



CITY OF CERES

**WATER MASTER PLAN – WELL FIELD AND
HYDROGEOLOGIC ASSESSMENTS**

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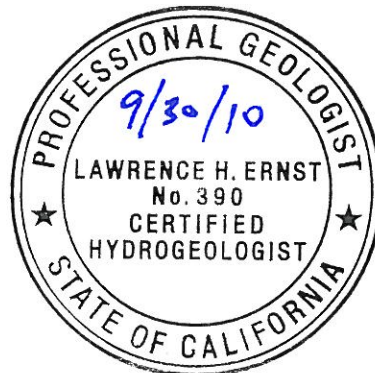


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Introduction

The City of Ceres (City) currently relies solely on groundwater to supply its municipal water supply needs. The City's water supply network consists of fifteen active permitted wells and three inactive wells. The locations of the wells are shown in Figure 1. Two of the active wells require well head treatment (one for uranium and one for arsenic and manganese) and two active wells are blended with water from the distribution system to produce acceptable water quality.

This report provides an assessment of the current condition, operation, and quality of the groundwater produced by the City of Ceres' wells. The narrative provided herein reports hydrogeologic and well depths with respect to ground surface, except where otherwise noted. Data reviewed and analyzed for this report was supplied by the City, previous work conducted by Wood Rodgers, Inc., the California Department of Public Health (CDPH), the California Department of Water Resources (DWR), and published geologic and hydrogeologic reports. Records provided by the City include the DWR Water Well Drillers Reports, geophysical surveys from exploratory test holes, current water quality data and recent pump efficiency testing data. Historic water quality data was obtained using the CDPH's "California Drinking Water" database (current to 2010). Wood Rodgers also conducted site visits with City staff to each of the active wells.

Location and Physical Setting

The City of Ceres is located in Stanislaus County, south of Modesto and north of Turlock along the State Highway 99 corridor. Ceres is situated in the San Joaquin Valley, which is the southern portion of the Central Valley. The Central Valley is a north-south trending valley bordered on the east by the Sierra Nevada Mountains and on the west by the Coast Range. Ground surface elevations for the City range from approximately 105 feet above mean seal level (MSL) in the northeast to approximately 80 feet MSL to the southwest. Land uses in the vicinity of the City have historically been agricultural. The City is currently bordered by active agricultural land uses to the south, east, and west, and by the City of Modesto to the north.

Hydrogeology

The City of Ceres overlies the Turlock groundwater subbasin, encompassing both Stanislaus and Merced Counties and covers about 540 square miles. The Turlock groundwater subbasin is a subset of the larger, San Joaquin Valley groundwater basin. The Turlock subbasin is bordered by the Tuolumne River on the north, the San Joaquin River on the west, the Merced River on the south, and the Sierra Nevada foothills on the east (Velayes and Durbin, 2010).

The geologic formations that make up the freshwater groundwater system underlying the City include: the Modesto, Riverbank and Turlock Lake Formations. The Modesto Formation is of late Pleistocene age (about 1 million years ago to recent). It outcrops in the western one-third of the City and is between 65 and 130 feet in thickness. The formation consists mostly of sand, gravel, silt and contains some silt and clay units. The formation yields moderate to large



quantities of water to wells, however, within the City; water quality within this formation has been heavily impacted by contamination.

The Riverbank Formation, which is of middle Pleistocene age (about 1.5 million to 1 million years ago), underlies the extent of the Modesto Formation. The thickness of the unit increases westward, but the thickness is generally less than 200 feet. The formation consists primarily of sand with scattered gravel and silt lenses and yields moderate to large quantities of water to wells. Water quality in the Riverbank Formation has also been impacted by surface contamination.

The Turlock Lake Formation, which is of early Pleistocene and late Pliocene age (2.5 million to 1.5 million years ago), underlies the Riverbank Formation. The thickness of the unit increases westward, but the thickness is generally less than 600 feet. The formation consists mostly of fine sand and silt (Marchand and Allwardt, 1981) and yields moderate to large quantities of water to wells. The Corcoran Clay member of the Turlock Lake Formation ranges in thickness from 10 to 100 feet. The Corcoran Clay is dark greenish-gray in color, but is commonly referred to as the blue clay. The clay is generally a well-sorted clay to a silty-clay with no sand. Other blue silt and clay beds are located both above and below the Corcoran Clay but can not be correlated over large distances (Page and Balding, 1973). The Corcoran Clay lies in the upper part of the Turlock Lake Formation. In Ceres, the water quality in the Turlock Lake Formation has also been impacted by contamination but the upper portion of the formation appears to still have acceptable water quality. Below a depth of 350 feet, however, naturally-occurring poor water quality is evidenced by high concentrations of specific conductance (dissolved salts), manganese, and arsenic.

Under natural conditions, regional groundwater flow progresses from the northeast to the southwest (Bulletin 118). Groundwater flow follows the regional dip of the sediments deposited in the valley, toward the south west in the direction of the valley trough (Phillips, 2009). The City has recently implemented a program to measure static water levels in all their wells several times a year. This information will be used to establish seasonal groundwater elevation fluctuations and to project future long-term trends.

Well Field Summary

Figure 1 presents the location of the City's eighteen production wells used for its municipal water supply network. Of these eighteen wells, fourteen are active, three are removed from the distribution system due to water quality concerns, and one is currently under construction. Four of the active wells require treatment to remove contaminants and/or sand production or blending with alternative sources to meet the CDPH primary and secondary drinking water requirements. The City wells were constructed using either the cable-tool or rotary drilling methods. The well depths range from 118 to 461 feet. Table 1 summarizes the location, as-built well construction details, construction method, water quality concerns, and well testing results for each well in the City's Well Field.



Constructing wells in aquifers not impacted by poor water quality has been an ongoing problem for the City. From 1983 to 1998, records indicate that the City drilled and constructed six wells. Of these six, only two produce water that does not require treatment or blending to meet the CDPH primary and secondary drinking water requirements. In 2002, the City implemented an exploratory test hole drilling program to assess potential well sites prior to the construction of a production well. Since 2002, the City has added five new wells to their well field. These five wells meet all of the CDPH primary and secondary drinking water requirements without requiring treatment; however many of these wells have either nitrate or arsenic levels very near to the CDPH Maximum Contaminant Level (MCL).

The available data that was reviewed for each well is included in Appendix A and consists of DWR Water Well Driller's Reports, water quality data, site location maps, recent efficiency testing data, and site photos. A detailed narrative of each well's construction, testing, current condition, and water quality data is provided below, following Table 2. Table 2 summarizes the current age, current well status, estimated remaining service life, and whether a new well could be constructed at the existing well site. The narratives include estimates of the remaining service life for each well and recommendations to improve the well condition where applicable.

Table 2
Well Status, Remaining Service Life, and Replacement

Well	Age of Well (Years)	Well Status	Estimated Remaining Service Life (Years)	Well Site Could Accommodate Replacement Well
Well 1	36	Operational w/ Treatment	< 3	Yes
Well 6	61	Not in Service	0	Yes
Well 14	50	Operational	< 3	No
Well 16	41	Operational	0-10	No
Well 19	39	Not in Service	0	No
Well 20	34	Operational	0-16	No
Well 21	33	Operational	0-7	Yes
Well 22	27	Operational w/ Treatment	3-13	No
Well 23	21	Operational	9-19	Yes
Well 24	21	Not in Service	0	No
Well 25	22	Operational w/ Treatment	8-18	Yes
Well 27	12	Operational	18-28	Yes
Well 28	7	Operational	23-33	Yes
Well 32	21	Operational w/ Treatment	9-19	No
Well 34	2	Operational	28-38	Yes
Well 35	2	Operational	28-38	No
Well 36	4	Operational	16-26	Yes
Well 38	<1	Operational	40-50	Yes



Well 1 – Smyrna

Background

Well 1 is located at 2650 Fowler Road at the Smyrna Community Park (shown on Figure 1). Well 1 was constructed by the cable tool method between November of 1973 and January of 1974, presently making this well 36 years old. The well was drilled to a depth of 202 feet. The upper portion of the well consists of a 24-inch diameter steel casing extending from the ground surface to a depth of 52 feet. Within the 24-inch diameter casing is an 18-inch diameter steel casing that extends to a depth of 100 feet. A cement grout sanitary seal was placed between the 24 and 18-inch diameter steel casings to 52 feet. In the lower portion of the well, a 16-inch diameter steel casing extends from 90 feet to 190 feet, with pre-cut vertical slots from 94 feet to 186 feet. The remaining 12 feet of the well is uncased and open borehole. After the well was constructed, a 15.5-inch inside diameter well casing liner was installed to a depth of 94 feet. The date of this modification is unknown.

Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (1986 to 2010) indicate that the water produced from Well 1 meets all the CDPH primary and secondary drinking water requirements with the exception of nitrate and uranium. Nitrate (as NO_3) concentrations range from non-detect to 44.7 mg/L and uranium concentrations from 3.2 to 35.7 pCi/L.

Well 1 is equipped with a 150 horsepower electric US Motor with a Peerless vertical turbine pump. To provide acceptable water quality to the City, Well 1 is blended with 60% distribution system water, using a 30 horsepower (1,000 gpm) booster pump, and 40% groundwater from Well 1. The well discharge is equipped with a sand separator and inline nitrate analyzer constantly monitors the water quality entering the City system at this site.

Current Operating Condition

Well 1 is currently an active permitted well. Testing to determine the current pumping costs was conducted on August 25, 2009. During the testing, a static water level was recorded to be 63 feet. Due to an obstruction in the well, the pumping water level could not be measured. The well was tested at a flow rate of 410 gpm. The specific capacity could not be calculated. The complete cost analysis report is included in Appendix A.

Well 1 produces unacceptable concentrations of nitrates, uranium, and sand. The production capacity has been reduced to 400 gpm to facilitate blending. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on the water quality. Well 1 appears to have less than three years of remaining service life. The south side of Smyrna Community Park has been selected as a site to conduct groundwater exploration with zone specific water quality sampling. Once that investigation has been completed, the City should conduct an assessment to determine if the quality of the water produced from Well 1 could be improved by modifying the well structure. Modification may include deepening the well by drilling deeper and installing a casing liner, gravel envelope, and



deeper annular seal. Modification of this well structure would reduce the casing diameter which would likely limit the production to approximately 400 gpm, however if successful, this well may not require treatment and may have the potential to produce sand-free water for several years. A new well at this location may provide a better long-term option for this site. There is adequate room at this well site to drill a new well.

If the groundwater exploration data suggests that modification of the well structure would not improve the quality of water produced, the well could remain in service as a blended source of capacity or it could be converted for use to irrigate the Smyrna Community Park. It is unlikely that this well would be approved by the CDPH as an emergency stand-by well for the City municipal water system due its high concentration of nitrates.

Well 6 – Hollister

Background

Well 6 is located at 1904 Hollister Street (as shown on Figure 1). Well 6 was constructed by the cable-tool drilling method in 1948, presently making this well 61 years old. The well was originally drilled to a depth of 118 feet. The upper portion of the well consists of a 14-inch diameter steel casing extending from the ground surface to a depth of 94 feet, the remainder of the well is open borehole.

Water quality records from the City (2007) and the CDPH Drinking Water Database (1986 to 2010) indicate that water produced from Well 6 meets all the CDPH primary and secondary drinking water requirements with the exception of nitrate (as NO_3). Nitrate (as NO_3) concentrations have ranged from 8.4 to 50 mg/L over the past 24 years. Well 6 is equipped with a 50 horsepower electric motor with a vertical turbine pump.

Current Operating Condition

Well 6 is currently not used for municipal water supply use due to elevated concentrations of nitrate over the CDPH MCL of 45 mg/L. Well 6 was not included in the system testing in the summer of 2009. During Wood Rodgers 2008 well evaluation and testing, Well 6 was tested at an average flow rate of 402 gpm with a 24-hour projected specific capacity of 34 gpm/ft of drawdown.

Well 6 is the City's shallowest well, with a depth of 118 feet. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on the water quality. Without modifications to the well structure to improve the water quality, Well 6 does not have any remaining service life. Water produced from Well 6 has nitrate concentrations that have averaged about 50 mg/L for the past 6 years. Our assessment of regional groundwater trends suggest that at this site, from a depth 130 feet to 200 feet, the aquifers may have a slightly lower concentration of nitrate, but will contain uranium concentrations exceeding the MCL. The aquifers below 240 feet would likely produce water with acceptable concentrations of nitrate and uranium, however we expect concentrations of arsenic, manganese, and total dissolved solids will increase with depth and likely exceed the



MCL for some or all of these constituents, below a depth of 340 feet. Well 6 could be deepened to complete the most favorable aquifers below 240 feet. The installation of a casing liner, gravel envelope, and annular seal would be required to isolate the aquifers with better water quality. A monitoring well at this site would improve the chances of targeting the aquifers with the best water quality for the well modification. A modified Well 6 would likely be limited to a capacity of 300 gpm due to the anticipated reduction in casing diameter and a smaller pump. A new well at this location may be a better long-term option to return this site to the City's system. There is adequate room at this well site to drill a new well.

Well 14 – Firesteins

Background

Well 14 is located at 1906 5th Street (as shown on Figure 1). Well 14 was constructed by the cable-tool drilling method in 1960, presently making the well 50 years old. The well was drilled to a total depth of 293 feet. The upper portion of the well consists of a 14-inch diameter steel well casing from the ground surface to a depth of 130 feet. A 12-inch diameter steel casing extends from 133 feet to a depth of 179 feet and a 10-inch diameter steel casing to a depth of 261 feet. The well casing includes a perforated section from 130 feet to 179 feet. The borehole is uncased from 261 feet to 293 feet.

Water quality records from the City (2008 to 2009) and from the CDPH Drinking Water Database (1986 to 2010) indicate that the water produced from Well 14 meets all the CDPH primary and secondary drinking water requirements with the exception of manganese and specific conductance. Manganese concentrations have ranged from non-detect to 6,600 µg/L. Specific conductance concentrations have ranged from 540 to 1,000 µmhos/cm.

Prior to 2008, Well 14 was off-line because it was producing unacceptable levels of manganese which exceeded the MCL of 50 µg/L. In 2008, a video survey was conducted to assess the condition of the well structure. The well casing appeared to be intact but had significant scale and evidence of corrosion. The existing pump was not operational due to holes in the column pipe. A test pump was installed to determine the sand production and specific capacity. To help reduce the production of sand, the well was “over pumped” and surged. Time-series water quality sampling was conducted with the test pump. The data suggested that the sand production was the reason for the elevated levels of manganese and that the water produced from Well 14 does not exceed the MCL for manganese. A lower flow rate was selected to reduce the production of sand which subsequently lowered the manganese concentrations to below the MCL. Well 14 now produces acceptable concentrations of sand and meets all CDPH primary and secondary drinking water quality standards with the exception of specific conductance, which slightly exceeds the secondary MCL of 900µmhos/cm.

Well 14 is equipped with a submersible 15 horsepower Franklin motor and Gould pump with a downhole Lakos sand separator. Water produced from Well 14 does not require treatment.



Current Operating Condition

Well 14 is currently an active permitted well. Testing to determine the current pumping cost was conducted on Well 14 on August 25, 2009. During the well testing, a static water level of 80 feet and a pumping water level of 95 feet were recorded. The well was tested at a flow rate of 155 gpm. The calculated specific capacity for Well 14 is 10 gpm/ft of drawdown. The complete testing summary is included in Appendix A.

CDPH has deemed that the water produced from Well 14 is acceptable for the City's municipal water system since it was rehabilitated in 2008. In 2008, Well 14 had a new pump installed and was returned to service to help increase the City's source capacity during a period of critical water supply shortage for the City. Well 14 is 50 years old and very near the end of its useful service life. Well 14 appears to have less than three years of remaining service life. The capacity of Well 14 has been reduced to less than 200 gpm to avoid pumping large amounts of sand. Well 14 is not a good candidate to be modified due to the poor condition of the casing and the diameter of the casings intervals, (which is already reduced to 10-inches in the lower section). The well site does not have adequate space to drill a replacement well due to the limited parcel size. We recommend using the well as long as it continues to produce water which is acceptable to the CDPH. If the water quality degrades or if the casing fails, it will be time to destroy Well 14.

Well 16 – Hatch & Mitchell

Background

Well 16 (Hatch & Mitchell) is located at 1441 Angie Avenue (as shown on Figure 1). Well 16 was constructed by the rotary drilling method in 1969, making the well presently 41 years old. The well includes a 26-inch diameter steel conductor casing to a depth of 76 feet. A neat cement sanitary seal extends the length of the conductor casing. Well 16 was drilled to a total depth of 261 feet. A 16-inch diameter steel well casing extends to 223 feet, inside a 261 foot deep 24-inch diameter borehole. The original well design included louvered perforations from 120 to 160 feet and 180 to 220 feet. An 8 x16 graded gravel envelope extends from 261 feet to ground surface inside the conductor casing.

Prior to 2008, Well 16 produced excessive amounts of sand and was off-line due to nitrate (as NO₃) concentrations that exceeded the CDPH MCL of 45 mg/L. In 2008, a testing and well modification program was designed and implemented to return this well to service. The well screens were first cleaned with an acid solution and brushed to remove excessive scale build up. A well liner, consisting of a 10.75-inch outside diameter steel well casing was installed to 220 feet. The liner included louvered well screen intervals from 150 to 160 feet and from 180 to 220 feet. A neat cement annular seal was installed under pressure in the annular space between the 16-inch casing and the 10-inch liner. Cement was allowed to enter the upper perforated section of the original 16-inch well casing from 120 to 140 feet to help seal off the shallow aquifers from the modified well structure. The rehabilitation of Well 16 reduced the nitrate concentration from



55 mg/L to 25 mg/L. Well 16 was then equipped with a new a submersible Gould pump and 20 horsepower Franklin motor.

Current Operating Condition

Well 16 is currently an active permitted well. Testing to determine the current pumping costs was conducted on Well 16 on August 25, 2009. During the testing, a static water level of 80 feet and a pumping water level of 117 feet were recorded. The well was tested at a flow rate of 194 gpm. The calculated specific capacity for Well 16 is 5.2 gpm/ft of drawdown. The complete testing summary is included in Appendix A.

The 2008 modification of Well 16 deepened the annular seal and the perforated interval of the well structure. Well 16 produces sand-free water and meets all of the CDPH primary and secondary drinking water quality standards. Wells with liners and gravel envelopes inside an existing cased well structure can be susceptible to plugging, but this well should continue to provide acceptable water quality to the City for several years. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on the water quality. Well 16 appears to have less than ten years of remaining service life. Well replacement at this location will likely not be possible due to the limited parcel size.

Well 19 – Paramount

Background

Well 19 is located at 1511 Giddings Street (as shown on Figure 1). Well 19 was constructed by the cable-tool drilling method in 1971, making the well presently 39 years old well. The well was originally drilled to a depth of 232 feet. The upper portion of the well consists of an 18-inch diameter steel casing extending from the ground surface to a depth of 114 feet. Within the 18-inch diameter casing, a 16-inch diameter mill-slotted perforated steel casing section that extends from 89 feet to 189 feet. The remaining 43 feet of the well was reported to be open borehole, however the well is filled in with sediment to the bottom of the well casing at 189 feet.

Water quality records from the City (2007) and the CDPH Drinking Water Database (1986 to 2010) indicate that the water produced from Well 19 meets all the CDPH primary and secondary drinking water requirements with the exception of uranium and nitrate (as NO₃). Uranium concentrations range from 6.7 to 26.8 pCi/L and nitrate concentrations range from 4.5 to 45 mg/L.

Current Operating Condition

Well 19 is equipped with well head treatment designed to decrease uranium concentrations to acceptable levels and a sand separator, however excessive sand production has been problematic and has clogged the uranium filter media. Well 19 is not currently equipped with a pump. In 2008, Well 19 was tested at an average flow rate of 1,233 gpm. The static water was measured at 46 feet. The 24-hour calculated specific capacity was 43 gpm/ft of drawdown. During this



testing, Well 19 continuously produced a significant amount of sand with periodic very high volumes “slugs” of sand for short durations.

Well 19 was assessed to determine if modifying the well structure would be feasible. In 2008, the sediment from the bottom of the well was bailed out, however the formation material outside the perforated intervals are very unstable. The borehole outside the well casing continued to unravel and kept refilling the well with sediment. Due to the unstable condition of the borehole and the large void outside of the well casing, Wood Rodgers suggested to the City that Well 19 would not be a good candidate for well modification. CDPH offered the City funding from the American Recovery and Reinvestment Act (ARRA) to replace Well 19. The replacement well (Well 38) has been constructed. Well 19 will not be returned to service for municipal water supply. Well 19 will either be converted into a monitoring well or destroyed.

Well 20 – Kinser

Background

Well 20 is located at 1905 Kinser Road (as shown on Figure 1). Well 20 was constructed using the cable-tool method in 1976, making the well presently 34 years old. The well was drilled to a depth of 302 feet. The well casing consists of a 24-inch diameter steel well casing from the ground surface to a depth of 48 feet, a 20-inch diameter steel casing from the ground surface to 140 feet, and an 18-inch diameter steel well casing from 134 feet to 208 feet. After this well was constructed, a 16-inch diameter steel well casing was installed below 209 feet. From recent geophysical surveys, there appears to be a foot of open borehole at the transition between the 16-inch and 18-inch casings. The 16-inch casing is visible to a depth of 281 feet, where the well is filled in with sediment. The well includes 1/8-inch by 1 1/2-inch vertical slot perforations from 138 feet to 210 feet. There is no information regarding the perforations of the 16-inch casing. A neat cement grout sanitary seal between the 20-inch and 24-inch diameter well casings extends from the ground surface to a depth of 50 feet.

Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (1986 to 2010) indicate that the water produced from Well 20 meets all of the CDPH primary and secondary drinking water requirements, however concentrations of arsenic, manganese, and specific conductance have occasionally drifted above the CDPH MCL's.

Well 20 is equipped with a US Motors 150 horsepower electric motor and a Peerless vertical turbine pump. The Well 20 station piping includes a sand separator. The well site is equipped with a diesel driven back-up generator.

In 2008, the pump failed and was removed by the City for maintenance and repairs. While the pump was out of the well, a well video, caliper and a deviation survey was conducted to assess the condition of the well structure. The surveys indicated that the well casing has heavy encrustation and many of the perforations appeared to be plugged. Sediment filled the bottom of the well to a depth of 280 feet, indicating approximately 22 feet of fill in the bottom of the well.



Current Operating Condition

Well 20 is an active permitted well. Testing to determine the current pumping costs was conducted on August 24, 2009. During the testing, the static water level of 75 feet and a pumping water level of 124 feet were recorded. The well was tested at a flow rate of 1,300 gpm. The calculated specific capacity for Well 20 is 72 gpm/ft of drawdown. The complete testing summary is included in Appendix A.

Well 20 is operating satisfactorily and currently produces acceptable water quality. The City reported that Well 20 produces a small amount of sand which is currently removed with a sand separator prior to the distribution system. The well casing has moderate to heavy encrustation, however it does not appear to be affecting the yield of the well. Well rehabilitation is not recommended for this well as it could alter the water quality and increase the sand production. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on the water quality. Well 20 appears to have less than 16 years of remaining service life. The remaining service life of Well 20 will be dependent on the water quality and sand production. There is not adequate room at this site to drill a replacement well due to the limited parcel size.

Well 21 – Roeding Heights

Background

Well 21 is located at 2824 Stanford Avenue within the Roeding Heights Park (as shown on Figure 1). Records indicate that Well 21 was constructed using the reverse rotary drilling method in 1977, making the well presently 33 years old. An 88 foot, 32-inch diameter conductor casing is cemented in place, providing for the sanitary seal for the well. An 18-inch diameter steel well casing inside a 30-inch diameter borehole extends to a depth of 355 feet, with perforated intervals (comprised of galvanized low-carbon mild steel well screen) from 100 feet to 124 feet, 145 feet to 155 feet, and from 290 feet to 327 feet. A “Monterey Sand” gravel envelope was placed in the annular space from 335 feet to the ground surface.

Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (1986 to 2010) indicate that the water produced from Well 21 meets all of the CDPH primary and secondary drinking water requirements. Historic water quality data indicated that nitrate (as NO₃) concentrations have been over 40 mg/L, but the majority of the data indicates nitrate concentrations between 20 and 35 mg/L since 1986. Historic water quality results for arsenic indicate that a single sample in 1995 exceeded the current CDPH MCL at a concentration of 12 µg/L, however since that date the arsenic concentrations have not exceeded the MCL of 10 µg/L.

Well 21 is equipped with a 150 horsepower US Motors electric motor and vertical Floway turbine pump. The well site includes a diesel driven back-up generator.



Current Operating Condition

Well 21 is an active permitted well. Testing to determine the current pumping costs was conducted on August 24, 2009. During the testing, the static water level of 91 feet and a pumping water level of 126 feet were recorded. The well was tested at a flow rate of 1,528 gpm. The calculated specific capacity for Well 21 is 44 gpm/ft of drawdown. The complete testing summary is included in Appendix A.

Well 21 is reported to be operating satisfactorily and produces acceptable water quality. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on water quality. Well 21 appears to have several years of remaining service life, however the City should plan on well replacement in the next seven years. A replacement well could likely be drilled in the adjacent City Park.

Well 22 – Rockefeller

Background

Well 22 is located at 1921 Rockefeller Avenue (as shown on Figure 1). Well 22 was constructed using the rotary drilling method in 1983, making the well presently 27 years old. Initially, an exploratory test hole was drilled to a total depth of 430 feet. The production well was drilled and constructed to a total depth of 252 feet. A 30-inch conductor casing is cemented in place to an unknown depth. A sanitary seal was placed from 110 feet to ground surface. An 18-inch diameter steel well casing extends to a depth of 252 feet, with perforated intervals from 124 feet to 147 feet, 162 feet to 173 feet, 192 feet to 210 feet and 228 feet to 246 feet. A gravel envelope of unknown material was placed from 252 feet to 110 feet.

Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (1986 to 2010) indicate that the water produced from Well 22 meets all of the CDPH primary and secondary drinking water requirements with the exception of uranium and specific conductance. Uranium concentrations range from 7 to 29.9 pCi/L. The well is equipped with well head treatment designed to remove uranium by the ion exchange process. Specific conductance has only exceeded the CDPH MCL a single time in 2005, however there has been a trend of increasing specific conductance since 1986. Nitrate and arsenic concentrations have both been reported near their respective MCL's, but have not exceeded the MCL's.

Well 22 is equipped with a 150 horsepower US Motors electric motor and a Gould vertical turbine pump. Well 22 will be equipped with sand removal equipment prior to the uranium treatment vessels.

Current Operating Condition

Well 22 is an active permitted well. Well 22 also produces sand, which is a problem with the uranium filter media. Sand removal treatment is being installed in conjunction with a ARRA funded treatment plant upgrade for this site. Testing to determine the current pumping costs was



conducted on October 6, 2009. During the testing, a static water level of 65 feet and a pumping water level of 124 feet were recorded. The well was tested at a flow rate of 1,394 gpm. The calculated specific capacity for Well 22 is 24 gpm/ft of drawdown. The complete analysis is included in Appendix A

Well 22 requires treatment for uranium and sand. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on water quality. Well 21 appears to have three to thirteen years of remaining service life. Well 22 should be assessed to determine if well modification/rehabilitation could be conducted to improve the water quality and reduce the sand production. Our preliminary data review suggests that Well 22 would be a good candidate for modification. Without modification, we anticipate that the sand production will likely become more severe over time. We understand that the uranium media is very expensive and adds additional cost to the operation of this facility. Well 22 may be able to operate for a few years with the sand removal and treatment facilities that are currently installed; however the City should plan on well modification or replacement of this well. A replacement well could not be drilled at this location due to the limited size of the parcel.

Well 23 – Hatch & Moffett

Background

Well 23 is located at 2607 Hatch Road (as shown on Figure 1). The well was constructed using the rotary drilling method in 1989, making the well presently 21 years old. The well was drilled to a depth of 435 feet. The well casing consists of an 18-inch diameter steel well casing to a depth of 264 feet, inside a 28-inch diameter borehole. The well includes perforated sections from 190 to 240 feet, 255 to 260 feet, 305 to 330 feet, 345 to 350 feet, 385 to 390 feet, and 400 to 420 feet with an unknown type of well screen. A 6 x 12 graded gravel envelope extends from 425 feet to 140 feet. A cement sanitary seal extends from 140 feet to the ground surface.

Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (1988 to 2010) indicate that the water produced from Well 23 meets all of CDPH primary and secondary drinking water requirements with the exception of specific conductance. The specific conductance of the water produced from Well 23 has increased from 720 to 1,300 $\mu\text{mhos/cm}$, exceeding the CDPH recommended MCL of 900 $\mu\text{mhos/cm}$. The increase in specific conductance may be related to the Well 24 construction details, which appears to have connected the deeper brackish water aquifers with the shallower aquifers. This is discussed in more detail in the Well 24 summary below.

Well 23 is equipped with a 150 horsepower US Motors electric motor and a Peerless vertical turbine pump. The well site includes a diesel driven back-up generator.

Current Operating Condition

Testing to determine the current pumping costs was conducted on August 25, 2009. During the testing, a static water level of 86 feet and a pumping water level of 145 feet were recorded. The



well was tested at a flow rate of 1,330 gpm. The calculated specific capacity for Well 23 is 22 gpm/ft of drawdown. The complete cost analysis is included in Appendix A.

Well 23 is reported to be operating satisfactorily and producing water quality that is acceptable to CDPH, however, City staff has indicated that Well 23 produces water with entrained air periodically. Well 23 draws water from several different aquifers between 190 and 420 to achieve the current water quality blend. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on the water quality. Well 23 appears to have several years of remaining service life, however the City should plan on well replacement in the next nine to nineteen years. A replacement well at this site would require partial removal of the exterior block wall and encroachment into the adjacent parking lot.

Well 24 – Central

Background

Well 24 is located at 845 Central Avenue (as shown on Figure 1). The well was constructed by the rotary drilling method in 1989, making the well presently 21 years old. The well was drilled to a depth of 465 feet and is the deepest well in the City's Well Field. The upper portion of the well consists of a 32-inch diameter steel conductor casing which extends from the ground surface to a depth of 160 feet. Inside the 32-inch conductor casing, an 18-inch diameter by 3/16-inch wall steel well casing and louvered well screen assembly extends to a depth of 465 feet. The well has perforated intervals from 225 to 235, 304 to 334, 425 to 430, and 441 to 461 feet. A sand/cement annular seal extends from the ground surface to a depth of 160 feet.

In 1989 when the well was constructed and first tested, the water produced exceeded the MCL's for specific conductance, arsenic, and manganese. It is likely that the aquifers below 425 feet contain brackish water with very high manganese and arsenic concentrations. The well then remained idle for four years. During this time, it is very likely that this poor water quality migrated up the Well 24 structure and was injected into the upper two aquifers (225 to 235 feet and 334 to 334 feet) that were completed in this well. In 1993, the bottom of the casing was filled with gravel and capped with a neat cement plug to a depth of 416 feet. The annular portion of the well was not sealed off during this process. This first plug back did not improve the water quality; however, it is possible that this well was not properly flushed to remove the poor water quality that had migrated out into the aquifers over the previous four years. Well 24 remained idle from 1993 to 2008. Well 24 was retested in 2008 with similar water quality results for specific conductance and manganese (1,600 μ mhos/cm and 570 μ g/L respectively), however the arsenic concentration reduced from 39 to 10 μ g/L.

In 2009, the City implemented a plan to seal off the deeper, brackish water aquifer from the shallow portions of the well structure. The well was filled with cement to a depth of 343 feet and the well casing was perforated with explosive charges placed at depths of 355, 385, and 405 feet. The cement grout was allowed to flow into the annular space between the well casing and the borehole. An additional cement plug back injected neat cement grout into the annular space through the perforations from 304 to 334 feet and the well was filled in with cement to a depth of



259 feet. The uppermost section of well screen (225 to 235 feet) was then pumped for 12 hours at a flow rate of approximately 400 gpm without seeing any decline in field measured specific conductance. The purging of the well was suspended after 12 hours due to budgetary constraints.

It is possible that the increase in specific conductance observed over the past fifteen years in Wells 23 may be related to the Well 24 structure. It should be noted that slight increases in specific conductance in Wells 14 and 20 were also observed over this period. Corrective measures completed in 2009 to seal the lower portions of Well 24 have likely stopped the migration of the poor water quality from the deeper brackish aquifers into the upper aquifers.

Current Operating Condition

Well 24 is not a permitted source and has never been connected to the municipal water supply system due to water quality concerns. Well 24 is not equipped with a pump. Well 24 is currently sealed to a depth of 259 feet.

Pumping this well for several weeks or months may be needed to lower the specific conductance and manganese concentrations to acceptable levels and it is possible that the CDPH MCL's may not be obtainable. Purging the well would however help remove some of the poorer water quality from the aquifer system and thus help reduce impacts to other City wells. New wells should not be drilled deeper than 225 feet within a mile of this location, as shown on Figure 10, until the water quality impacts from this well have been assessed in greater detail. Shallow wells in this area will likely have problems with high nitrates and uranium unless they are located near the Tuolumne River (similar to Wells 34 and 36).

Well 25 – Boothe

Background

Well 25 is located at 1501 Boothe Road (as shown on Figure 1). Well 25 was constructed using the rotary drilling method in 1988, making the well presently 22 years old. Initially, an exploratory test hole was drilled to a depth of 340 feet. The production well was drilled and constructed to a total depth of 264 feet. A 32-inch diameter steel conductor casing is cemented in place to a depth of 82 feet providing the sanitary seal for this well. An 18-inch diameter steel well casing extends to a depth of 264 feet inside a 28-inch diameter borehole. The well casing is perforated with 0.045-inch slot size wire-wrapped well screen intervals from 84 to 166 feet, 172 to 199 feet, 227 to 241 feet and 253 to 260 feet. An 8 x 12 graded gravel envelope was placed from 264 feet to the ground surface inside the conductor casing.

Well 25 produced unacceptable levels of DBCP when it was first constructed and was subsequently equipped with a carbon filtration system. The concentrations of DBCP have reduced to acceptable levels and carbon filtration is no longer used. Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (1996 to 2010) indicate that the water produced from Well 25 meets all of the CDPH primary and secondary drinking water requirements with the exception of uranium and nitrate (as NO₃). Uranium concentrations



range from 17 to 30 pCi/L and nitrate concentrations range from 28 to 52 mg/L. The elevated concentrations require that the water produced from Well 25 is blended with the water produced from Well 28 to provide acceptable water quality.

Well 25 is equipped with a 50 horsepower US Motors electric motor and Peerless vertical turbine pump. The well discharge is equipped with an inline nitrate analyzer which constantly monitors the water entering the City system.

Current Operating Condition

Well 25 is an active permitted well. Testing to determine the current pumping costs was conducted on August 25, 2009. During the testing, a static water level of 70 feet and a pumping water level of 82 feet were recorded. The well was tested at a flow rate of 510 gpm. The calculated specific capacity for Well 25 is 41 gpm/ft of drawdown. The complete cost analysis report is included in Appendix A.

A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on the water quality. Well 25 appears to have eight to eighteen years of remaining service life. Water produced from Well 25 cannot be distributed without first blending with system water or water treatment. Well 25 is perforated in the very shallow aquifers above 170 feet which are known to have elevated concentrations of nitrates and uranium, in the vicinity of this well. A well modification program to seal off the shallow aquifers would improve the water quality with regard to uranium, but may not be able to reduce the nitrate concentrations below the MCL. Our assessment suggests that a well modification would have about a 50% chance of success at meeting all of the CDPH water quality standards. In addition, the well modification would reduce the casing diameter and the well yield would likely be limited to a capacity of approximately 400 to 800 gpm. Well 25 connects several aquifers. When it is permanently removed from service, it will need to be properly destroyed to prevent inter-aquifer communication which can degrade water quality. There is room at this well site to construct a replacement well.

Well 27 – Sixth Street

Background

Well 27 is located at 2953 6th Street (as shown on Figure 1). Well 27 was constructed using the rotary drilling method in 1998, making the well presently 12 years old. An exploratory test hole was drilled to a depth of 442 feet. The production well was drilled and constructed to a depth of 320 feet. A 14-inch diameter well casing extends to a depth of 320 feet inside a 24-inch diameter borehole. The well casing has perforated screen intervals from 195 to 202 feet, 212 to 236 feet and 308 to 316 feet with a 0.048-inch slot size. An 8 x 16 graded gravel envelope was placed from 320 feet to 165 feet. A cement sanitary seal was placed from 165 feet to the ground surface.

Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (1998 to 2010) indicate that the water produced from Well 27 meets all of the CDPH



primary and secondary drinking water requirements, however arsenic concentrations were reported to be at the CDPH MCL of 10 µg/L when the well was new. The arsenic concentration has remained between 6 and 9µg/L over the past 6 years.

Well 27 is equipped with a 125 horsepower General Electric motor and a Peerless vertical turbine pump.

Current Operating Condition

Well 27 is currently an active permitted well. Testing to determine the current pumping costs was conducted on August 24, 2009. During the testing, a static water level of 76 feet and a pumping water level of 98 feet were recorded. The well was tested at a flow rate of 1,230 gpm. The calculated specific capacity for Well 27 is 55 gpm/ft of drawdown. The complete cost analysis report is included in Appendix A.

Well 27 is reported to be operating satisfactorily and produces acceptable water quality. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on water quality. The City should plan for replacement of Well 27 in approximately three to thirteen years. A replacement well could likely be drilled 25 feet west of the current Well 27 location.

Well 28 – River Bluff

Background

Well 28 is located at 3643 East Hatch Road (as shown on Figure 1). Well 28 was constructed using the rotary drilling method in 2003, making the well presently 7 years old. An exploratory test hole (TH 9) was drilled at this approximate location to a depth of 380 feet near this well site. The production well was drilled and constructed to a depth of 315 feet. A 30-inch steel conductor casing was cemented into place to a depth of 25 feet. A 16-inch by ¼-inch wall steel well casing extends to a depth of 315 feet inside a 26-inch diameter borehole. The well casing includes a single perforated interval from 245 to 305 feet, with a 0.060-inch slot size. The type of perforations are not known. An 8 x 16 graded gravel envelope extends from 315 to 210 feet. A cement annular seal extends from 210 feet to ground surface.

Water quality records from the City (2007 to 2009) and from the CDPH Drinking Water Database (2004 to 2010) indicate that the water produced from Well 28 meets all of the CDPH primary and secondary drinking water requirements. The concentration of nitrate (as NO₃) is currently at 24 mg/L. The concentration has been steadily increasing at about 2 mg/L per year over the past five years. If this rate continues, Well 28 could exceed the CDPH MCL of 45 mg/L within the next 11 years. Well 28 is equipped with a 125-horsepower U.S. Motors electric motor and a Floway vertical turbine pump.



Current Operating Condition

Well 28 is currently an active permitted well. Testing to determine the current pumping costs was conducted on August 25, 2009. During the testing, a static water level of 93 feet and a pumping water level of 154 feet were recorded. The well was tested at a flow rate of 1,134 gpm. The calculated specific capacity for Well 28 is 19 gpm/ft of drawdown. The complete cost analysis report is included in Appendix A.

Well 28 is reported to be operating satisfactorily and produces acceptable water quality. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on water quality. Well 28 appears to have 23 to 33 years of remaining service life, however increasing nitrate concentrations in this well should be closely monitored. A replacement well with a deeper seal could likely be drilled in the adjacent City Park; however the concentrations of arsenic appear to increase with depth in this area and the City should first confirm the water quality before constructing a production well in the deeper aquifers.

Well 32 – Blaker

Background

Well 32 is located at 4209 Blaker Road (as shown on Figure 1). Well 32 was constructed using the rotary drilling method in 1989, making the well presently 21 years old. An exploratory test hole was drilled to a depth of 450 feet. The production well was drilled and constructed to a depth of 360 feet. An 18-inch steel well casing extends to a depth of 360 feet, with unknown type of well screen intervals from 205 to 210 feet, 218 to 248 feet, 258 to 270 feet, 300 feet to 308 feet, and 342 to 356 feet. A 6 x 12 graded gravel envelope was placed from 360 to 181 feet. A cement sanitary seal extends from 181 feet to ground surface.

According to City records, the water produced from Well 32 meets all of the CDPH primary and secondary drinking water requirements with the exception of arsenic and manganese. Arsenic concentrations range from 11 to 18 µg/L and manganese concentrations range from 91 to 130 µg/L.

Well 32 is equipped with an electric 200-horsepower U.S. Motors motor with a Flowserve vertical turbine pump. The discharge has a digital totalizing flow meter. The well site is equipped with well head treatment to remove arsenic and manganese, utilizing green sand (coagulation) with the addition of ferric chloride and chlorine. Well 32 is currently off-line pending an upgrade to the water treatment system.

Current Operating Condition

Well 32 is currently an active permitted well. Testing to determine the current pumping costs was conducted on August 24, 2009. During the testing, a static water level of 99 feet and a pumping water level of 157 feet were recorded. The well was tested at a flow rate of 1,311 gpm.



The calculated specific capacity for Well 32 is 23 gpm/ft of drawdown. The overall plant efficiency is 56%. The complete cost analysis report is included in Appendix A.

The water quality treatment plant has experienced numerous problems over the years. With treatment designed to remove both manganese and arsenic, Well 32 produces water quality that is acceptable to the CDPH. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on water quality. Well 32 appears to have nine to nineteen years of remaining service life.

The Well 32 pilot borehole penetrated the aquifer from 434 to 441 feet, which is very high in specific conductance, manganese, and arsenic. Well 24 was completed in this aquifer zone, making that well unusable. From our Well 24 analysis, we believe that this lower aquifer has a much higher head than the aquifers above it. The lower portion of the Well 32 pilot borehole was not sealed and could be acting as a conduit allowing the water from this lower aquifer to migrate into Well 32, thus increasing the manganese and arsenic concentrations above the CDPH MCL's. In addition, temporary zone sampling at the TH-8 location (as shown in Figure 1) and the data in Table 3 suggests that the aquifer from 345 to 365 feet has very high concentrations of specific conductance, manganese, and arsenic. It is possible that if the lowest section of the well screen from 342 to 356 feet were sealed off in Well 32, the water quality may improve. Plugging back Well 32 would reduce the specific capacity of the well and thus may reduce the well yield from the original recommended design capacity.

Well 34 – Lions Park

Background

Well 34 is located in the proposed Lions Park at 1852 River Road (as shown on Figure 1). Well 34 was constructed by the rotary drilling method on March 27, 2008, presently making this well two years old. An exploratory test hole was initially drilled to a depth of 300 feet. The production well was drilled and constructed to a total depth of 235 feet. A 30-inch diameter steel conductor casing extends to a depth of 25 feet. A sand/cement sanitary seal extends the length of the conductor casing. A 16-inch diameter steel well casing extends to a depth of 235 feet, inside a 26-inch diameter borehole drilled to a total depth of 230 feet, with screened intervals from 120 to 140 feet and 170 to 230 feet. An 8 x16 graded gravel envelope extends from 240 feet to 110 feet. A sand/cement annular seal extends from 110 feet to the ground surface.

Water quality records from the City (2008 to 2009) indicate that the water produced from Well 34 meets all of the CDPH primary and secondary drinking water quality requirements. Well 34 is equipped with a submersible electric 60 horsepower Hitachi motor and a Gould pump.

Current Operating Condition

Well 34 is an active permitted well. Testing to determine the current pumping costs was conducted on August 25, 2009. However, during the testing, the water level measurements were not accurately recorded. When Well 34 was constructed, the calculated specific capacity was 15 gpm/ft of drawdown. The complete cost analysis report is included in Appendix A.



Well 34 is reported to be operating satisfactorily and produces acceptable water quality, however, City Staff has indicated that the specific capacity has reduced to approximately 7 gpm/ft with a pumping water level of 142 feet. Well 34 is also reported to producing water with entrained air. Wells 34 and 36 are only 63 feet apart and therefore have significant mutual pumping interference. There is also significant seasonal drawdown from other wells in this area. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on the water quality. Well 34 appears to have 28 to 38 years of remaining service life, however, Well 34 recently has had a significant drop in its specific capacity, from 15 gpm/ft of drawdown from when it was new to 7 gpm/ft of drawdown in May 2010. Rehabilitation to restore the specific capacity of this well is recommended at this time. If this well were to fail, a replacement well could likely be drilled in the adjacent City Park.

Well 35 – Hackett

Background

Well 35 is located at 401 Hackett Road (as shown on Figure 1). The well was constructed using the rotary drilling method in 2008, presently making the well two years old. An exploratory test hole was drilled to a depth of 330 feet. The production well was drilled and constructed to a total depth of 180 feet. A 30-inch diameter conductor casing is cemented in place to a depth of 25 feet. A 16-inch diameter steel well casing extends to a depth of 180 feet inside a 26-inch diameter borehole. The well is screened with a single perforated interval from 125 feet to 170 feet, with 0.060-inch slot size vertical mill slot perforations. An 8x16 graded gravel envelope was placed from 180 feet to 115 feet. A sand/cement sanitary seal was placed from 115 feet to the ground surface.

Water quality records from the City (2009) indicate that the water produced from Well 35 meets all of the CDPH primary and secondary drinking water requirements. Well 35 is equipped with a 50 horsepower US Motors electric motor and a Gould vertical turbine pump.

Current Operating Condition

Well 35 is an active permitted well. Testing to determine the current pumping costs was conducted on August 24, 2009. During the testing, a static water level of 39 feet and a pumping water level of 82 feet were recorded during the well testing. The well was tested at a flow rate of 642 gpm. The calculated specific capacity for Well 35 is 15 gpm/ft of drawdown. The complete cost analysis report is included in Appendix A

Well 35 is reported to be operating satisfactorily and produces acceptable water quality. A service life of 30 to 40 years is typical for wells using similar casing materials. Actual service life can vary greatly depending on water quality. Well 35 appears to have 28 to 38 years of remaining service life. A replacement well could not likely be drilled at this site.



Well 36 – Little Lions

Background

Well 36 is located at 1856 River Road, adjacent to the Well 34 site (as shown on Figure 1). The well was constructed using the mud rotary drilling method in 2006, presently making the well four years old. A 10-inch diameter PVC well casing extends to a depth of 230 feet inside a 20-inch diameter borehole. The well is screened from 120 feet to 140 feet and 170 feet to 230 feet with a slot size of 0.045-inches. An 8 x 16 graded gravel envelope extends from 230 feet to 50 feet. A sanitary seal was placed from 50 feet to the ground surface. Well 36 originally was constructed with a 20-foot deep bentonite sanitary seal. The City removed this seal and installed a cement annular seal to a depth of 50 feet in 2009.

Water quality records from the City (2008 through 2009) indicate that water produced from Well 36 meets all the CDPH primary and secondary drinking water requirements. Well 36 is equipped with a submersible 30 horsepower Franklin motor with a Gould pump.

Current Operating Condition

Well 36 is currently an active permitted well. Testing to determine the current pumping costs was conducted on August 25, 2009. During the testing, a static water level of 71 feet and a pumping water level of 77 feet were recorded. The well was tested at a flow rate of 330 gpm. The calculated specific capacity for Well 36 is 52 gpm/ft of drawdown. The complete cost analysis report is included in Appendix A.

Well 36 is reported to be operating satisfactorily and produces acceptable water quality. A service life of 20 to 30 years is typical for wells using similar casing materials. Wells 34 and 36 are only 63 feet apart and therefore have significant mutual pumping interference. Well 36 is also reported by City Staff to cause significant drawdown to shallow domestic wells in this vicinity. There is also significant seasonal drawdown from other wells in this area. Well 36 appears to have 16 to 26 years of remaining service life. A replacement well could likely be drilled in the adjacent City Park.

Well 38 – Eastgate (AKA Well 19R)

Background

Well 38 is located at 1600 Eastgate Boulevard (as shown on Figure 1). Well 38 was constructed by the rotary method in December 2009 as a replacement for Well 19. An exploratory test hole was drilled to a depth of 355 feet. The production well was drilled and constructed to a total depth of 329 feet adjacent to the test hole. A 36-inch outside diameter steel conductor casing is cemented into place to a depth of 30 feet, inside a 48-inch diameter borehole. An 18-inch outside diameter well casing extends to a depth of 324 feet inside a 30-inch diameter borehole, with stainless steel wire wrapped well screens from 260 feet to 264 feet and from 278 feet to 318 feet. A CEMEX 8x16 graded gravel envelope extends from 329 feet to 242 feet with a bentonite



seal from 242 feet to 240 feet. A sand/cement sanitary seal extends from 240 feet to the ground surface. A 3-inch black steel gravel feed pipe extends from ground surface to 248 feet and a 2-inch black steel sounding pipe enters the well casing at 229 feet.

Water quality data from the newly constructed well indicates that the water produced from Well 38 meets all of the CDPH primary and secondary drinking water requirements. Well 38 is equipped with a 100 horsepower Hitachi submersible motor and Gould pump, with a design capacity of 1,150 gpm.

Current Operating Condition

A pumping test was conducted on January 6, 2010. The static water level was measured at 72 feet. The 24-hour projected specific capacity for Well 38 is 19 gpm/ft of drawdown, with a projected 24-hour pumping water level of 131 feet at 1,150 gpm.

The Well 38 pump station was completed during the preparation of this document and is fully operational as of June 2010. A service life of 40 to 50 years is typical for wells using similar casing materials. A replacement well could likely be drilled at this well site if it is ever needed.

Test Hole Exploration and Temporary Zone Sampling (1989 to 2005)

The City has records for eleven exploratory test holes drilled from 1989 to 2005. The test hole locations are shown in Figure 1. The locations of the test holes are approximate and are based on information gathered through personal communication with former City Staff Engineer, Len Guillette. The test holes were drilled to assess potential well sites for acceptable aquifer material and water quality. Table 3 details the location and depth (feet below ground surface) of the exploratory test holes. Each test hole was geophysically logged and some included lithologic descriptions by the water well driller. The geophysical, lithologic descriptions, and Water Well Drillers Reports (where available) are included in Appendix B. Temporary zone sampling was conducted in six of the eleven test holes (TH 1, TH 5, TH 7, TH 8, TH 9, and TH 11) to evaluate zone-specific water quality. Table 3 also includes the depth interval and the water quality results for the zone-specific sampling; which were sampled and tested for specific conductance, nitrate (as NO₃), arsenic, manganese, and uranium.

Geologic Cross Sections

Data obtained from the City wells and exploratory test holes indicate that the quality of the groundwater within the City varies horizontally and vertically (with depth). To illustrate these variations, two geologic cross sections were prepared that depict some of the City's wells in the sub-surface and the geologic formations that they penetrate. The approximate elevations that the geologic formations can be anticipated to be encountered and the City's water wells are depicted on the cross sections with respect to mean sea level. Ground surface elevations are higher in the northeast area of the City and are less in the southwest area of the City, by approximately 25 feet. Published geological reports, lithologic data from the water well drillers reports and geophysical logs from the test holes were used to approximate the top and bottom of the formations. The



cross sections illustrate the well depth, screen interval sections and associated water quality data. Table 1 includes the ground surface elevation for each well. The cross sections are scaled to provide for a useful tool to identify the depths below ground surface which the formations can be anticipated throughout the City.

The Corcoran Clay, a regional stratigraphic marker bed throughout the San Joaquin Valley, was identified throughout the City in the subsurface. The Corcoran Clay is the confining layer (aquitard) that separates what is reported to be the unconfined shallow aquifer from the confined, deeper aquifers. The top of the Corcoran Clay was chosen to represent the contact of the Turlock Lake Formation with the shallower, Riverbank Formation. The Riverbank Formation and the Turlock Lake Formation are lithologically similar, but differentiate in terms of grain size. A lack of textural descriptions inhibited the identification of the contact of these two formations. The locations of the two geologic cross sections are as shown on Figure 2.

Cross section A-A' (Figure 3) transects northeast-southwest and cross section B-B' (Figure 4) transects approximately north-south. Cross-section A-A' illustrates that very high nitrate (as NO_3) concentrations are found in the shallow wells (less than 120 feet deep, such as Well 6). Wells in the central and eastern portion of the City, with major production zones ranging from 120 to 160 feet, such as Wells 1, 22, and 25, have high concentrations of uranium. In the northern and western portion of the City, uranium concentrations in the 120 to 160 foot interval are low, such as in Wells 34, 35, and 36. Wells deeper than 400 feet, such as Well 23 and 24, tend to have high concentrations of dissolved salts (as measured by the specific conductance), as shown on cross section B-B'. Within the City, concentrations of manganese and arsenic increase with increasing depth and to the southwest, as illustrated by Well 32 on cross section B-B'. The quality of groundwater produced from Well 32 exceeds the CDPH MCL for both manganese and arsenic.

Information presented on the cross sections suggests that the most favorable aquifers in the central portion of the City are located between 250 and 320 feet. Wells in north Ceres, near the Tuolumne River and in the West Ceres Specific Plan area, appear to have acceptable water quality in the 130 to 210 foot intervals, based on the water quality data and cross sections. The water quality below 210 feet is currently not known in the West Ceres Specific Plan area.

Groundwater Quality

The City is located in an area that has numerous groundwater quality problems. Groundwater contamination is a result of naturally occurring contaminants, point source contamination, and regional contamination. Naturally occurring contaminants of concern include dissolved salts (as measured by the specific conductance), arsenic, manganese, and uranium. Point source contamination is identified as single source plumes. Point source contaminant plumes that have been identified in Ceres are mostly from fuel and solvent releases, originating mostly from gas stations and dry cleaners. As shown on Figure 10, the State of California Water Resources Control Board GeoTracker data set identifies known contamination cleanup sites. Regional sources of contamination include applied fertilizers, salts, and leaky septic systems (nitrates and salt loading). The costs of this regional contamination are evidenced by increased concentrations



of nitrate and specific conductance readings in the groundwater. Synthetic organic compounds have also been detected within the City. When first constructed and tested, Well 25 produced water that contained the synthetic organic compound DBCP (1,2,-dibromo-3-chloropropane).

Drinking water quality standards for the City are regulated by the CDPH. Table 4 illustrates the MCL's for the main constituents of concern for the City.

Table 4
Constituents of Concern
Maximum Contaminant Levels

Constituent	CDPH MCL	Units
Specific Conductance	900 ¹	µmhos/cm
Nitrate (as NO ₃)	45	mg/L
Arsenic	10	µg/L
Manganese	50 ²	µg/L
Uranium	20	pCi/L

Historic water quality data for the constituents of concern for each of the City's wells were plotted on individual graphs, and are included in Appendix A. The graphs depict the concentrations of the constituents of concern including: specific conductance, nitrate, arsenic, manganese, and uranium. These graphs were reduced in size and plotted with the respective well location, as shown in Figures 5 through 9. From this data set, water quality trends for each of the constituents of concern for the City's Well Field are discussed below.

Specific Conductance

The specific conductance of groundwater is the measure of how effectively the water will conduct electricity, reported in micro-mhos (µmhos) per centimeter. Specific conductance provides for the indirect measurement of the amount of dissolved solids (salts) in the groundwater. Applied irrigation and fertilizers add salts to the water that percolate into the hydrogeologic system. Figure 5 indicates that shallow wells, such as Wells 1, 6, and 19, have elevated concentrations of specific conductance. The elevated concentrations of specific conductance are likely a result of the surface contamination. Within the City, concentrations of specific conductance decrease with depth to approximately 320 feet and then begin to increase in concentration with depth. Based on our analysis, we believe that below a depth of 350 feet (approximately 280 feet below mean sea level), the specific conductance will likely exceed the recommended CDPH MCL of 900 µmhos/cm.

Nitrate

Nitrate is an anthropogenic contaminant which does not naturally occur in the subsurface. Elevated concentrations of nitrate are widespread in the Central Valley. The

¹ Recommended CDPH MCL; upper limit is 1,600 µmhos/cm; short term is 2,200 µmhos/cm

² Secondary CDPH MCL



water quality data from the zone-specific test hole sampling indicate that nitrate concentrations decrease with depth throughout the City. This observation is typical in agricultural areas that have experienced nitrate loading from fertilizer use and applied irrigation, along with the likely contribution from septic systems or possible leaking sewer pipes. Nitrate concentrations are elevated in the shallow aquifers above a depth of approximately 250 feet in the central portion of the City. The data suggests that concentrations of nitrate appear to decrease west of Highway 99, near the Tuolumne River. Figure 6 indicates that Wells 1, 6, 19, and 25 exceed the MCL for nitrate.

Arsenic

Arsenic is a naturally occurring element found in rocks and minerals. Its presence in well water is resultant from the dissolution of the naturally occurring element of sediments in geologic formations. The zone-specific temporary zone sampling performed in several of the test holes indicate that concentrations of arsenic increase with depth, as shown in Table 3, and with progression to the southwest area of the City as shown in Figure 7. Well 32 exceeds the MCL for arsenic and Wells 20, 21, and 27 are very close to the MCL. The reported concentrations of arsenic (over the period of record) vary for all the City wells; likely due to the sensitivity of the analytical instruments and reporting errors, which can vary by $\pm 20\%$, while still following EPA analytical methods. Arsenic concentrations appear unchanged for most wells with a possible slight decrease in concentration over the reporting period.

Manganese

Manganese is a naturally occurring element found in rocks and minerals. Its presence in well water originates from groundwater moving through sediments containing manganese, which can dissolve it and transport it through the aquifer. The water quality data suggests that groundwater below 350 feet will likely have elevated concentrations of manganese exceeding the CDPH MCL of 50 $\mu\text{g/L}$. Figure 8 indicates that Wells 32 and 24, which extend below this depth, exhibit high concentrations of manganese. Although Well 23 is constructed deep, it nevertheless produces water with low manganese concentrations; most likely a result of dilution with groundwater originating in the deeper aquifer mixing with groundwater from shallower aquifers that does not contain manganese.

Uranium

Uranium is a naturally occurring element and is found in groundwater by the erosion of sediments containing minerals that originate from igneous rocks. Elevated concentrations exceeding the CDPH's MCL for uranium are found in the aquifers ranging from between 120 feet to 170 feet in the central portion of the City. Well 22 is equipped with a well head treatment system designed to decrease uranium to acceptable concentrations. Figure 9 indicates that the water produced from Wells 1, 19, and 25 also have elevated concentrations of uranium above the MCL. The test hole zone sampling indicates that uranium concentrations decrease below a depth of 170 feet.



Regulatory Trends

As existing constituents of concern, unregulated contaminants, and emerging unregulated contaminants in drinking water are further studied and analyzed by the Federal and State Government, new monitoring requirements and regulations will most likely be promulgated. Recently in 2008, an update to Title 22 of the California Code of Regulations (CCR) included the revision of the arsenic rule, which lowered the MCL from 50 µg/L to 10 µg/L. Currently, the CDPH is proposing to adopt the Federal “Ground Water Rule”, which states that a public water system that uses groundwater shall comply with the provision of 40 Code of Federal Regulations as they appear in the Ground Water Rule. Other upcoming updates to regulated contaminants that are currently in the review process include the revision of the MCL for hexavalent chromium (Chromium 6), perchlorate, and radon. The constituents that are currently under review for revision were not a focus of this assessment. In the future, new drinking water regulations that lower the MCL for current constituents of concern could potentially further restrict the use of wells where the water quality is presently close to the MCL.

Requirements for Future Well Site Locations

The goal for future production wells is to construct wells that produce water that is not only acceptable by current regulations, but also anticipated stricter regulations in the future. The most desirable well is one that does not require well head treatment. New wells should be constructed in areas and in aquifers that have both favorable water quality and good well yields. Groundwater quality varies in the City’s aquifers not only with respect to depth, but laterally within the various aquifers. Because of these variations, we recommend that each prospective well site include exploratory drilling that includes test hole assessment. Monitoring wells should be constructed at Smyrna Park, Hollister, the Corporation Yard and the Super Wal-Mart sites, where zone-specific water quality information is needed. Additionally, we recommend that new wells be constructed with sufficient cement annular seals to isolate the deeper aquifers from the shallow aquifers where the water quality exceeds the MCL for the constituents of concern, such as uranium and/or nitrate, in order to prevent the downward migration of contamination through the gravel envelope in the annular space. Exploratory drilling below 360 feet is not advised due to the rapidly increasing concentrations of specific conductance, arsenic and manganese below that depth. Capacities for new wells could range from 600 to 2,500 gpm. Higher capacity wells are possible, but could have a greater chance of requiring water quality treatment to meet the CDPH drinking water requirements.

Wells should also be sited to facilitate the equipment to construct the well, operations and maintenance of the well, and to utilize existing infrastructure (when possible). Figure 10 shows five potential locations for new municipal supply wells for the City. These sites were selected to avoid identified point source contamination of volatile organic compounds. Four new wells are also planned to provide water supply to the West Ceres Specific Plan (WCSP).



Conclusions and Recommendations

The City's new water superintendent, Jeremy Damas, has recently implemented several important programs to track the performance and to document the condition of the City's wells and of the groundwater basin. These programs include the testing of all the City's wells for static water levels, pumping water levels, sand production, specific capacity, and overall pumping plant efficiency on a scheduled periodic basis. The data gathered from these programs will help track when wells will require maintenance, repairs, or replacement. These programs will also allow the City to work proactively to identify necessary future water system upgrades as opposed to working in response to CDPH mandate orders.

Candidate locations for new well sites should be initially screened by assessing the site suitability with regards to site access, well construction equipment size requirements, proximity to known groundwater contamination plumes, and CDPH set back requirements. Well sites meeting the above ground requirements should be further assessed in the subsurface. An exploration drilling program should be conducted at all potential well locations prior to proceeding with well construction. The exploration program should include drilling a test hole to identify the aquifer depths and lithologic characteristics. It is our recommendation that multiple-depth monitoring wells should be constructed at all of the new well sites to assess the water quality prior to designing the well.

The City has abundant groundwater resources; however, aquifers that meet all of the CDPH water quality requirements are very limited within the City. New wells will require very selective screen interval and annular seal placement to avoid the aquifers with poor water quality. Alternately, new wells could be completed in aquifers with known water quality contaminants, but will need to be equipped with well head treatment. Water treatment alternatives are addressed in other sections of this Water Master Plan.

New wells in growth areas will require additional site specific exploration to confirm the quality of depth specific groundwater and to estimate potential well yields. The existing test hole data suggests that groundwater that meets all of the CDPH water quality requirements may be difficult to locate in the southeast and south-central growth areas of the City. Well 35 is located in the WCSP area. Well 35 is a shallow, 180-foot deep well, which meets all of the CDPH drinking water quality requirements; however, it is only equipped to produce 640 gpm. Higher capacity wells in the WCSP area are likely possible, but they may require well head treatment to meet the CDPH drinking water quality requirements.

To maximize the service life of the City's future wells, new wells should be designed to be efficient well structures and constructed with corrosion-resistant materials. Annular seals should be installed to prevent inter-aquifer transfers of poor water quality as well as to help slow down the migration of surface contamination. Wells that are no longer in service and especially wells which connect shallow and deep aquifers together should be properly destroyed by sealing the well to stop the vertical movement of groundwater through the conduit created by the well structure.



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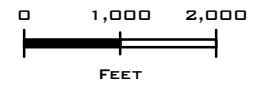
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WELL LOCATION
LOCATION MAP
CITY OF CERES WATER MASTER PLAN
CERES, CALIFORNIA
JULY 2010



- Permitted Well
- Inactive Well
- Test Hole
- City of Ceres Boundary

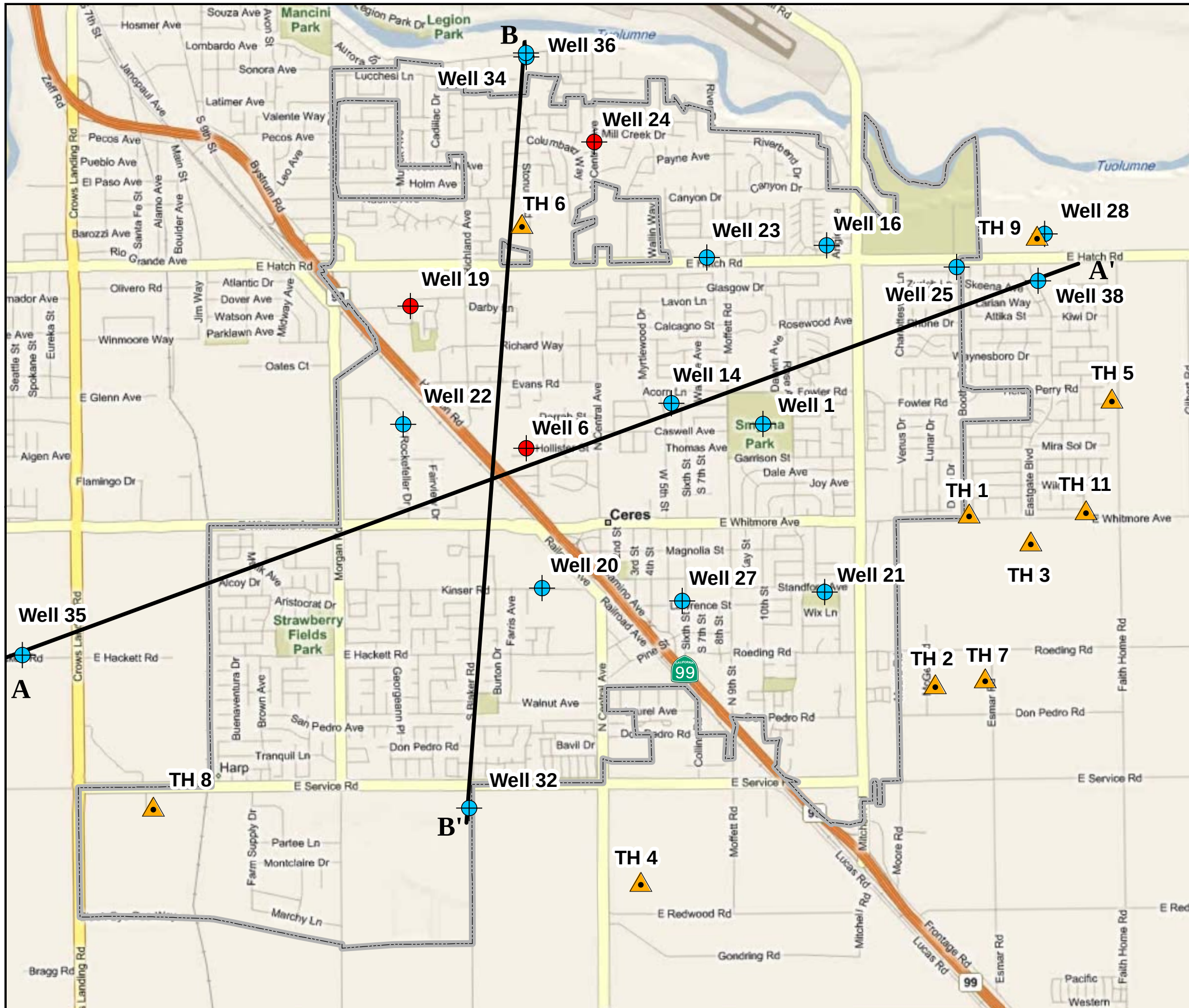
Vicinity Map



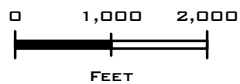
NOTES: Test hole locations are approximate.
SOURCE: Background Map - Microsoft Bing



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GEOLOGIC CROSS SECTION
LOCATION MAP
CITY OF CERES WATER MASTER PLAN
CERES, CALIFORNIA
JULY 2010



- Permitted Well
- Inactive Well
- Test Hole Location
- Cross Section Location
- City of Ceres Boundary

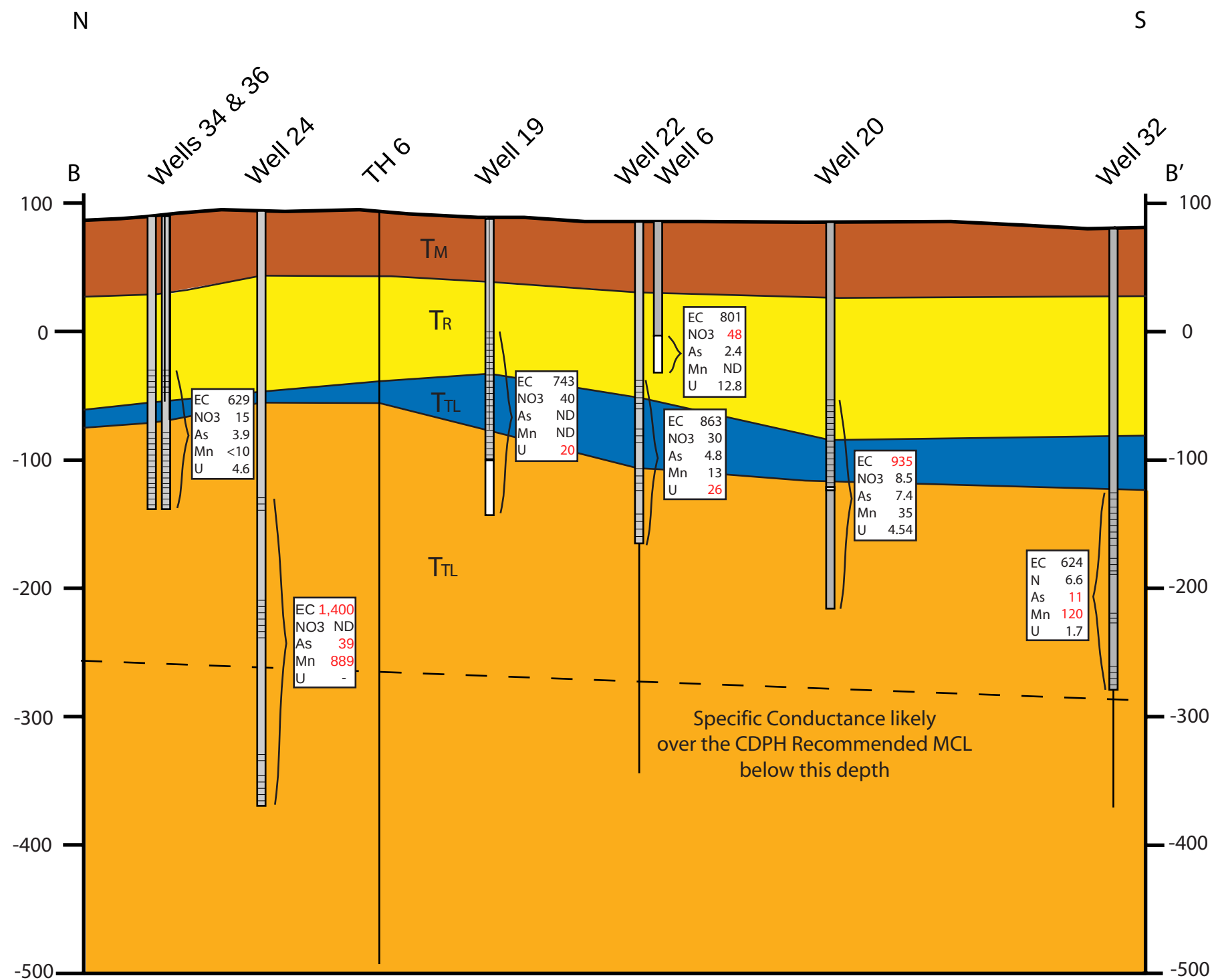
NOTES: Test hole locations are approximate.
SOURCE: Background Map - Microsoft Bing



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FIGURE 3

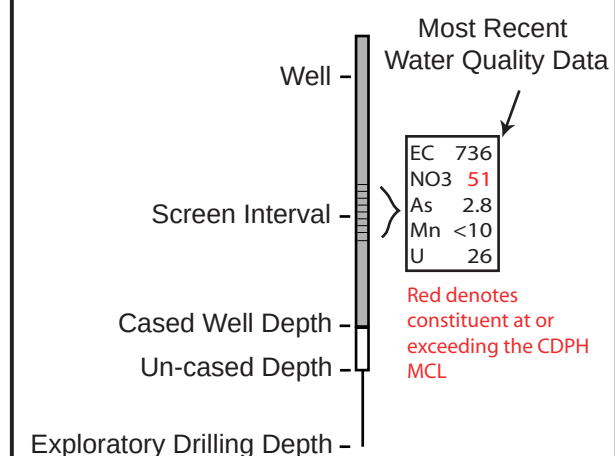
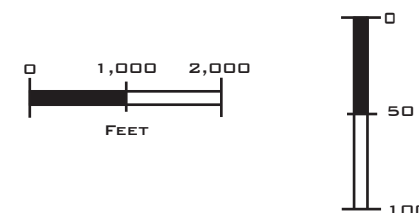


Geologic Legend

Pleistocene	T _M	Modesto Formation - Arkosic sand, gravel, and silt consisting of mainly quartz and feldspar with lesser amounts of heavy minerals.
	T _R	Riverbank Formation - Arkosic sand, gravel and silt of mainly quartz and feldspars. with reddish clay.
	T _{TL}	Corcoran Clay member of the Turlock Lake Formation - Dark greenish gray, commonly referred to as the blue clay. Generally well sorted clay to silty clay with no sand (Page and Balding, 1973).
	T _{TL}	Turlock Lake Formation - Arkosic sand, gravel, and silt that coarsen upward; sand and silt size sediments are mostly quartz, feldspars, biotite, and minor amounts of heavy minerals.

Adapted from: Burrow and Shelton, "Hydrogeologic Characterization of the Modesto Area, San Joaquin Valley, California", 2004

GEOLOGIC CROSS SECTION B-B' CITY OF CERES WATER MASTER PLAN CERES, CALIFORNIA JULY 2010

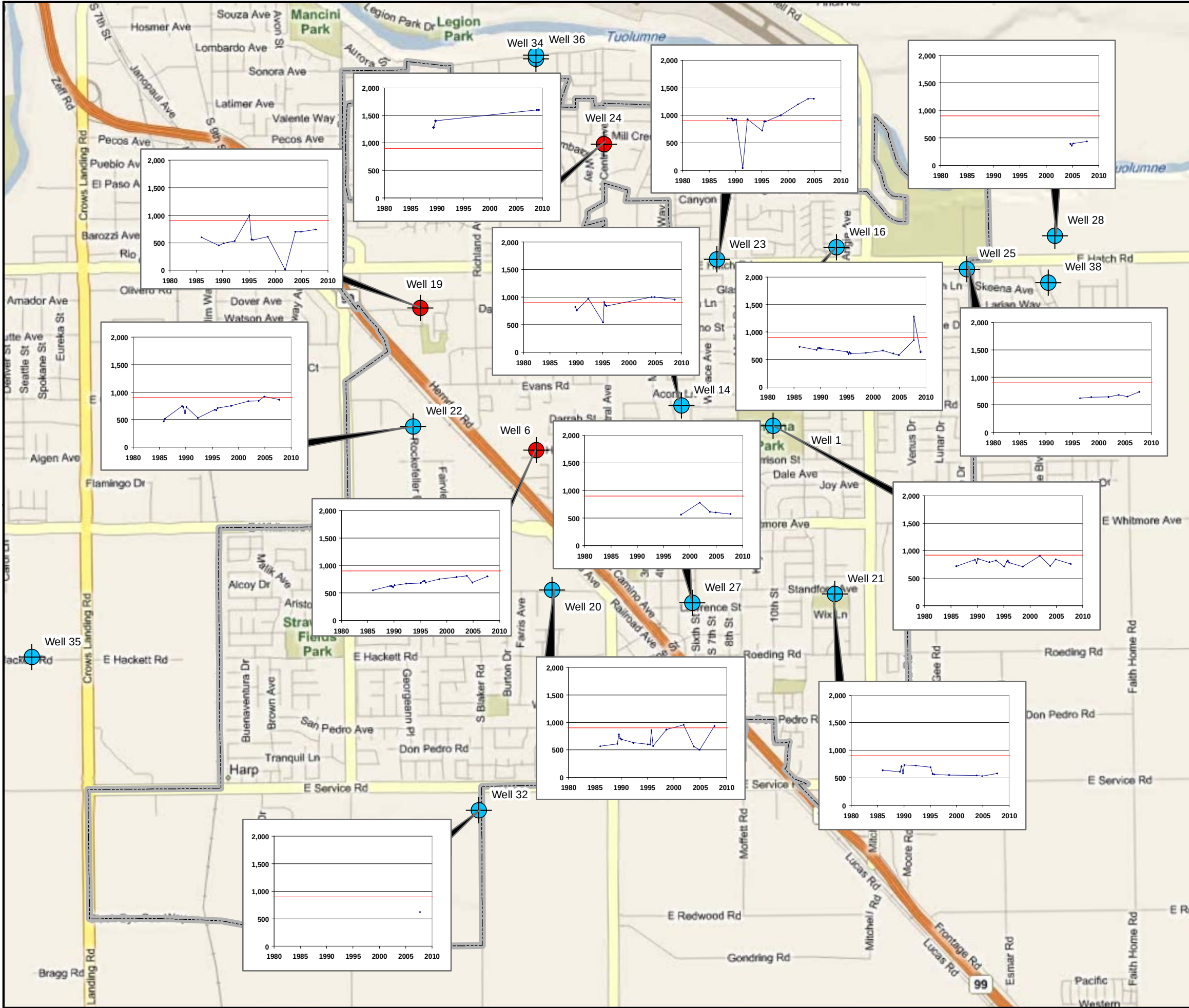


Water Quality

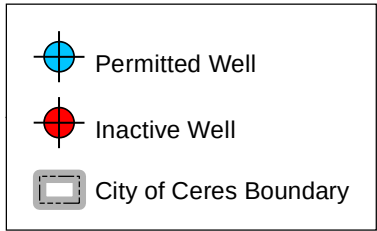
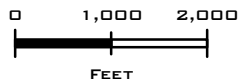
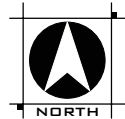
Constituent	MCL w/ units
Specific Conductance (EC)	900 umhos/cm*
Nitrate (NO ₃)	45 mg/L
Arsenic (As)	10 ug/L
Manganese (Mn)	50 ug/L**
Uranium (U)	20 pCi/ L

Notes: Ground surface elevation is approximate; Elevations are in Feet of Mean Sea Level (MSL); Water quality data represents most recent CDPH/City of Ceres data; MCL - CDPH Maximum Contaminant Level; *CDPH Recommended MCL; **CDPH Secondary MCL (Recommended and Secondary MCL denotes an aesthetic concern and not a health concern); ND - non detection above laboratory reporting limits; (-) not sampled; Vertical exaggeration is 20x.

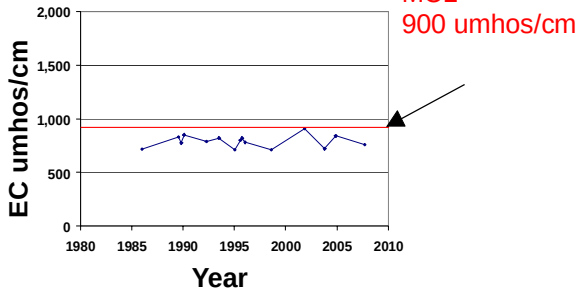




WATER QUALITY TREND
SPECIFIC CONDUCTANCE
CITY OF CERES WATER MASTER PLAN
CERES, CALIFORNIA
JULY 2010



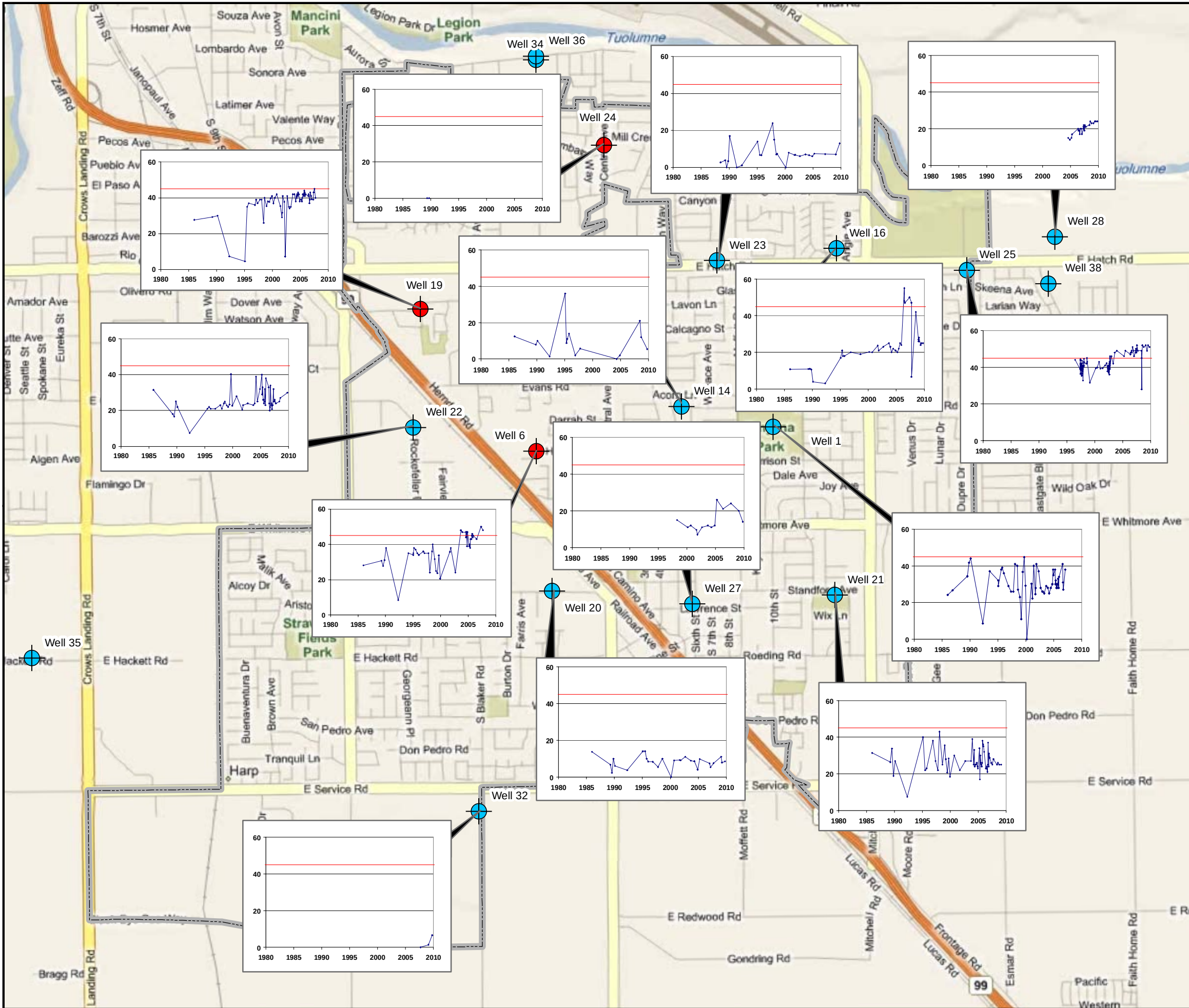
Water Quality
Chart Explanation



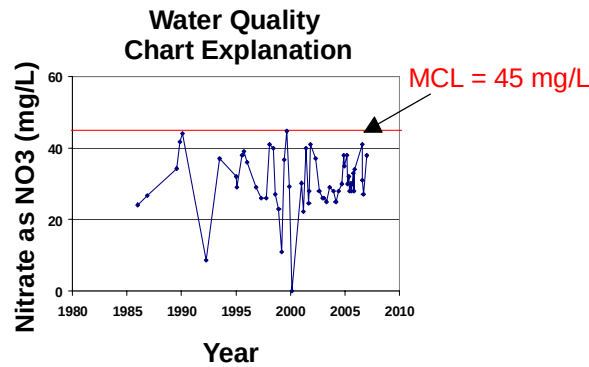
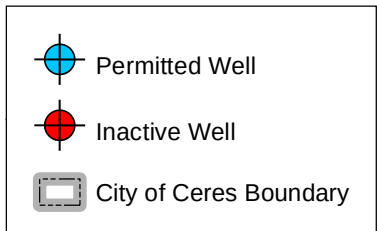
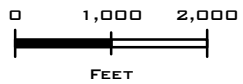
NOTES: Specific Conductance (EC) MCL denotes the California Department of Public Health (CDPH) Recommended (aesthetic) Maximum Contaminant Level of 900 umhos/cm, 1,600 umhos/cm is the upper limit, 2,200 is short term maximum.
SOURCE: Background Map - Microsoft Bing; Water Quality data queried from CDPH Drinking Water Database (current to 2007) and City of Ceres records. Earliest queried data was from 1986.



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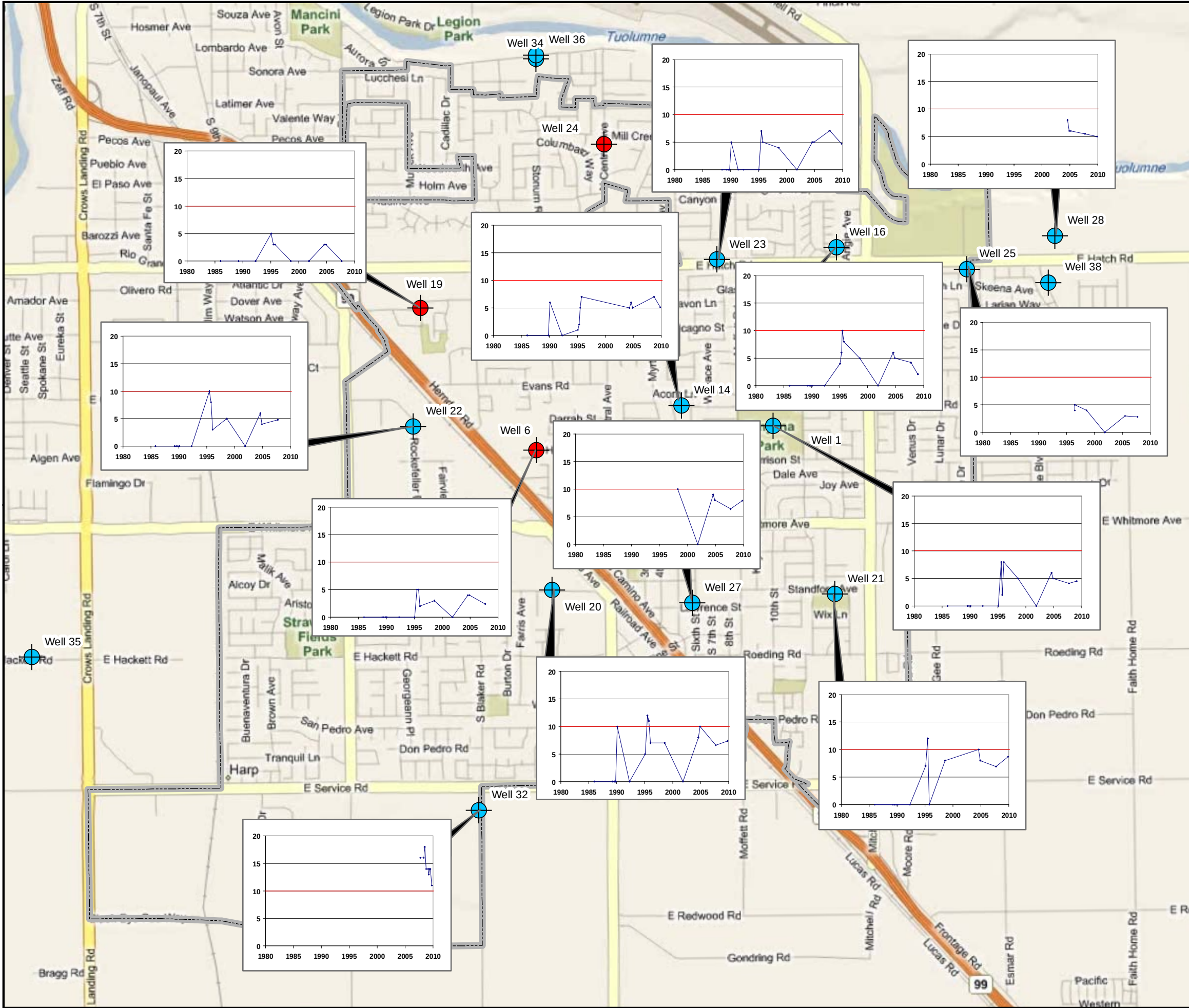


WATER QUALITY TREND
NITRATE (AS NO₃)
CITY OF CERES WATER MASTER PLAN
CERES, CALIFORNIA
JULY 2010

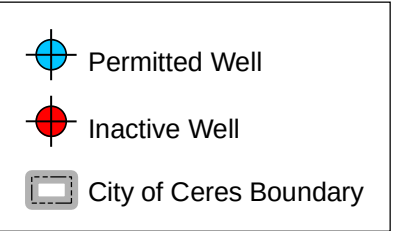
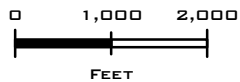


NOTES: Nitrate (as NO₃) MCL denotes the California Department of Public Health (CDPH) Primary (Health Based) Maximum Contaminant Level of 45 mg/L; Wells that exceed MCL (Wells 1 and 25) are blended to produce acceptable water quality.
SOURCE: Background Map - Microsoft Bing; Water Quality data queried from CDPH Drinking Water Database (current to 2007) and City of Ceres records. Earliest queried data was from 1986.

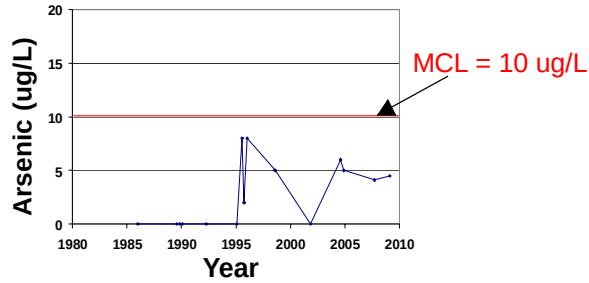

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WATER QUALITY TREND
ARSENIC
CITY OF CERES WATER MASTER PLAN
CERES, CALIFORNIA
JULY 2010



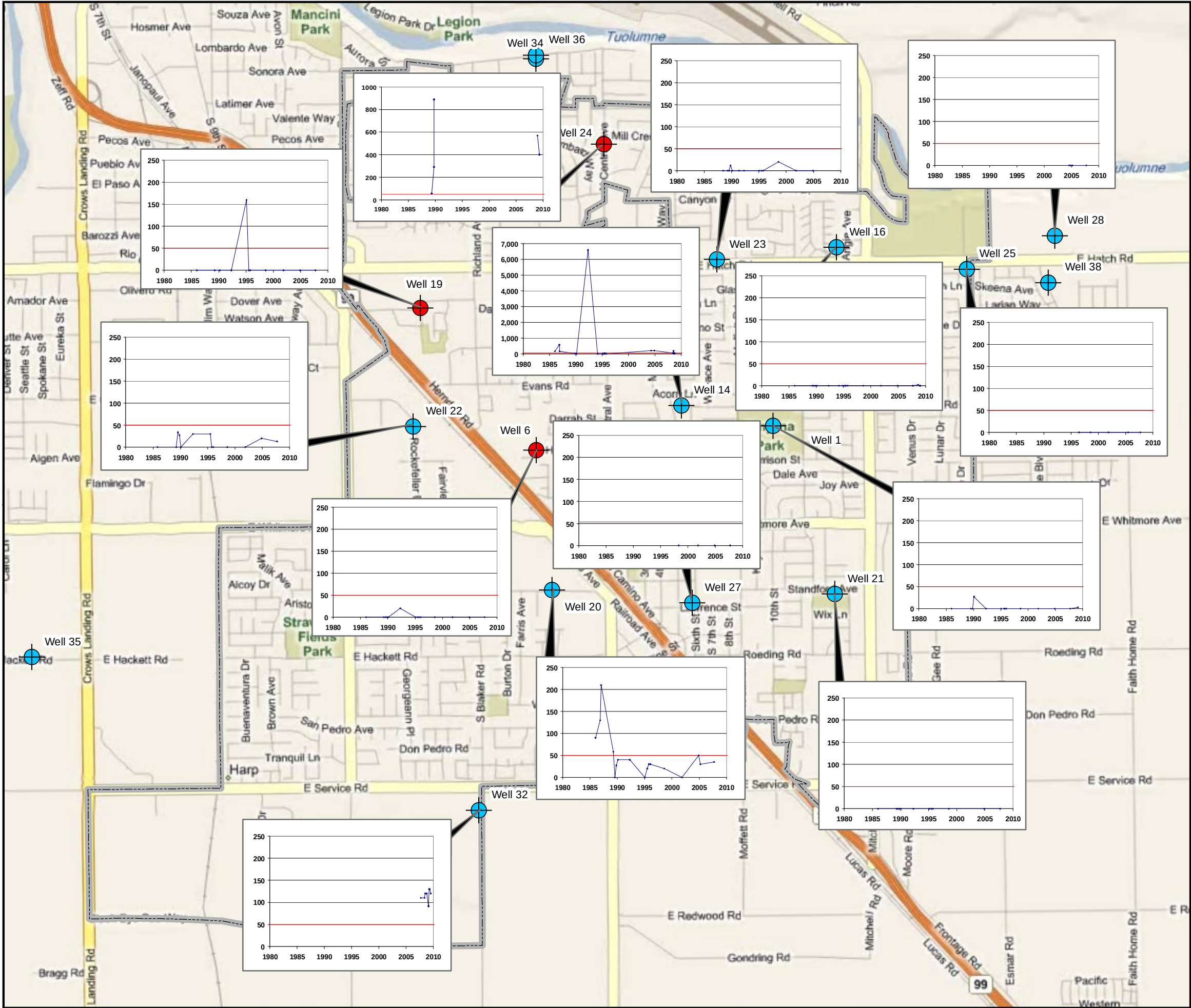
Water Quality
Chart Explanation



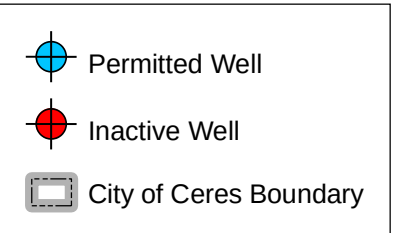
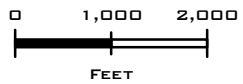
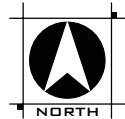
NOTES: Arsenic MCL denotes the California Department of Public Health (CDPH) Primary (Health Based) Maximum Contaminant Level; The CDPH adopted a revised MCL for Arsenic in November of 2008, effectively lowering the MCL from 50 ug/L to 10 ug/L; Arsenic exceeds the MCL in Well 32 and requires well head treatment prior to distribution.
SOURCE: Background Map - Microsoft Bing; Water Quality data queried from CDPH Drinking Water Database (current to 2007) and City of Ceres records. Earliest queried data was from 1986.



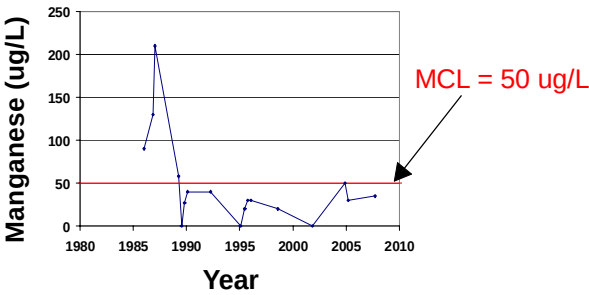
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WATER QUALITY TREND
MANGANESE
CITY OF CERES WATER MASTER PLAN
CERES, CALIFORNIA
JULY 2010



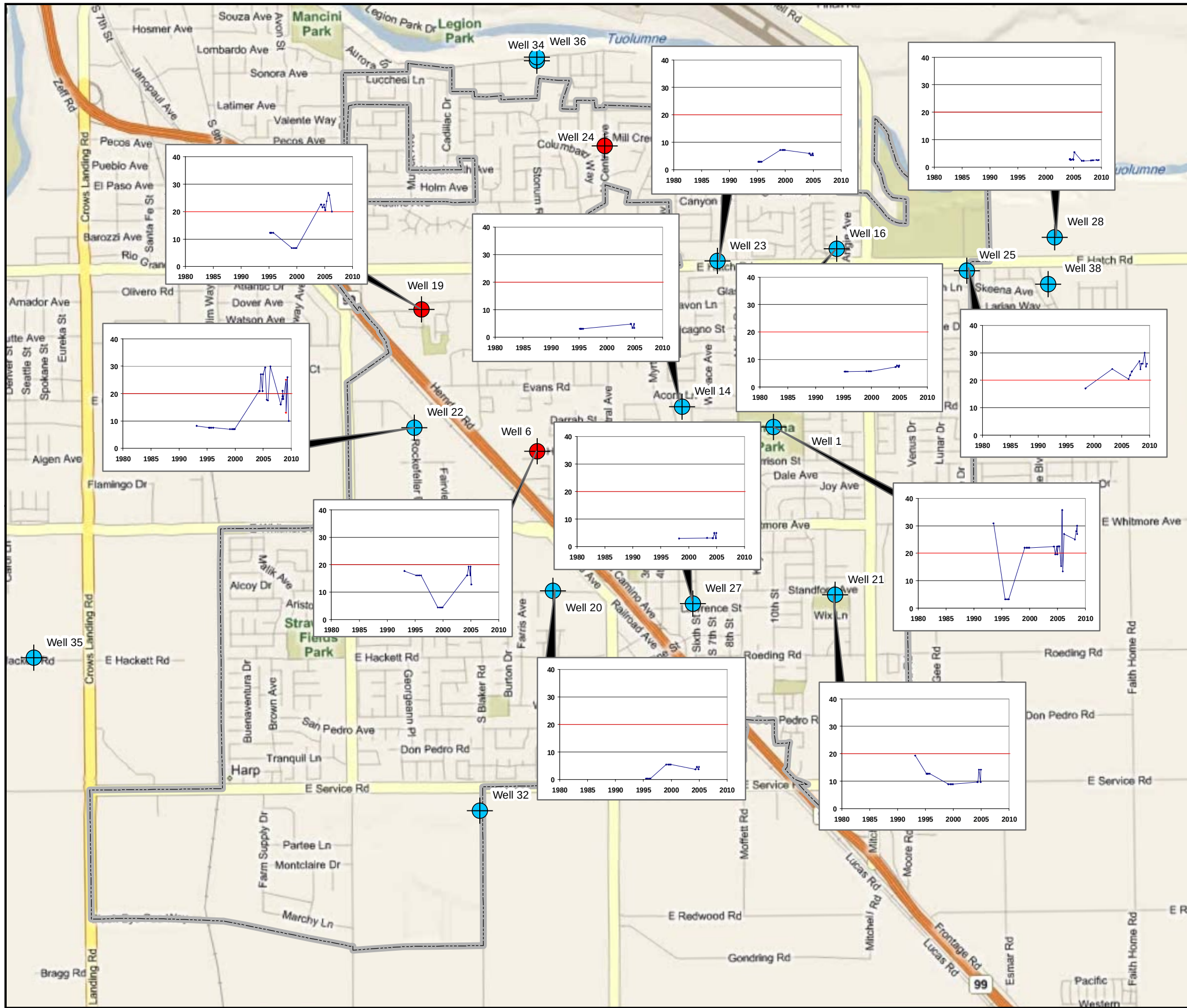
Water Quality
Chart Explanation



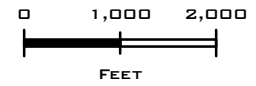
NOTES: Manganese MCL denotes the California Department of Public Health (CDPH) Secondary (aesthetic) Maximum Contaminant Level of 50 ug/L, this is not a health based MCL. Manganese exceeds the MCL in Well 32 and requires well head treatment prior to distribution.
SOURCE: Background Map - Microsoft Bing; Water Quality data queried from CDPH Drinking Water Database (current to 2007) and City of Ceres records. Earliest queried data was from 1986.



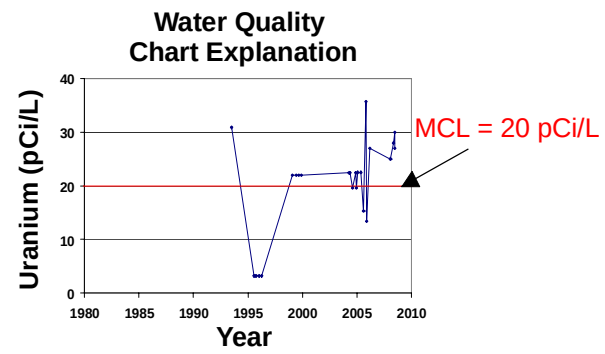
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WATER QUALITY TREND URANIUM CITY OF CERES WATER MASTER PLAN CERES, CALIFORNIA JULY 2010



- Permitted Well
- Inactive Well
- City of Ceres Boundary



NOTES: Uranium MCL denotes the California Department of Public Health (CDPH) Primary (Health Based) Maximum Contaminant Level of 20 pCi/L; Uranium exceeds the MCL in Well 22 and requires well head treatment prior to distribution.

SOURCE: Background Map - Microsoft Bing; Water Quality data queried from the CDPH Drinking Water Database (current to 2007) and City of Ceres records. Earliest queried data was from 1986.

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FIGURE 10