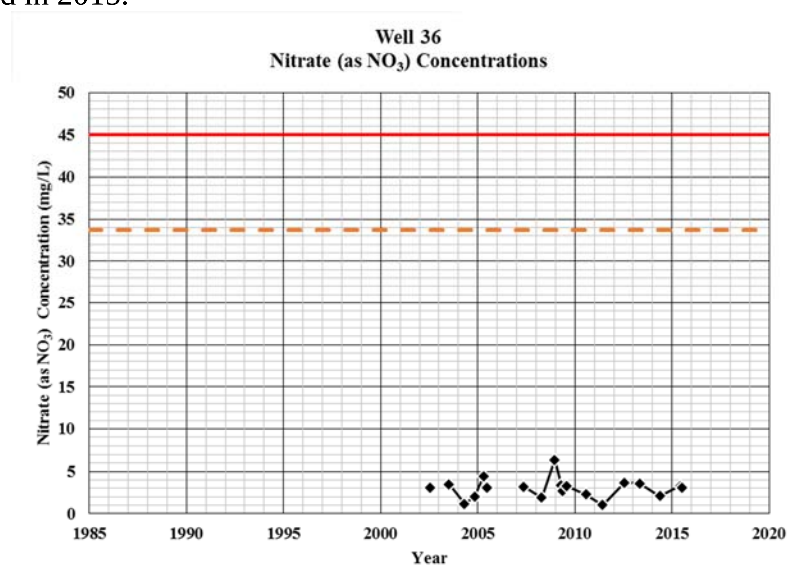
Arsenic

Historic arsenic concentrations have fluctuated widely from 5 to 12 µg/L, exceeding the current MCL on one sampling event. The most recent concentration of 9.1 µg/L was reported in 2015. There appears to be inter-aquifer movement within this well, which may explain the fluctuations in arsenic.



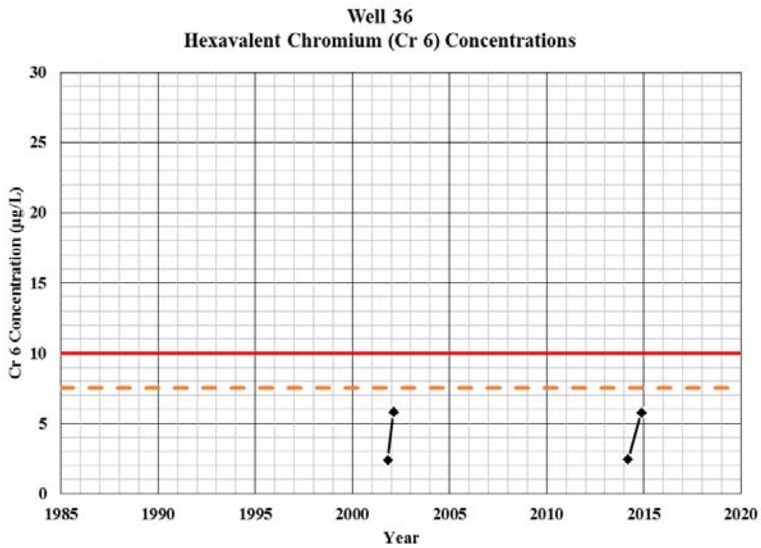
Nitrate (as NO_3)

Nitrate concentrations have maintained a stable trend below the MCL for the period of record. Concentrations have ranged between 1 mg/L and 6.4 mg/L, with the most recent concentration of 3.1 mg/L reported in 2015.



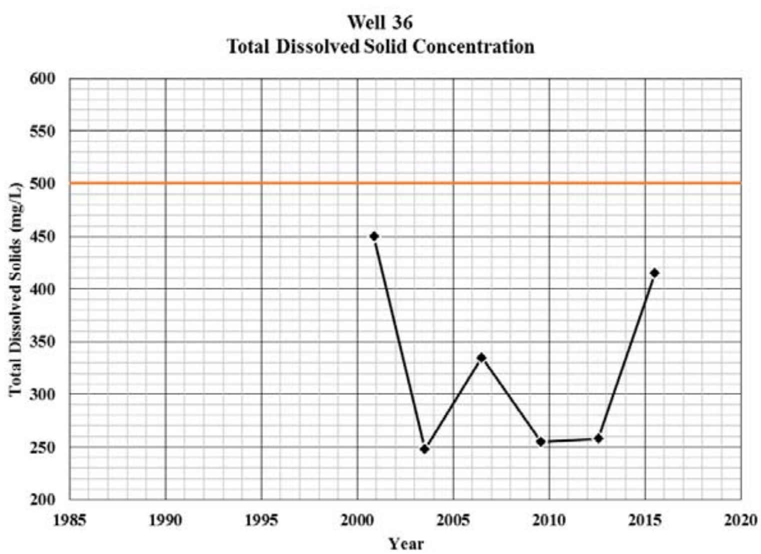
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 5.8 µg/L reported in 2014. Well 36 has been sampled for Cr^{6+} on four different dates, with two sampling events clustered near each other. Each sampling event indicates a fluctuation in concentration of approximately 3.5 µg/L, likely within the laboratory reporting error allowed by testing methods.



Total Dissolved Solids

TDS concentrations have fluctuated over the period of record, with concentrations ranging between 248 to 450 mg/L. The most recent concentration of 415 mg/L was reported in 2015, below the Recommended Limit of 500 mg/L. There appears to be inter-aquifer movement within this well, which may explain the fluctuations in TDS.



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10.25 Well 37 (Active)

Well Location and Construction

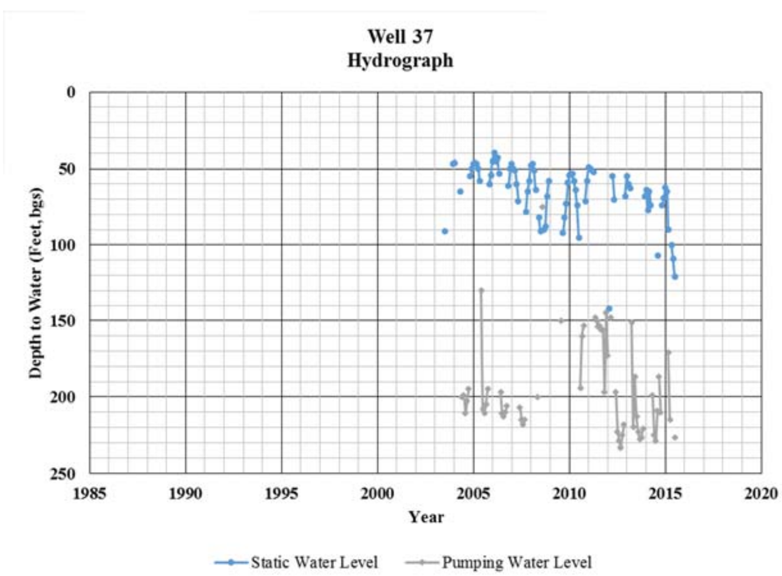
Well 37 is located on the northeast corner of 4510 Crowell Road as shown in Figure 1. Well 37 was constructed by the reverse rotary drilling method in 2003, presently making this well 13 years old. A 32-inch diameter conductor casing and sanitary seal was placed from the ground surface to a depth of 50 feet. The borehole was drilled to a total depth of 605 feet. The well structure consists of an 18.625-inch outside diameter well casing with a wall thickness of 5/16-inches to a depth of 580 feet, with perforated intervals (unspecified screen pattern) of 0.070-inch slot size from 285 to 570 feet. The annular space is filled with a gravel envelope (unspecified gradation) from the total depth to 265 feet. Bentonite seals were placed from a depth 595 to 593 feet and 265 to 260 feet. A cement annular seal was placed from 260 feet to the ground surface. The lower bentonite seal was likely placed due to poorer water quality with respect to total dissolved solids in the lower portion of the borehole.

Well Equipment and Production

Well 37 is equipped with a 350 horsepower motor and an American Marsh line-shaft oil-lubricated pump set to a depth of 270 feet. In 2014, the well was reported to produce an average 2,983 gpm to the system, with a specific capacity of approximately 25 gpm/ft of drawdown. Well 37 produced approximately 639,634,000 gallons of groundwater, approximately 10% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 37 since 2003 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 62 feet (January 2015). Spring static water levels have declined by approximately 16 feet from January 2004 to January 2015 at a rate of approximately 1.5 feet per year.

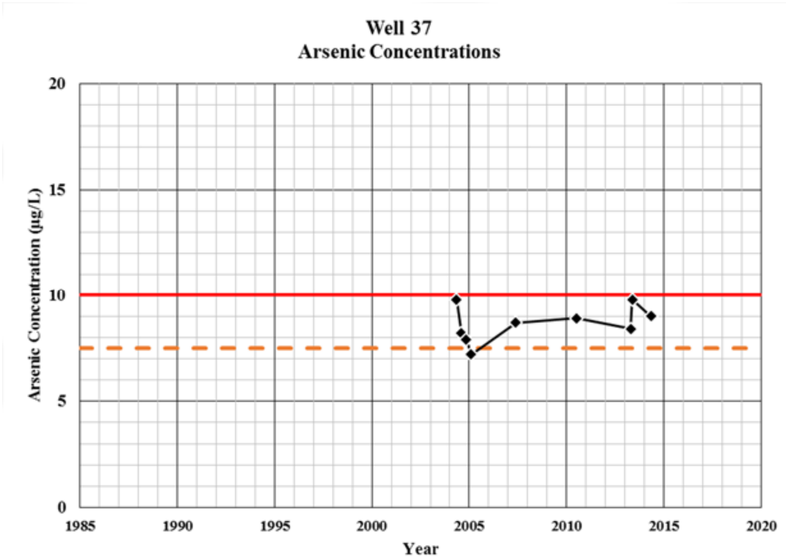


Water Quality

Water quality records indicate that the water produced from Well 37 meets all DDW primary and secondary drinking water requirements. Well 37 is currently active and provides untreated water to the system.

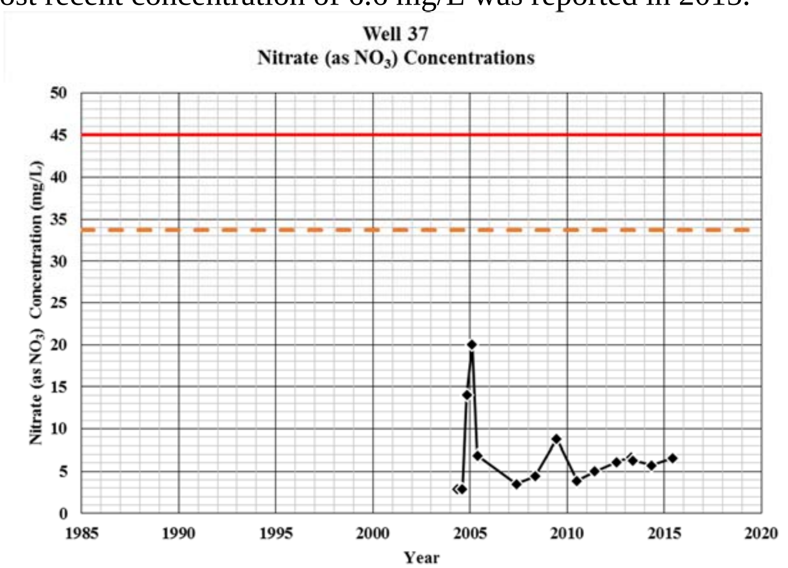
Arsenic

Historic arsenic concentrations have remained below the MCL, but are within 75% of the MCL over the period of record. Concentrations have ranged between 7.1 to 9.9 µg/L, with the most recent concentration of 9 µg/L reported in 2014. It appears that arsenic is relatively stable at these concentrations.



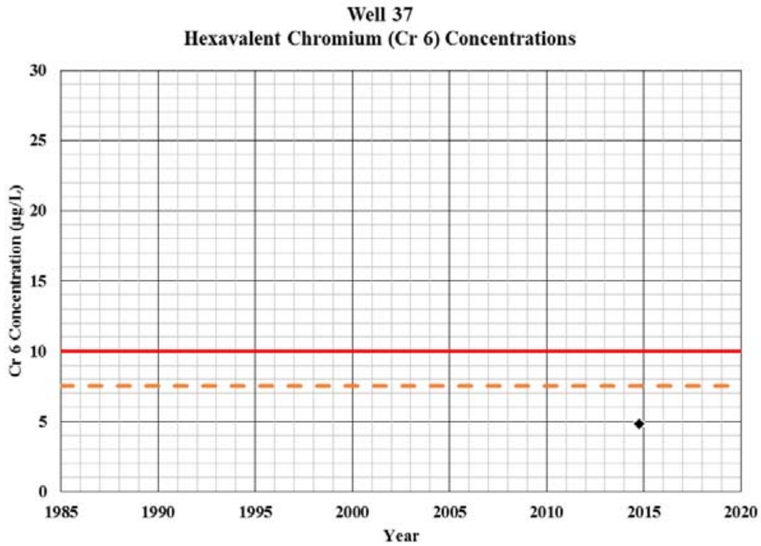
Nitrate (as NO_3)

Concentrations have ranged from 3 to 20 mg/L, with a spike to 20 mg/L occurring in 2005. Nitrate has remained below the MCL, but has shown a slight increase by 5 mg/L per year over the period of record. The most recent concentration of 6.6 mg/L was reported in 2015.



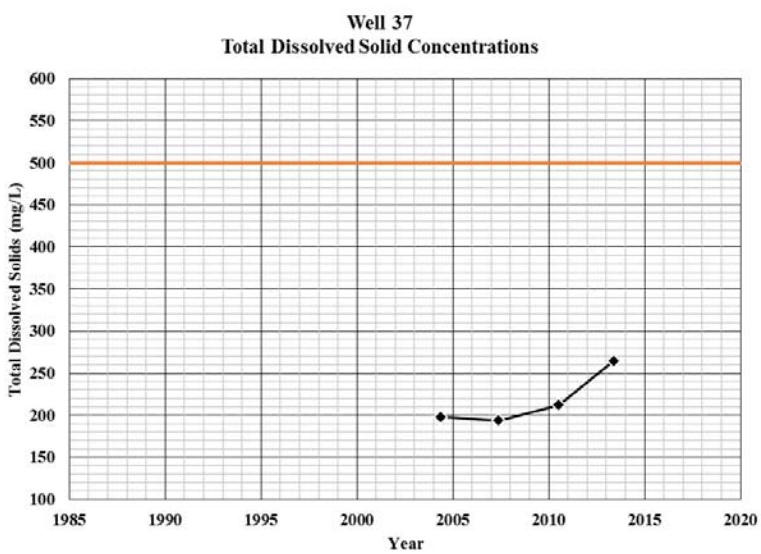
Hexavalent Chromium

Concentrations of Cr^{6+} are below the MCL, with the most recent concentration of 4.8 µg/L reported in 2014.



Total Dissolved Solids

Concentrations of TDS have remained below the Recommended Limit of 500 mg/L. As shown below, concentrations have shown an increase over the period of record from 198 mg/L in 2004 to 265 mg/L in 2015.



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10.26 Well 38 (Inactive)

Well Location and Construction

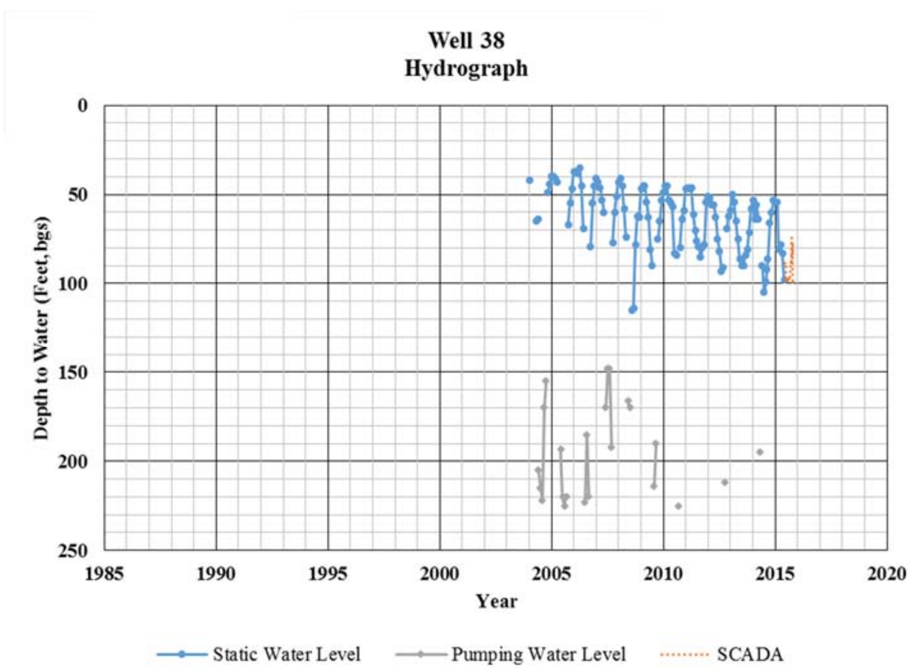
Well 38 is located at 2919 W. Christoffersen Parkway as shown in Figure 1. Well 37 was constructed by the reverse rotary drilling method in 2003, presently making this well 13 years old. A 32-inch diameter conductor casing and cement sanitary seal were placed from the ground surface to a depth of 50 feet. A 30-inch diameter borehole was drilled to a total depth of 617 feet. The well casing consists of an 18.625-inch outside diameter with a wall thickness of 5/16-inches to a depth of 615 feet, with a single perforated interval (unspecified screen pattern) of 0.060-inch slot size from 285 to 595 feet. The annular space was filled with a gravel envelope (unspecified gradation) from the total depth to 260 feet, followed by a bentonite seal from 260 to 255 feet and a cement annular seal from 255 feet to the ground surface.

Well Equipment and Production

Well 38 is equipped with a 350 horsepower motor and an American March oil-lubricated vertical line-shaft turbine and the pump set to a depth of 270 feet. In 2014, the well is reported to produce an average 2,793 gpm to the system, with a specific capacity of approximately 19 gpm/foot of drawdown. Well 38 produced approximately 30,858,000 gallons of groundwater, less than 1% of the total well field production

Groundwater Levels

Groundwater levels have been measured in Well 38 since 2004 and include both static and pumping water level measurements. The most recent spring high static groundwater level measurement was 54 feet (January 2015). Spring static water levels have declined by approximately 12 feet from January 2004 to January 2015 at a rate of approximately one foot per year.

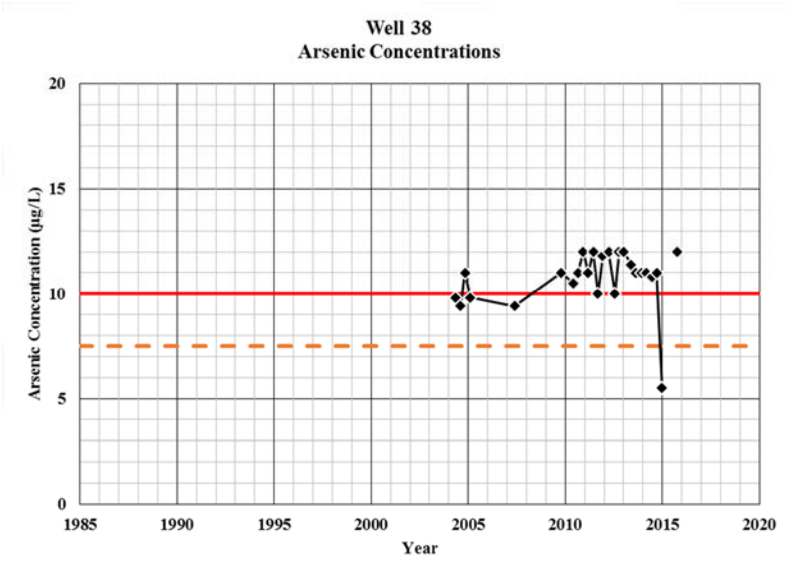


Water Quality

Water quality records indicate that the water produced from Well 38 meets all DDW primary and secondary drinking water requirements, with the exception of arsenic. Well 38 is classified as active, but is currently offline due to elevated concentrations of arsenic above the MCL>

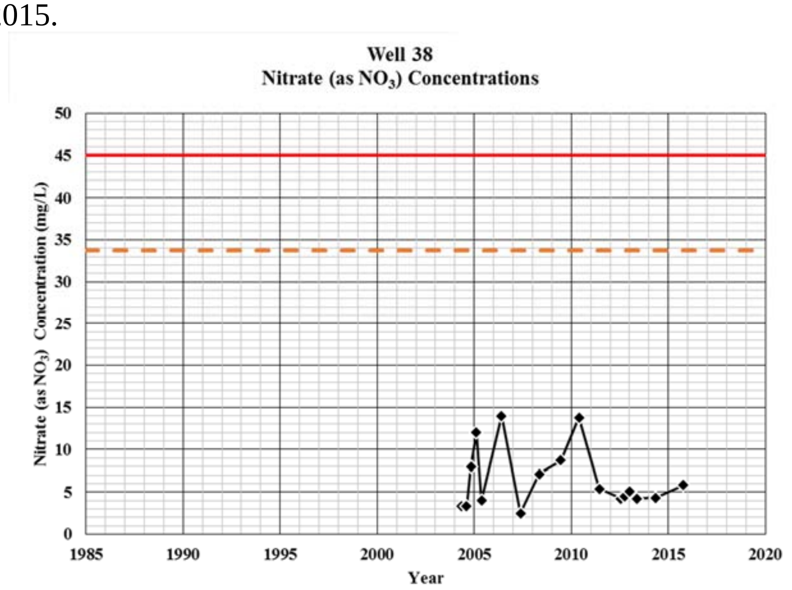
Arsenic

Water produced from Well 38 has consistently produced water with concentrations near or above the MCL of 10 µg/L over the period of record. Concentrations have ranged from 9.4 µg/L to 12 µg/L, with one result of 5.5 µg/L. The most recent concentration of 12 µg/L was reported in 2015.



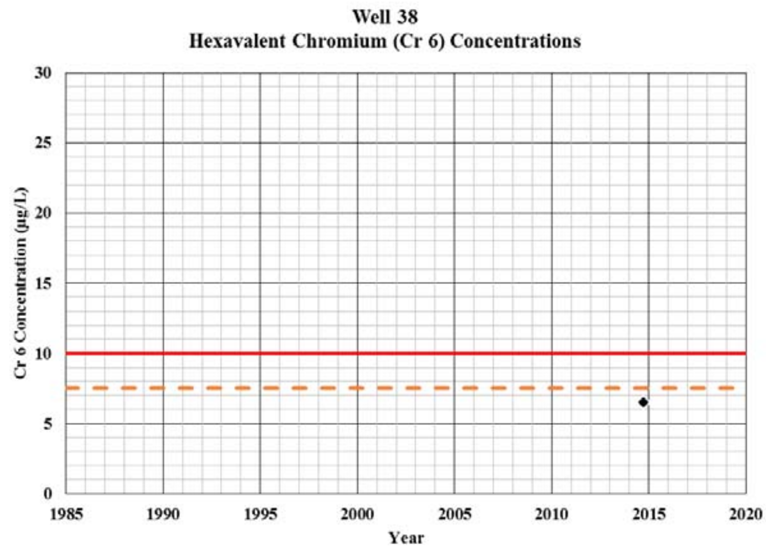
Nitrate (as NO_3)

Between 2004 and 2011, nitrate concentrations fluctuated between 2.5 mg/L and 14 mg/L, before becoming relatively stable from 2011 through 2015. The most recent concentration of 5.8 mg/L was reported in 2015.



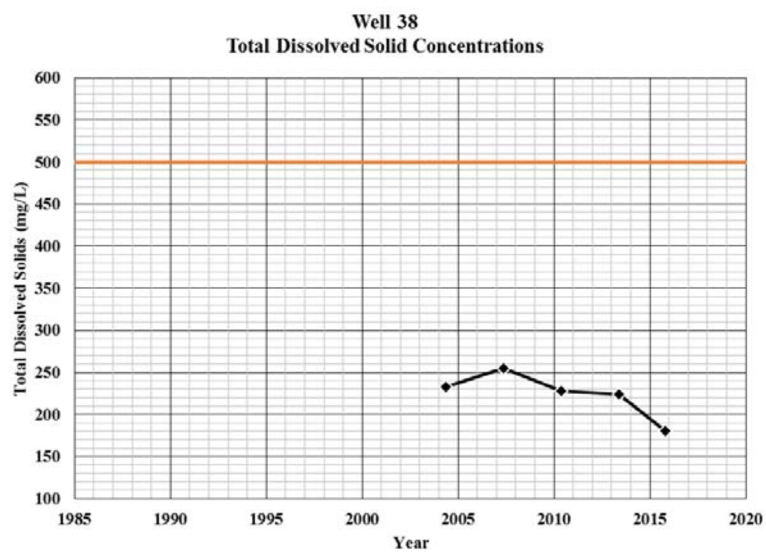
Hexavalent Chromium

Cr^{6+} has only been sampled for once in Well 38. The concentration of 6.5 µg/L is below the MCL of 10 µg/L.



Total Dissolved Solids

TDS concentrations of have ranged between 255 mg/L and 180 mg/L, decreasing over the period of record at a rate of 5 mg/L per year. The most recent concentration of 180 mg/L was reported in 2015. This trend is contrary to the trends observed in the rest of the City's well field.



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10.27 Well 39 (Active)

Well Location and Construction

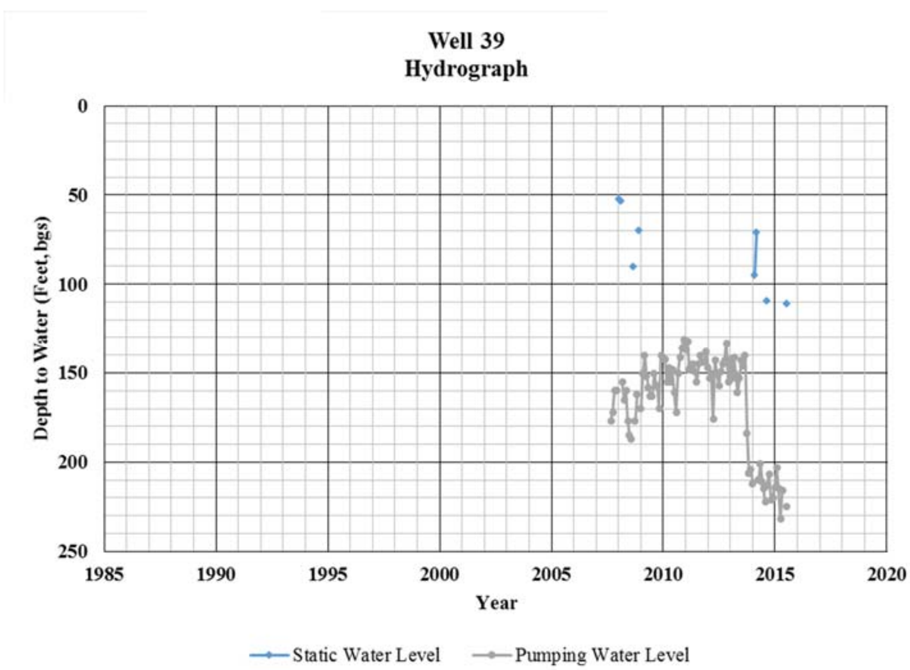
Well 39 is located at 3900 Wellington Lane as shown in Figure 1. The well was constructed by the reverse rotary drilling method in 2006, presently making this well 10 years old. A 32-inch diameter conductor casing and cement sanitary seal were placed from the ground surface to a depth of 50 feet. A 30-inch diameter borehole was drilled to a total depth of 380 feet. The well structure consists of an 18-inch outside diameter copper bearing well casing with a wall thickness of 5/16-inches to a depth of 375 feet, with a single louvered well screen interval with 0.045-inch slot size from a depth of 250 to 365 feet. The annular space was filled with a graded gravel envelope (8 x 20) from the total depth to 235 feet, followed by a cement annular seal from 235 feet to the ground surface.

Well Equipment and Production

Well 39 is equipped with a 125 horsepower Fairbanks/Morse motor with an oil-lubricated line-shaft pump set to a depth of 300 feet. In 2014, the well was reported to produce an average 715 gpm to the system, with a specific capacity of approximately 6 gpm/ft of drawdown. Well 39 produced approximately 390,577,000 gallons of groundwater, approximately 6% of the total well field production.

Groundwater Levels

Groundwater levels have been measured in Well 39 since 2007 and include both static and pumping water level measurements, with the majority of measurements collected while the pump was operating. Static groundwater level trends are difficult to ascertain due to Well 39 operating on almost a continuous cycle; however, in September 2013, pumping water levels dropped by over 60 feet. Reported static water levels also declined; however, it is difficult to determine if the water level was allowed to fully recover to pre-pumping conditions prior to the measurement.

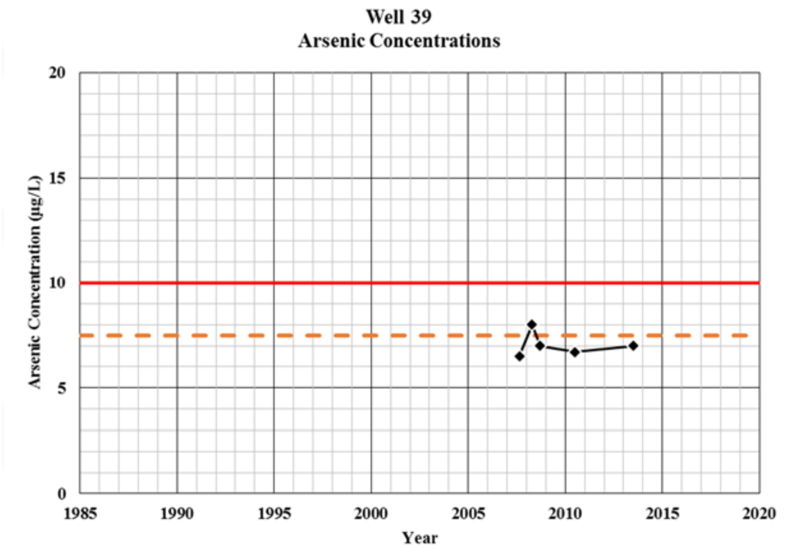


Water Quality

Water quality records indicate that the water produced from Well 39 meets all DDW primary and secondary drinking water requirements. Well 39 is currently active and provides untreated water to the system.

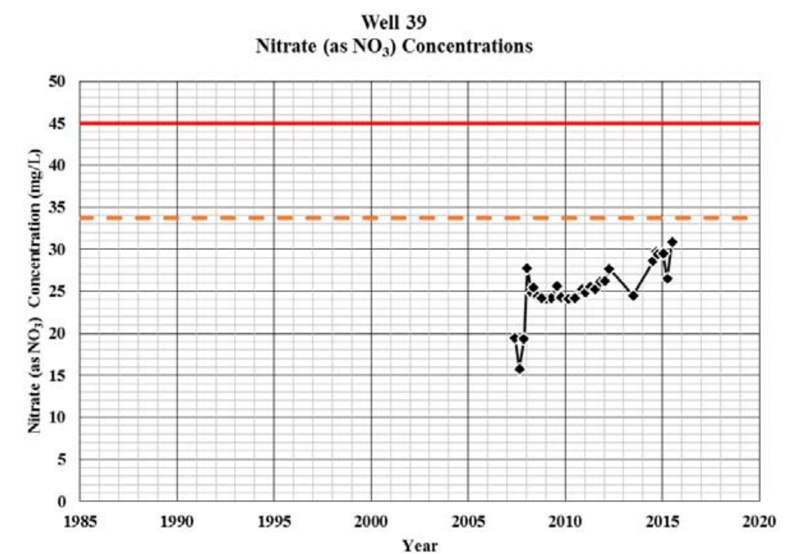
Arsenic

Concentrations of arsenic have ranged between 6.5 µg/L and 8.0 µg/L over the period of record and appear to be relatively stable. The most recent concentration of 7.0 µg/L was reported in 2013.



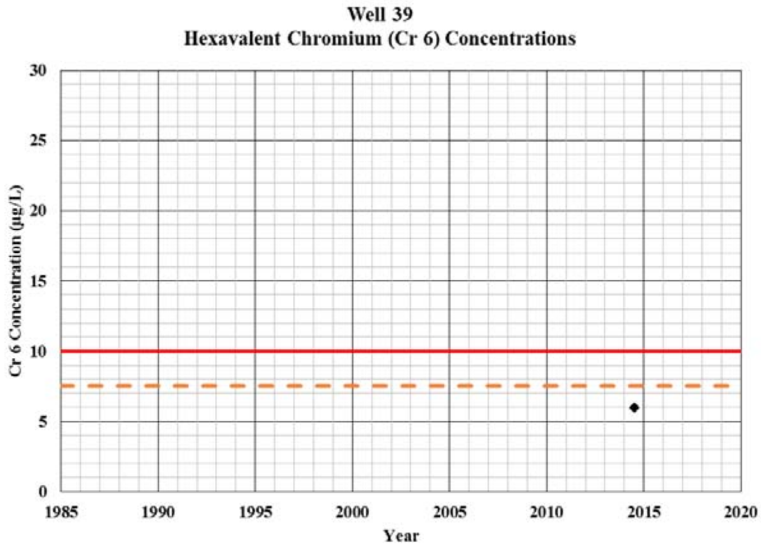
Nitrate (as NO_3)

Nitrate concentrations have remained below the MCL over the period of record, but indicate an overall increasing trend with values fluctuating between 16 mg/L and 31 mg/L. Concentrations are increasing at an average rate of approximately two mg/L per year. The most recent reported concentration of 30.9 mg/L was reported in 2015.



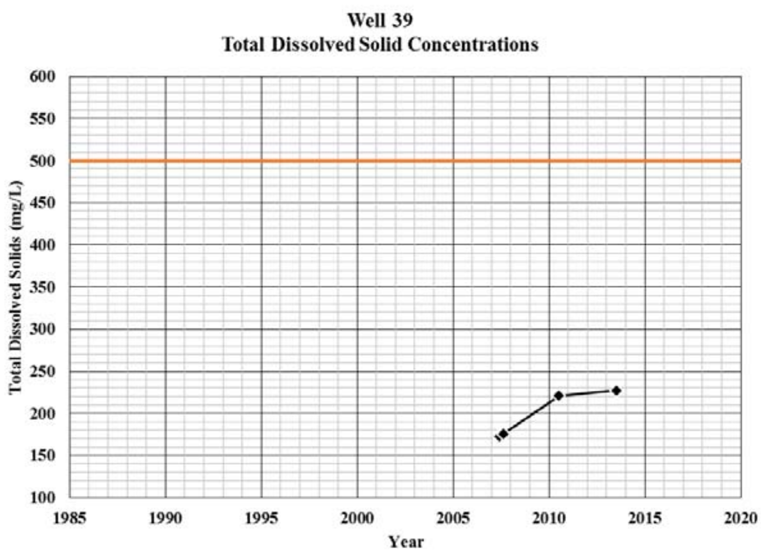
Hexavalent Chromium

Cr^{6+} has been sampled for once in Well 39, with a concentration of 6.0 µg/L reported in 2014, below the MCL.



Total Dissolved Solids

Concentrations of TDS have increased over the period of record at a rate of approximately 9.3 mg/L per year. The most recent concentration of 227 mg/L was reported in 2015.



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10.28 Well 40 (Active)

Well Location and Construction

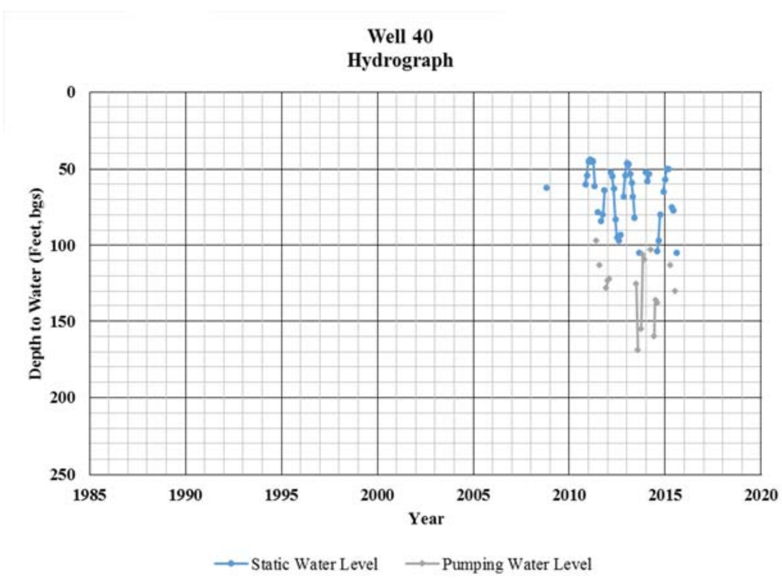
Well 40 is located 501 South Walnut Road as shown in Figure 1. The well was constructed by the reverse rotary drilling method in 2008, presently making this well 8 years old. A 32-inch diameter conductor casing and cement sanitary seal were placed from the ground surface to a depth of 50 feet. A 30-inch diameter borehole was drilled to a total depth of 535 feet. The well structure consists of an 18-inch outside diameter copper bearing steel with a wall thickness of 5/16-inches to a depth of 530 feet, with a single perforated well screen interval (unspecified screen pattern) of 0.060-inch slot size from a depth of 210 to 510 feet. The annular space was filled with a gravel envelope (unspecified gradation) from the total depth to 190 feet, followed by a cement annular seal from 190 feet to the ground surface.

Well Equipment and Production

Well 40 is equipped with a 150 horsepower motor and a Floway oil-lubricated vertical turbine pump set to a depth of 260 feet. In 2014, the well was reported to produce an average of 1,143 gpm to the system, with a specific capacity of approximately 22 gpm/ft of drawdown. Well 40 produced approximately 151,376,000 gallons of groundwater, approximately 2% of the total well field production

Groundwater Levels

Groundwater levels have been measured in Well 40 since 2008 and include both static and pumping water level measurements, with the majority of measurements being while the pump was operating. Static groundwater level trends are difficult to ascertain due to the almost continuous operation of the well, in addition to long-term trends due to the short period of record. The most recent spring high static groundwater level measurement was 50 feet (March 2015). From March 2011 to March 2015, spring static water levels have declined by approximately 5 feet at a rate of less than one foot per year.

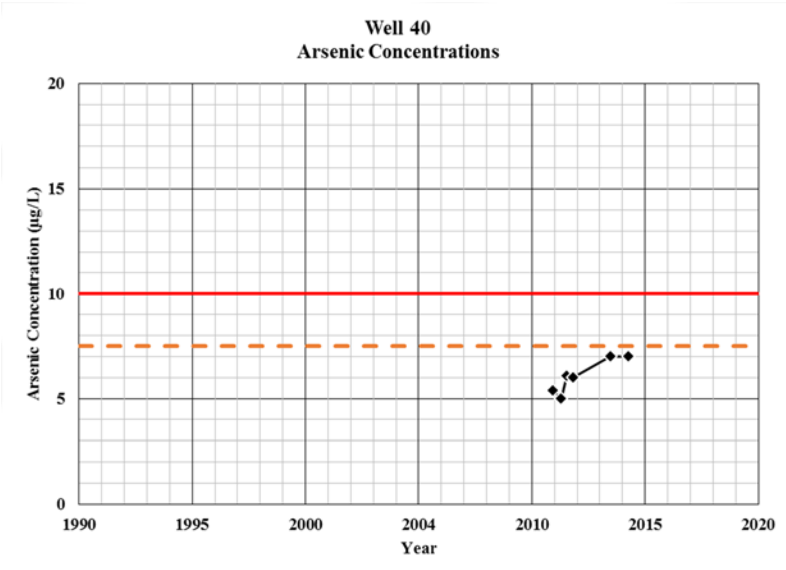


Water Quality

Water quality records indicate that the water produced from Well 40 meets all DDW primary and secondary drinking water requirements. Well 40 is currently active and provides untreated water to the system.

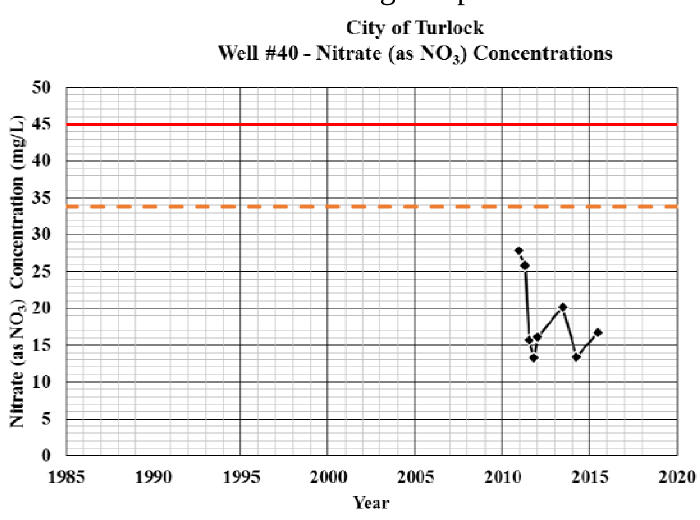
Arsenic

Arsenic concentrations have been below the MCL for the period of record, however, they have shown an increasing trend, from 5 µg/L to 7 µg/L at a rate of 0.6 µg/L per year. The limited data set prohibits identifying a long-term trend, but arsenic concentrations should continue to be monitored in Well 40.



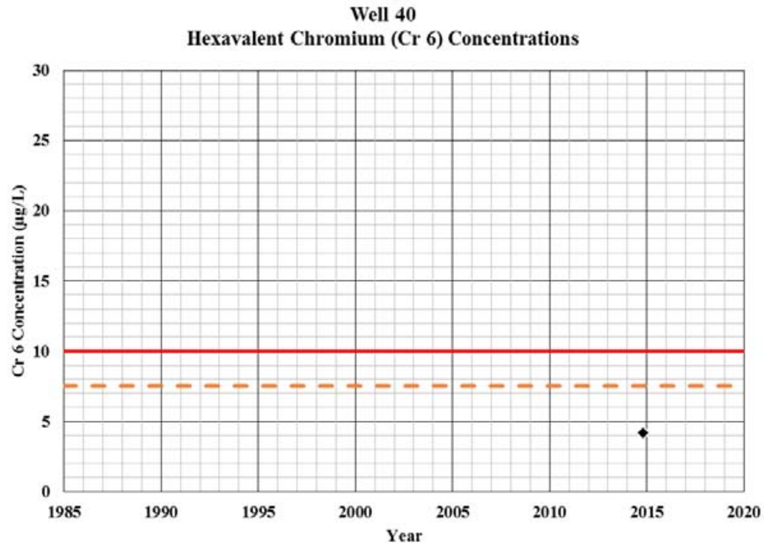
Nitrate (as NO_3)

Concentrations have remained below the MCL and indicate an overall decreasing trend over the period of record. Concentrations have decreased at a rate of approximately 3 mg/L from 2011 to 2015, with the most recent concentration of 16.7 mg/L reported in 2015.



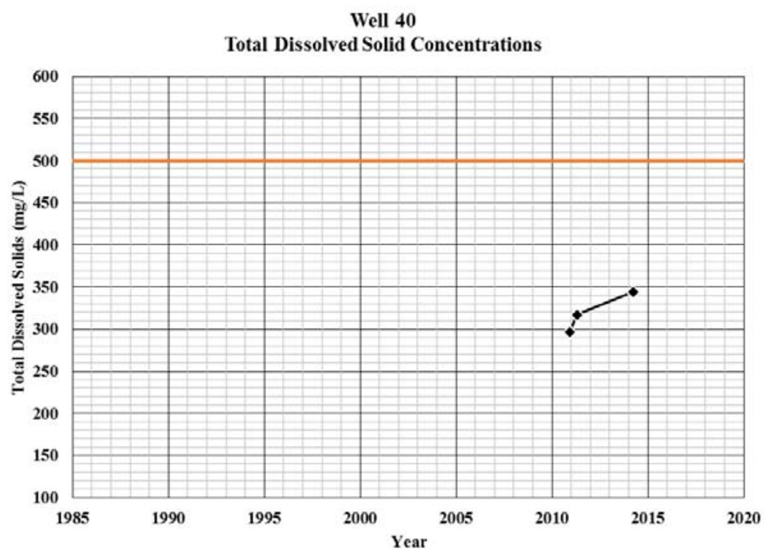
Hexavalent Chromium

Cr^{6+} has been sampled for once in Well 40, with a concentration of 4.2 µg/L reported in 2014, below the MCL.



Total Dissolved Solids

Concentrations of TDS have increased over the period of record at a rate of approximately 12 mg/L per year. The most recent concentration of 344 mg/L was reported in 2015, below the Recommended Limit of 500 mg/L.



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