



APPENDIX D

Groundwater Quality and Modeling Evaluation (Todd Groundwater)



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FINAL TECHNICAL MEMORANDUM

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Re: Groundwater Quality and Modeling Evaluation to Support CVWD's Source of Supply and Treatment Study

The Coachella Valley Water District (CVWD) is currently evaluating its current and future water supply and treatment options to ensure ongoing compliance with California Title 22 drinking water regulations. In addition to water treatment facilities, CVWD is considering non-treatment compliance strategies, including the modification of existing wells and installation of new wells to re-distribute production and improve pumped groundwater quality.

To assess the viability of the non-treatment compliance strategies, CVWD authorized Todd Groundwater (Todd) to perform a two-part hydrogeologic evaluation. The evaluation includes mapping of the horizontal and vertical distribution of key constituents of concern (COCs) across the Coachella Valley Groundwater Basin (Basin) using data from CVWD's production and monitoring wells. Additionally, Todd evaluated potential impacts from increased groundwater production in the Date Palm Pressure Zone (PZ) using CVWD's regional MODFLOW groundwater model. By increasing production in the Date Palm Pressure Zone (PZ), an area with generally good groundwater quality, CVWD could replace existing production wells impacted by chromium-6.

This technical memorandum (TM) describes the technical approach, data sources, ambient groundwater quality conditions, and modeling results. It also presents key findings, knowledge gaps, and recommendations for additional work to further assess the feasibility of each compliance strategy.

PROJECT BACKGROUND

As part of the recently completed Mid-Valley Recharge Feasibility Study (Todd, June 2015), screen intervals and concentrations for key COCs were plotted on a set of vertical cross sections covering a 20-square mile area (primarily in the Date Palm and Sky Mountain PZs). Well screens on each cross section were color-coded according to the representative ambient concentration of target COCs, which included chromium-6, nitrate, total dissolved

solids (TDS), and sulfate. In addition to the cross sections, plan-view maps were developed showing the same well concentrations along with time-concentration (trend) plots for CVWD production wells in the study area.

The vertical cross sections revealed clear spatial patterns in groundwater quality between the shallow and deeper aquifers. Nitrate, TDS, and sulfate concentrations were generally highest in the shallow aquifers and progressively decreased in production wells screened in deeper aquifers. While time-concentration plots for most wells showed flat trends over the past 25-30 years, plots for some of the shallower-screened production wells revealed gradually increasing trends over the past 15-20 years. These trends are indicative of the downward migration of higher nitrate/TDS/sulfate groundwater from shallow aquifers to deeper aquifers induced by groundwater pumping. Higher concentrations are associated with anthropogenic return flows (deep percolation of water applied on the land surface), including possibly legacy agricultural return flows and urban return flows (e.g., septic tank discharge and golf course irrigation return). Sources of TDS and nitrate in return flows include nitrogen-based fertilizers and soil amendments used in agriculture and turf management, as well as naturally-occurring salts and nitrate in soils from atmospheric deposition and decomposition of organic litter derived from historical mesquite forests, as identified in the Coachella Salt and Nutrient Plan (MWH, 2015). Increasing TDS/sulfate trends in some wells to the northeast also likely indicate the arrival (as subsurface inflow) of higher-TDS Colorado River water historically recharged at CVWD's Whitewater Groundwater Replenishment Facility (WW-GRF) into the Date Palm PZ.

In contrast, chromium-6 concentrations in the shallow and intermediate aquifers were lower than in deeper production wells. The vertical contrast in chromium-6 concentrations suggests that longer residence times of groundwater in deeper aquifers (where chromium-bearing sediments are present) result in higher chromium-6 concentrations.

GROUNDWATER QUALITY CHARACTERIZATION

Mapping techniques used in the Mid-Valley Recharge Feasibility Study were applied to active and inactive CVWD production wells and monitoring wells to characterize groundwater quality across the Basin. Water well driller's reports and water quality data for a total of 133 CVWD production wells (98 active and 35 inactive) were incorporated (well locations are shown on **Figure 1**). Most of the CVWD production wells are concentrated in the northern half of CVWD's service area with a small subset of wells located in the Lake Cahuilla, Middleton, and Mecca PZs. In addition to CVWD production wells, data were also incorporated for the shallow monitoring well installed for the Mid-Valley Recharge Feasibility Study (MV MW1); the single and nested monitoring wells associated with CVWD's Whitewater and Thomas E. Levy Groundwater Replenishment Facilities (WW-GRF and TEL-GRF), Wastewater Reclamation Plant (WRP) #7 and WRP #10; and the two wells along the north shore of the Salton Sea.

Target Constituents of Concern (COCs)

Eight (8) target COCs were evaluated – chromium-6, nitrate, TDS, sulfate, arsenic, perchlorate, strontium, and historically-detected volatile organic compounds (VOCs). Plan-view maps were prepared for all target COCs. Vertical cross sections were prepared for chromium-6, nitrate, TDS, and sulfate. Cross sections were not prepared for other COCs, because historical sampling is limited to a small subset of wells for strontium, and the number of wells with detections above respective reporting limits is limited for arsenic, perchlorate, and VOCs. Emphasis is placed on chromium-6 and nitrate for identifying suitable areas for future production wells and evaluating the feasibility of modifying existing wells to improve pumped groundwater quality.

Selected Concentration Statistics

With the exception of chromium-6, a single well concentration for each target COC was used on plan-view maps and cross sections (a historical well chromium-6 concentration range is also presented on cross sections, if available). The data were reviewed with CVWD staff to ensure that the selected concentrations were accurate and representative. A description of the selected well concentration for each COC is described below:

- **Chromium-6:** For active CVWD production wells, the current well compliance concentration (based on the most recent sample ranging from 2013 to 2015) was applied. The historical chromium-6 concentration range (based on data from 2000 to 2014) is shown on cross sections. Additionally, depth-discrete chromium-6 concentrations collected at the time of drilling for selected wells are provided. For inactive wells, the most recent chromium-6 sample (which ranged from 2000 to 2014) was applied. For monitoring wells sampled for chromium-6, the most recent sample (which for all applicable wells was collected in 2015) was applied.
- **Nitrate, TDS, sulfate, arsenic, and VOCs:** For active CVWD wells, the most recent sample (which ranged from 2012 to 2015) was applied. For inactive wells, the most recent sample (which typically ranged from 1990 to 2012) was applied. For monitoring wells sampled, the most recent sample (which for all applicable wells was collected in 2014 or 2015) was applied.
- **Perchlorate:** A combination was applied of special sampling in 2004 (which had a lower detection limit of 1.4 micrograms per liter [ug/L]) and the most recent sample (which ranged from 2012 to 2014).
- **Strontium:** The most recent concentration was used in plan-view maps based on data collected from 2013 to 2015 as part of the US EPA Unregulated Contaminant Monitoring Rule 3 (UCMR3) special sampling of selected wells.

Groundwater Quality Maps and Cross Sections

Figures 2 through 9 show the plan-view maps for each target COC. Water quality data are also presented on eleven (11) sets of cross sections (**Figures 10 through 20**). Cross section locations (shown on **Figures 1 through 9**) were chosen to ensure complete coverage of CVWD production wells. The cross section locations also optimize the grouping of wells with similar groundwater quality in the same pressure zones. Screen intervals on the cross section are highlighted the same color as shown in the plan-view maps. The depth of the well cement seal is also shown as a double burgundy red line for each well. The groundwater level shown on each cross section is based on 2015 measurements.

To support the interpretation of groundwater quality trends identified from plan-view maps and cross sections, two additional maps are presented. **Figure 21** shows the current (2015) groundwater levels across the Basin. The figure illustrates the general northwest-to-southeast direction of groundwater flow across the valley (perpendicular to groundwater elevation contours). The only region where groundwater flow deviates is in the southern portion of the Valley PZ, where outcropping bedrock forces groundwater in an easterly direction before entering the La Quinta PZ.

Figure 22 shows the recent average (2014-2015) annual production for CVWD wells. The figure highlights areas of concentrated production, where the downward migration of shallow groundwater (and associated water quality) to deeper aquifers may occur more rapidly. As shown by **Figure 21** and **22**, concentrated production occurs in the Sky Mountain and Valley PZs. But while production has affected groundwater levels locally, it has not caused any major shifts in groundwater flow direction. It is noted that concentrated production has caused groundwater to flow in a more southerly direction in the La Quinta PZ.

Observed groundwater quality patterns are described in more detail below.

Chromium-6

Figure 2 shows a map of well chromium-6 concentrations across the Basin. As shown on the figure, there are 31 active CVWD wells with compliance concentrations that exceed 10.4 ug/L (larger red circles) with another 21 active wells with chromium-6 compliance concentrations ranging from 8.0 to 10.4 ug/L (larger yellow circles).

While it is evident that chromium-6 concentrations are highly variable on a regional-scale, there are distinctive spatial patterns. For example, in areas upgradient of the La Quinta PZ, most of the chromium-impacted wells are located within a 2- to 3-mile wide corridor centered along and oriented parallel with Highway 10, indicating chromium-bearing deposits are associated with alluvial fan deposits extending from the northern hills toward the central axis of the valley. Cross section C-C' (**Figure 12**) includes 12 wells in the Sky Mountain, Valley and Sun City PZs with chromium-6 concentrations ranging from 11 to 20 ug/L. Based on the screen interval depths, it appears that groundwater chromium-6 concentrations are consistently near or above 10 ug/L below -350 feet above mean sea level (ft msl) (or 300 feet below the water table) along the entire section.

Within the Valley, Sky Mountain, and Date Palm PZs, wells located about 1.5 miles southwest of Highway 10 have relatively low chromium-6 concentrations (generally below 3-4 ug/L). Cross section A-A' (**Figure 10**) reveals that from the northwestern edge of the Date Palm PZ to Well 4630-1, chromium-6 concentrations are low (typically less than 4-5 ug/L) for wells screened above -350 ft msl. Wells screened below -350 ft msl have elevated chromium-6 concentrations ranging from 8 to 10 ug/L. Three wells located south/southeast of Well 4630-1 on Cross Section A-A' have higher chromium-6 concentrations (ranging from 12 to 14 ug/L). Examination of the wells screen depths indicates that chromium-bearing sediments also occur at shallower depths (up to -200 ft msl) in the southeastern portion of A-A', continuing into cross section C-C'.

In the La Quinta PZ, Lake Cahuilla PZ, and two wells clusters in the Middleton PZ, well chromium-6 concentrations are near and/or exceed the compliance threshold. As shown on Cross Section G-G' (**Figure 16**), chromium-6 concentrations in the La Quinta PZ are elevated (ranging from 8 to 16 ug/L in CVWD wells) below about -600 to -700 ft msl. However, data for three shallower wells in the northern portion of G-G' (5709-1, 5708-1, and inactive 5712-1), indicate that chromium-6 concentrations in the upper 500 feet of saturated aquifer (above -600 ft msl) in the northern La Quinta PZ are likely to be below 3-4 ug/L.

In the Lake Cahuilla PZ, chromium-bearing sediments appear to be widespread and occur at consistently elevated concentrations (above 10 ug/L) in groundwater approximately 250 feet below the water table (see cross section H-H' on **Figure 17**). No existing CVWD wells are screened in the upper 250 feet of saturated aquifer for determining whether chromium-6 concentrations are significantly lower in the shallow aquifer. The effect of recharge operations at the TEL-GRF is shown by chromium-6 concentrations for wells 6728-1 and 6729-1 in cross section H-H'. It is evident from the non-detected chromium-6 concentration that recharge water has reached down to -500 to -800 ft msl in the vicinity of well 6729-1, but has not fully reached 6728-1.

In the northern Sky Valley Area (**Figure 20**), the data indicate that the compliance threshold is exceeded throughout the saturated water column (from 700 to -200 ft msl).

Nitrate

The nitrate concentration map shown on **Figure 3** indicates that nitrate concentrations are below the primary maximum contaminant level (MCL) of 45 mg/L across much of the Basin. Of the active and inactive CVWD wells with elevated nitrate concentrations (orange wells; greater than 20 mg/L), most are located in the central portion of the Basin within the Valley PZ and western half of the La Quinta PZ, with a few inactive wells scattered in the Sky Mountain/Mission Hills/Sun City PZs. Of 12 CVWD wells that historically exceeded the primary MCL for nitrate, 10 wells are located in the Valley PZ and 2 wells are located in the La Quinta PZ (all 12 wells are currently inactive). There are currently 8 wells with nitrate concentrations between 20 and 45 mg/L; 5 wells are located in the Valley PZ, and 3 wells are in the La Quinta PZ.

Examination of all cross sections indicates that nitrate concentrations generally decrease with increasing well screen depth. However, the combination of historical and current

nitrate loading source, lithology and groundwater flow contribute to variable subsurface nitrate concentrations.

Cross section A-A' (**Figure 10**) indicates that in the Date Palm, Mission Hills, and Sky Mountain PZs, nitrate concentrations are generally very low (3-5 mg/L) at depths exceeding about 200 to 300 feet below the water table (below 0 to -100 ft msl). However, data from MV MW1 indicate that nitrate levels may be much higher in the upper 100 feet of saturated aquifer. More monitoring wells are needed to confirm shallow nitrate concentrations across this area.

Cross Section B-B' (**Figure 11**) reveals that nitrate concentrations east of Rancho Mirage are locally elevated in the Sky Mountain PZ at greater depths exceeding 300 to 400 feet below the water table.

In contrast to the elevated chromium-6 concentrations, well nitrate concentrations on cross section C-C' are very low (generally below 4-5 mg/L). Nitrate loading associated with WRP #7 in the eastern portion of the Sun City PZ is confirmed by the contrast in nitrate concentrations between WRP7 2s/2d (upgradient of effluent discharge ponds) WRP7 3s/3d and 4s/4d (downgradient of the effluent discharge ponds).

To support the interpretation of groundwater quality patterns within the Valley and La Quinta PZs, maps zoomed into the areas covered by cross sections D-D', E-E', F-F', and G-G' were developed for chromium-6 (**Figure 23**) and nitrate (**Figure 24**).

As shown on **Figure 24**, nitrate concentrations above 20 mg/L are typical in Valley PZ wells. However, a pocket of low-nitrate (and low-chromium-6) groundwater exists in the northwestern portion of the Valley PZ (dashed polygon labeled "A") and in the eastern half of the La Quinta PZ (dashed polygon labeled "B"). Examination of the cross sections indicates that groundwater nitrate concentrations at depths exceeding 300 feet below the water table (-350 ft msl) in the northwestern portion of the Valley PZ (dashed polygon A) are around 2 to 10 mg/L. The shape of polygon A indicates that deep aquifer permeability may be higher in this location, thus allowing more subsurface inflow of low-nitrate water from the Sky Mountain PZ to dilute presumably high-nitrate shallow groundwater migrating downward to deeper aquifer zones. Less nitrate loading and/or shallow clay lenses inhibiting downward migration of return flows in this area may also contribute to lower nitrate in deeper aquifers in this area.

Examination of cross section G-G' (**Figure 16**) indicates that in the eastern half of the La Quinta PZ (Area B), low-nitrate groundwater (less than 5 mg/L) occurs at depths exceeding 650 feet below the water table (or about -700 ft msl, as shown on the cross section).

Well nitrate concentrations in the Lake Cahuilla, Middleton, and Mecca PZs are generally low at production zone depths.

In the northern Sky Valley Area (**Figure 20**), nitrate concentrations are relatively low (4-8 mg/L).

TDS and Sulfate

Well TDS and sulfate concentrations across the Basin (**Figures 4 and 5**) are generally below the recommended secondary MCL range of 500 to 1,000 mg/L for TDS and 250 mg/L for sulfate. In general, TDS and sulfate concentrations have increased relative to native groundwater in the same areas and at the same depths where nitrate concentrations have increased, indicating that the sources (i.e., anthropogenic return flows) and pathways for nitrate, TDS, and sulfate are similar. Previous evaluations of CVWD and private wells also indicate that elevated TDS and sulfate concentrations are found naturally along the San Andreas fault zone north of Highway 10 (in and along the boundaries between the Mission Springs and Desert Hot Springs subbasins), in portions of the Thousand Palms and Oasis subareas, and in perched groundwater in the eastern portion of Coachella Valley.

TDS and sulfate concentrations have increased in areas downgradient of CVWD recharge operations using Colorado River water (e.g., downgradient of the WW-GRF and TEL-GRF). For example, TDS and sulfate concentrations in the Date Palm PZ support modeling results confirming that Colorado River water recharged at the WW-GRF in the 1970's has recently entered the Date Palm PZ as subsurface inflow. Simulated recharge flowpaths are shown on **Figure 28**, and further discussion is provided in the modeling section of this TM.

Arsenic

Figure 6 shows well arsenic concentrations across the Basin. The figure shows that arsenic-bearing sediments are generally limited to the southern pressure zones, including Lake Cahuilla, Middleton, and Mecca. Arsenic concentrations in a total of 4 active wells in the Middleton and Mecca PZs exceed the primary MCL of 10 ug/L (ranging from 23 to 32 ug/L). Additionally, 4 other active wells have detectable arsenic concentrations below 10 ug/L (ranging from 2.3 to 7.4 ug/L). There are also 4 inactive wells in the Mission Hills and Valley PZs with relatively low-level arsenic detections (0.5 to 4.1 ug/L).

Perchlorate

Figure 7 shows well perchlorate concentrations across the Basin. As shown on the map, perchlorate has been detected in the nested monitoring wells associated with WW-GRF (ranging from 0.53 to 0.97 ug/L in 2015). Perchlorate has only been detected (at 5.4 ug/L) in one CVWD production well (inactive well 6721-1 in the Lake Cahuilla PZ). The source of perchlorate in WW-GRF monitoring wells is hypothesized to be historical Colorado River water. The perchlorate source in the one inactive well is unknown.

Volatile Organic Compounds (VOCs)

Figure 8 shows well VOC concentrations across the Basin. As shown on the figure, wells with detectable VOC concentrations are located primarily in the Valley PZ. Currently, there are only two active wells with detectable historical VOCs –

- Well 5669-1 - 0.042 ug/L of 1,2-dibromo-3-chloropropane [DBCP] in June 2015
- Well 5667-1 - 1.1 ug/L dimethyl tetrachloroterephthalate [DCPA]) and 0.52 ug/L tetrachloroethylene (PCE)

DBCP, DCPA, and/or Tetrachloroethylene (PCE) have been detected in 10 inactive CVWD wells in the Valley and La Quinta PZs.

It is noted that the three favorable groundwater quality areas/depth zones identified in the Valley and La Quinta PZs (**Figures 23 and 24**) do not appear to be impacted by VOC contamination. VOC detections southwest of Area A also have elevated nitrate, confirming the downward migration of shallow groundwater in this area. While Well 6702-1 in the southern portion of the La Quinta PZ (Area B) has 0.07 ug/L DBCP, more than likely the contaminant pathway is via the upper screen (see cross section G-G' on **Figure 16**), which is above the recommended -500 to -700 ft msl depth zone.

Strontium

Strontium is not currently regulated but has a health reference level of 1,500 ug/L. **Figure 9** shows well strontium concentrations for 28 active and 2 inactive CVWD wells sampled as part of the UCMR3 special sampling events. With the exception of one well (6729-1), which has a strontium concentration of 2,000 ug/L, measured well concentrations are all below the health reference level, ranging from 150 up to 870 ug/L. As discussed previously, the effect of recharge operations at the TEL-GRF is shown by chromium-6 concentrations for Well 6729-1 in cross section H-H'. The higher strontium concentration in this well also reflects the arrival of Colorado River water, although the concentration is slightly higher than that of Colorado River water. Review of historical water quality data indicates that strontium concentrations in Colorado River water have averaged about 1,100 ug/L over the past 20 years, with a peak value of 1,300 ug/L (below the health reference level).

EVALUATION OF NON-TREATMENT COMPLIANCE STRATEGIES

Installation of New Production Wells to Improve Pumped Groundwater Quality

The spatial distribution of groundwater quality across the Basin indicates that CVWD could install new replacement wells in several locations within its service area to improve overall pumped groundwater quality. Regions and depths with favorable water quality are provided below.

- In the Date Palm, Mission Hills, and Sky Mountain PZs, new production wells should be located more than 1.5 miles southwest of Highway 10 if possible and perforated about 200 feet below the water table (0 ft msl) to avoid shallow zones of potentially elevated nitrate concentrations and above about 800 feet below the water table (-600 ft msl) to avoid potentially elevated chromium-6 concentrations. Screen intervals depths may be increased to 1,200 feet below the water table (to -1,000 ft msl) with increasing distance away from Highway 10 to the southeast, as chromium-6 concentrations appear to remain low with increasing depth more than 1.5 miles southwest of Highway 10 in this area.
- In the Valley PZ, new production wells should be drilled more than about 1.25 miles southwest from Highway 10 to avoid elevated chromium-6 concentrations. To avoid elevated nitrate, wells should be drilled in the identified area with favorable water quality (dashed polygon labeled “A” on **Figures 23** and **24**) and screened at least 300 feet below the water table (-350 ft msl).
- In the La Quinta PZ, wells could be drilled in the identified area of favorable water quality (dashed area labeled “B” on **Figures 23** and **24**). Wells should be screened at least 400 feet below the water table (-500 ft msl) to avoid elevated nitrate, and no deeper than 600 feet below the water table (-700 ft msl) to avoid elevated chromium-6.

Feasibility of Existing Well Modifications to Improve Pumped Groundwater Quality

The spatial distribution of groundwater quality across the Basin indicates that modification of existing well screens to avoid pumping from zones with elevated chromium-6 is not a feasible compliance strategy. For example, cross section C-C' (which includes 12 non-compliant wells with respect to chromium-6) shows that chromium-6 concentrations are relatively uniform and exceed 10.4 ug/L below approximately -500 ft msl. Because only small portions of the well screen in each of the non-compliant wells are above -500 ft msl, abandonment of the well screens below -500 ft msl would drastically reduce the production capacity of the well and is thus not a viable option. Similarly, existing non-compliant wells in the Lake Cahuilla PZ cannot be modified to avoid elevated chromium-6, which appears to occur uniformly up to about 250 feet below the water table (-400 ft msl).

Modification of existing well screens to avoid pumping from zones with elevated nitrate, while potentially feasible, does not appear to be a reliable feasible compliance strategy for most wells. For example, most nitrate-impacted wells in the Valley and La Quinta PZs have continuous screens across from predominantly coarse-grained sediments. There are perhaps two active wells that could be modified to inhibit entry of groundwater from shallow screens: 5656-1 and 5670-1 (see **Figure 13**). These two wells have multiple screens with the upper screen or set of screens located above -450 ft msl and a lowest screen below -500 ft msl. The cross section indicates that nitrate concentrations opposite the lower screen may be significantly lower than the composite nitrate concentration pumped from each well. No other wells appear to be suitable for well modification to reduce pumped nitrate concentrations.

Given the limited opportunities for modifying existing wells to improve pumped groundwater quality without significantly decreasing well production capacity, the installation of new wells in areas with favorable water quality appears to be a viable compliance strategy that can complement/supplement new water treatment facilities.

Groundwater Flow Modeling of Date Palm Replacement Wells

The existing regional MODFLOW model of the Coachella Valley (Fogg, et al., 2000) was modified and used to evaluate the feasibility and predict the potential impacts of 25,000 AFY of additional groundwater production in the Date Palm PZ to potentially replace the 27 wells impacted by chromium-6 throughout the valley. Groundwater flow and drawdown over time in the deep aquifer zone was simulated with and without the additional production. Groundwater flowpaths from the WW-GRF to the Date Palm area were also simulated to determine when water quality changes in the Date Palm area may occur as a result of inflow of Colorado River water recharged at the WW-GRF.

The regional model historical simulation period is from 1936 through 2014, using annual stress periods. Todd imported the regional model to the Groundwater Modeling System™ (GMS) and performed a model grid translation/rotation to register the model from its previous local coordinate system to the California State Plain NAD83 coordinate system. This allows the model to be coupled with a Geographic Information System (GIS), such that input data from a GIS can be imported to the model, and model simulation results can be exported back to GIS.

Date Palm Production Simulations

The first step in the Date Palm modeling analysis was the simulation of transient flow under baseline historical conditions. Simulated deep aquifer groundwater elevations were plotted and reviewed. **Figure 25** shows a hydrograph of observed and simulated groundwater elevations in CVWD Well 4567-1, located in the central portion of the Date Palm PZ. The hydrograph shows that the simulated baseline groundwater elevation for the well is constant over time between January 2003 and December 2014 at an elevation of approximately 90 ft msl. The simulated groundwater elevation is constant over time because local boundary conditions, annual recharge, and pumping rates are held uniform in the regional model for this period. Note that the regional model is not well-calibrated at this

location, given that observed groundwater elevations in Well 4567-1 between January 2003 and December 2014 ranged from around 130 to 160 ft msl, or around 40 to 70 feet higher than the model-simulated groundwater elevation. Notwithstanding this discrepancy, the regional model was used as a predictive tool to assess relative drawdown in the local area with and without the additional production.

For the additional production simulation, 25,000 AFY of additional production was simulated at 17 hypothetical new production wells distributed across the Date Palm pressure area, west of Highway 10. Note that larger wells than the current 27 wells were assumed, reaching the same total production volume. **Figure 26** shows the locations of the 17 hypothetical wells, along with existing CVWD production wells. The hypothetical new wells were located away from known private properties, such as golf courses, although some wells were sited in residential neighborhoods similar to some existing District wells. A closer examination would be necessary in the future to identify specific sites owned by the District or available for purchase. The additional production pumping was simulated using the existing regional model for the most-recent six-year period, corresponding to January 2009 through December 2014 conditions. The regional MODFLOW model well input file was modified to include production at the 17 new wells.

Predicted groundwater elevations and drawdown in the local area with and without the additional production are shown on **Figures 25, 26, and 27**. On the hydrograph for Well 4567-1 (**Figure 25**), the simulated water level in the well begins to decline in January 2009, reflecting the drawdown caused by the additional local pumping. Water levels continue to decline over the simulated 6 year additional pumping period, reaching a simulated groundwater elevation of approximately 62 feet, or around 28 feet of drawdown at the Well 4567-1 location. The simulated elevation continues to decline throughout the pumping simulation, indicating that the simulated groundwater flow system had not reached a state of equilibrium, and additional drawdown would occur if pumping simulation were continued. Actual future pumping and recharge operations are not known; presumably some pumping offsets (in the form of reduced pumping further downgradient in the valley and/or additional recharge) could result in different drawdown patterns and durations than simulated with the predictive model.

Figures 26 and 27 show the simulated groundwater elevations and net drawdown contours (relative to the baseline model) in December 2014 after 6 years of additional production. The simulated groundwater elevations (**Figure 26**) indicate that groundwater flow down the valley (from northwest to southeast) is maintained, similar to current conditions, but with lower overall groundwater elevations. The simulated drawdown after six years of additional pumping (**Figure 27**) across the western portion of the Date Palm pressure area is around 20 to 29 feet. The drawdown contours reveal that the maximum drawdown after six years of pumping occurs within and adjacent to the hypothetical well locations, with the degree of drawdown decreasing away from the new wells.

The results of the predictive simulations indicate that increased production up to 25,000 AFY in the Date Palm PZ is feasible. Water level drawdown after 6 years of sustained pumping at

25,000 AFY is estimated to be on the order of about 30 feet. While additional drawdown may occur with sustained pumping at 25,000 AFY, the operational yield of existing District production wells in the vicinity should not be impacted. While beyond the scope of this study, locations and screen interval depths of non-CVWD production wells within the Date Palm PZ should be inventoried to assess potential negative impacts of increased drawdown on private pumpers. Additionally, the degree to which recharge at the WW-GRF and redistribution of CVWD and non-CVWD pumping may influence future groundwater levels in the Date Palm PZ can and should be evaluated using the regional MODFLOW model.

Travel Times from Whitewater Recharge Facilities to Date Palm

Groundwater flowpaths from the WW-GRF were also simulated to determine when water quality changes in the Date Palm PZ may occur. Forward flowpaths from the WW-GRF were simulated with MODPATH. MODPATH uses the three-dimensional flow solution from MODFLOW and tracks particles (flowpaths) from the recharge site to downgradient areas. Flow velocities and travel times are also calculated. Note that estimated flow velocities and travel times from the ponds to the production wells are dependent on aquifer hydraulic properties including hydraulic conductivity and effective porosity. For this analysis, an effective porosity of 20% was assumed for all model layers. The regional model baseline solution (without additional Date Palm production) was used, with flowpaths at the WW-GRF beginning in January 1975, around the time when historical recharge operations were initiated.

Figure 28 shows the simulated forward flowpaths from the WW-GRF. The flowpaths reflect 40 years of recharge water migration in the subsurface from 1975 through 2014. As illustrated by the distribution and endpoints of the flowpaths, travel times from the Whitewater recharge site to the Date Palm PZ supply wells are around 40 years, indicating Colorado River water recharged at the WW-GRF beginning in the 1970's have begun to enter the Date Palm PZ. Note that the flowpath lines shown on **Figure 28** are 2-dimensional projections of the simulated 3-dimensional curvilinear paths calculated within the three-layer model. The recharge flowpaths extend through model Layers 2 through 4, with a portion of the recharged water flowing vertically into the production zones of the deeper supply wells. This suggests that groundwater quality changes in Date Palm area production wells are occurring or will occur in the near future as recharged Colorado River water mixes with native groundwater. Observed increasing trends in TDS and sulfate in production wells in the northwestern portion of the Date Palm PZ (see Cross Section A-A' on Figure 10) confirm the simulated flowpath and travel time results.

CONCLUSIONS

Based on the groundwater quality characterization and modeling analysis, the following conclusions can be made:

Groundwater Quality Conditions

- Groundwater quality in CVWD production wells are variably influenced by shallow groundwater migrating downward as a result of pumping from deeper aquifers.
- Shallow groundwater generally has elevated nitrate, TDS, and sulfate as it receives anthropogenic (agricultural and urban) return flows. Sources of TDS, sulfate, and nitrate in return flows include nitrogen-based fertilizers and soil amendments used in agriculture and turf management, as well as naturally-occurring salts and nitrate in soils from atmospheric deposition and decomposition of organic litter derived from historical mesquite forests.
- The spatial distribution of chromium-impacted wells is dependent on the horizontal and vertical distribution of chromium-bearing sediments and residence time (age) of groundwater.
 - In areas upgradient of the La Quinta PZ, chromium-impacted wells are located within a 2- to 3-mile wide corridor centered along and oriented parallel with Highway 10.
 - Chromium-bearing sediments are widespread across the La Quinta, Lake Cahuilla, and Middleton PZs. Chromium-6 concentrations are consistently elevated in groundwater (above 10 ug/L) approximately 250 feet below the water table.

Evaluation of Non-Treatment Compliance Strategies

- Modification of existing wells does not appear to be a technically feasible compliance strategy for improving pumped groundwater quality with respect to chromium-6 and nitrate.
 - Chromium-6 concentrations in the saturated aquifer column are relatively uniform in active CVWD wells with chromium concentrations above 10.4 ug/L. Further, selective abandonment of well screens to improve chromium-6 concentrations in impacted wells would also significantly reduce the well's production capacity and is thus not a viable compliance strategy.
- Wells impacted by nitrate are generally screened shallower. Opportunities for selective screening are limited to two wells in the Valley PZ (5656-1 and 5670-1). Over the long-term, nitrate will continue to migrate downward into the well's deeper screen.

- The installation of new wells in areas with favorable water quality appears to be a more viable compliance strategy that can complement/supplement new water treatment facilities. CVWD could install new wells in several locations within its service area to improve overall pumped groundwater quality. Regions with favorable water quality include:
 - Areas at least 1.5 miles southwest of Highway 10 in the Date Palm, Mission Hills, and Sky Mountain PZs (between 0 and -600 feet near the 1.5 mile boundary from Highway 10 to -1,000 feet with increasing distance from Highway 10.
 - A localized pocket below -350 ft msl in the northwest portion of the Valley PZ.
 - The western half of the La Quinta PZ between -500 and -700 ft msl.
- The Date Palm PZ could accommodate increased production to replace downgradient production wells impacted by chromium-6.
 - Predictive simulations indicate that increased production up to 25,000 AFY in the Date Palm PZ is feasible. Water level drawdown after 6 years of sustained pumping at 25,000 AFY is estimated to be on the order of about 30 feet.
 - The operational yield of existing District production wells in the vicinity should not be impacted. Impacts to non-CVWD production wells within the Date Palm PZ would need to be assessed to determine impacts of increased drawdown on private pumpers.
 - Colorado River water historically recharged at the WW-GRF has reached the northwestern portion of the Date Palm PZ.

RECOMMENDATIONS

- While the favorable water quality areas presented in this TM have been characterized based on the evaluation of a relatively dense network of wells, additional evaluation of shallow and private domestic well pumping and water quality data is recommended to refine the selection of future well sites. Possible installation of new monitoring or test production wells may also be warranted.
- The degree to which recharge at the WW-GRF and re-distribution of CVWD and non-CVWD pumping may influence future groundwater levels in the Date Palm PZ can and should be evaluated using the regional MODFLOW model.
- Locations and screen interval depths of non-CVWD production wells within the Date Palm PZ should be inventoried to assess potential negative impacts of increased drawdown in this area on private pumpers.

REFERENCES

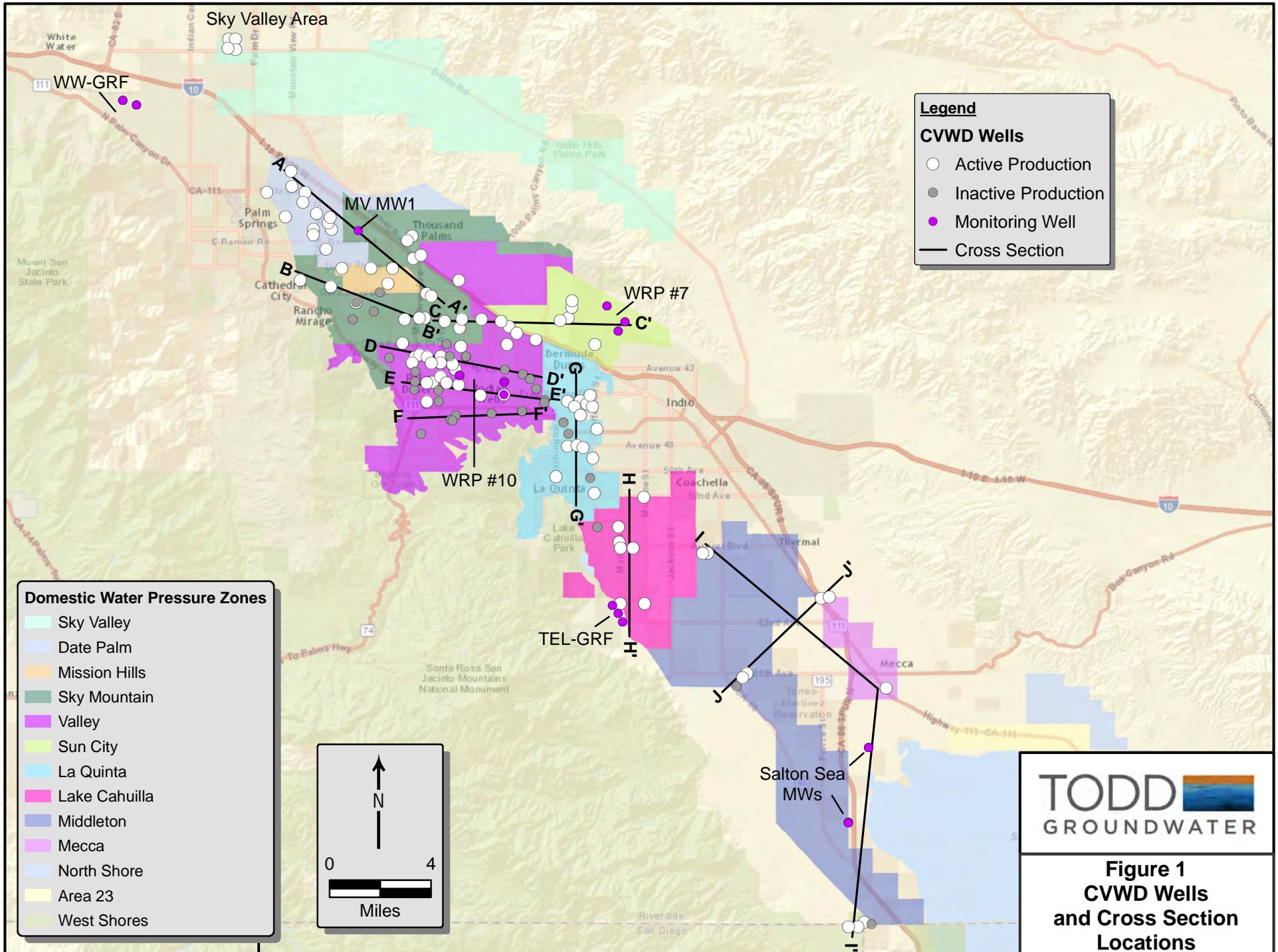
Fogg, G.E., G.T. O'Neill, E.M. LaBolle, and D.J. Ringel (2000) Groundwater Flow Model of Coachella Valley, California: An Overview.

MWH (2015) Draft Salt and Nutrient Management Plan for the Coachella Valley. Prepared for Coachella Valley Water District, Desert Water Agency, and Indio Water Authority, April 2015.

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List of Figures

| | |
|-----------|--|
| Figure 1 | CVWD Wells and Cross Section Locations |
| Figure 2 | Chromium-6 Concentration Map |
| Figure 3 | Nitrate Concentration Map |
| Figure 4 | TDS Concentration Map |
| Figure 5 | Sulfate Concentration Map |
| Figure 6 | Arsenic Concentration Map |
| Figure 7 | Perchlorate Concentration Map |
| Figure 8 | Volatile Organic Compounds (VOCs) Concentration Map |
| Figure 9 | Strontium Concentration Map |
| Figure 10 | Cross Section A-A' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 11 | Cross Section B-B' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 12 | Cross Section C-C' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 13 | Cross Section D-D' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 14 | Cross Section E-E' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 15 | Cross Section F-F' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 16 | Cross Section G-G' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 17 | Cross Section H-H' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 18 | Cross Section I-I' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 19 | Cross Section J-J' with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 20 | Cross Section Sky Mountain with TDS, Sulfate, Nitrate-NO ₃ , and Chromium-6 |
| Figure 21 | 2015 Groundwater Levels |
| Figure 22 | CVWD Average Annual Well Production (2013-2014) |
| Figure 23 | Chromium-6 Valley and La Quinta Pressure Zones |
| Figure 24 | Nitrate Valley and La Quinta Pressure Zones |
| Figure 25 | Observed and Simulated Groundwater Levels CVWD Well 4567-1 |
| Figure 26 | Simulated Groundwater Levels with Additional Date Palm Production |
| Figure 27 | Simulated Net Drawdown with Additional Date Palm Production |
| Figure 28 | Recharge Flowpaths from Whitewater-GRF (1974-2014) |

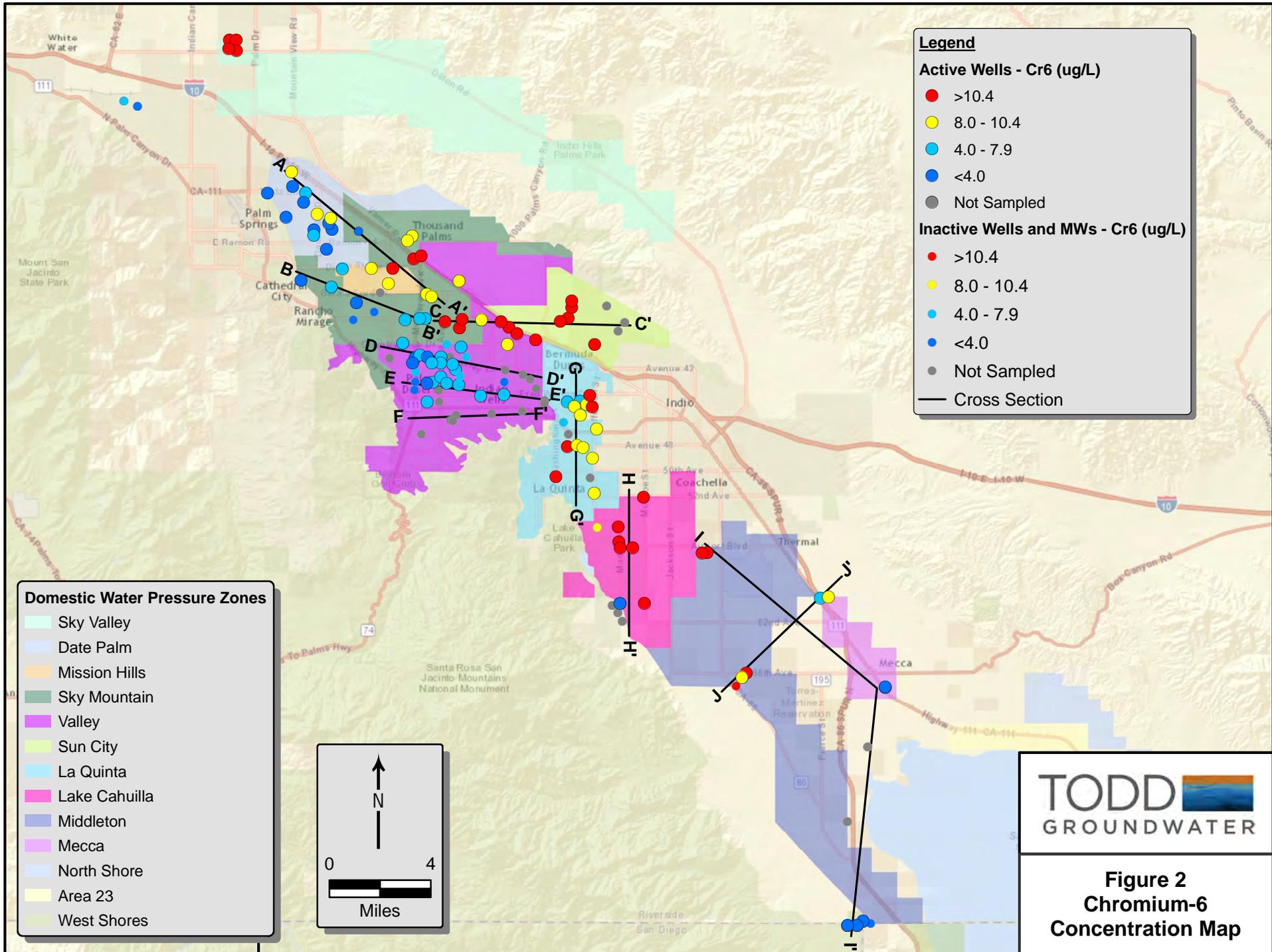


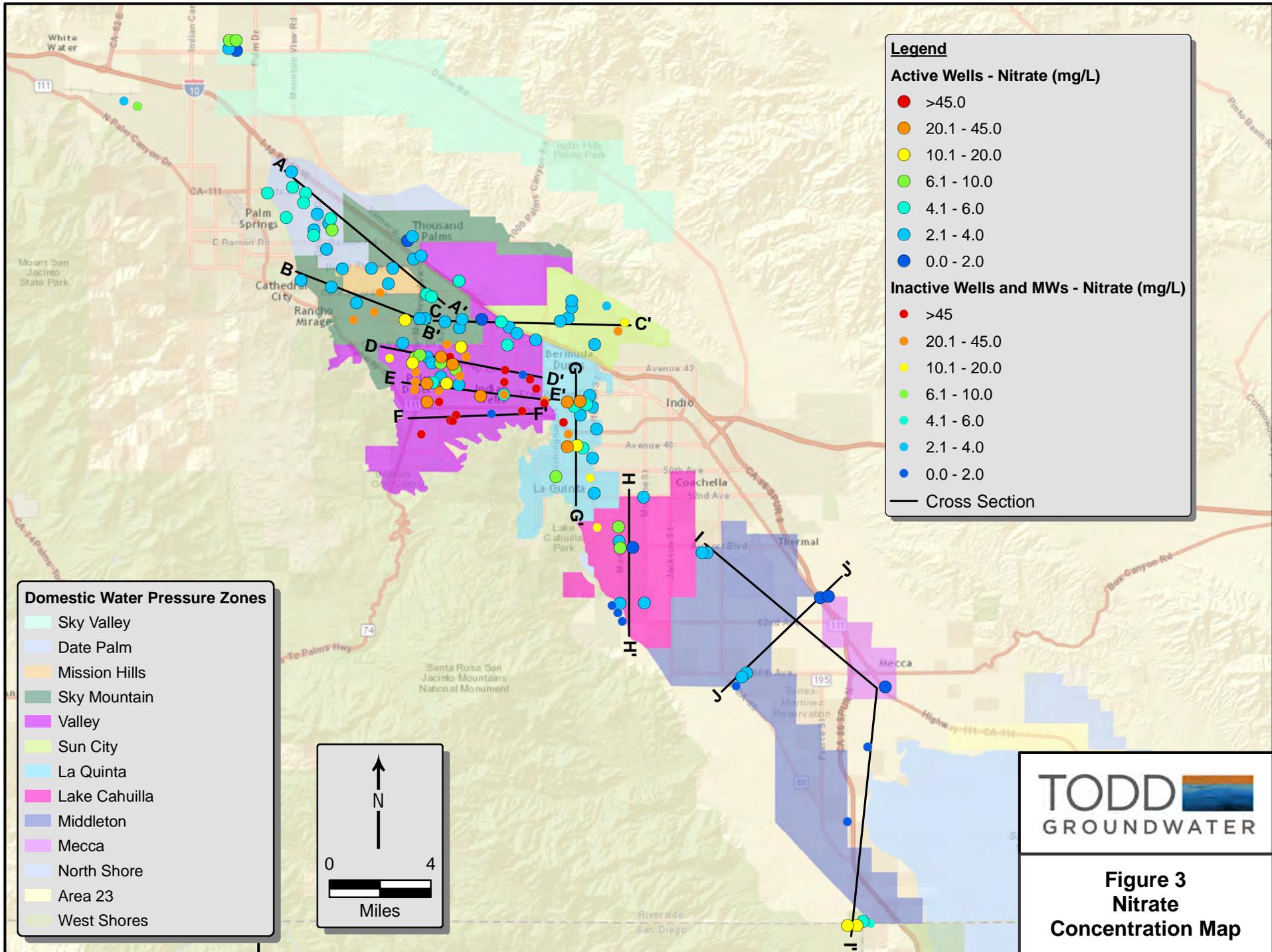
- Domestic Water Pressure Zones**
- Sky Valley
 - Date Palm
 - Mission Hills
 - Sky Mountain
 - Valley
 - Sun City
 - La Quinta
 - Lake Cahuilla
 - Middleton
 - Mecca
 - North Shore
 - Area 23
 - West Shores

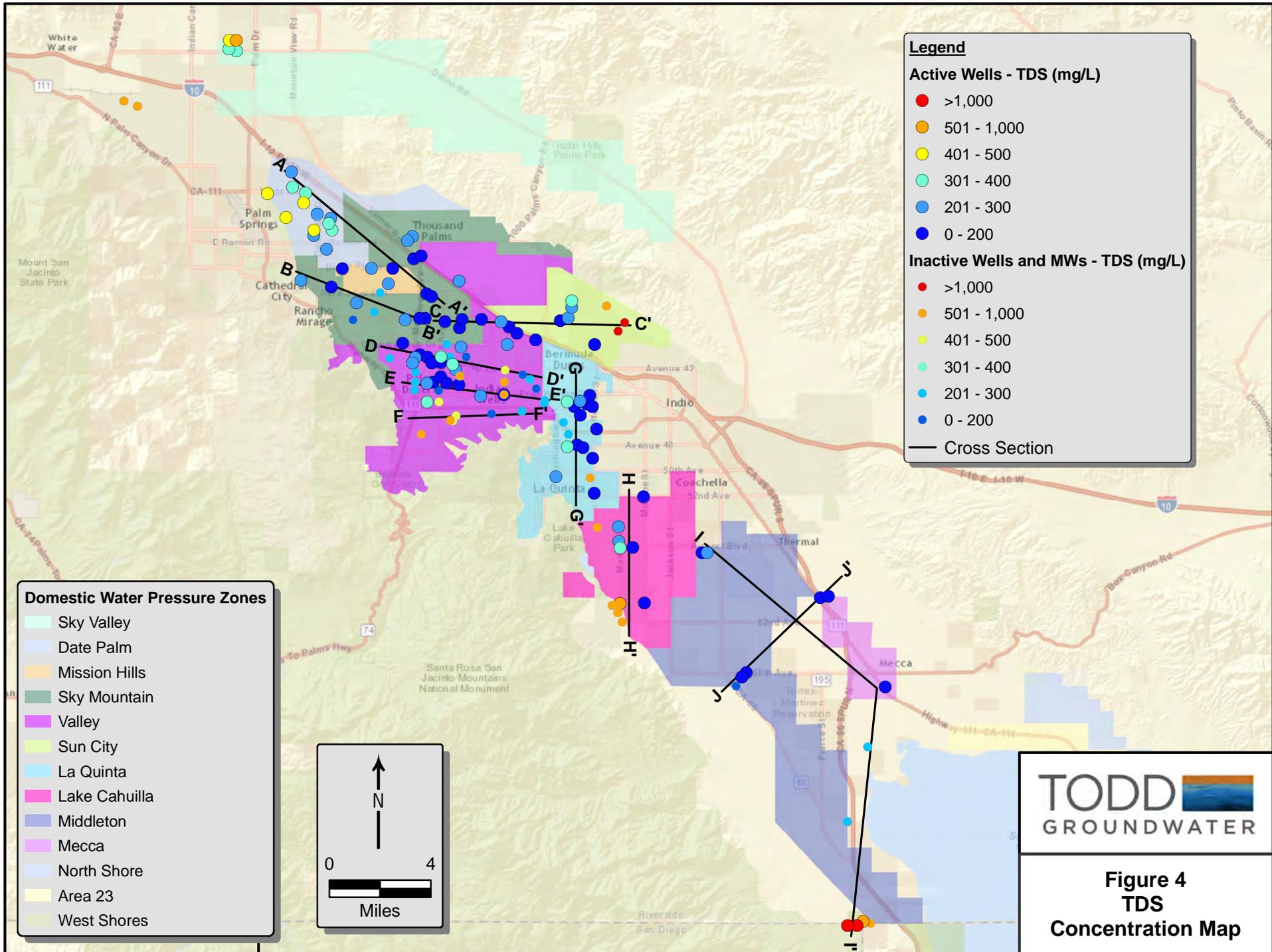
- Legend**
- CVWD Wells**
- Active Production
 - Inactive Production
 - Monitoring Well
 - Cross Section

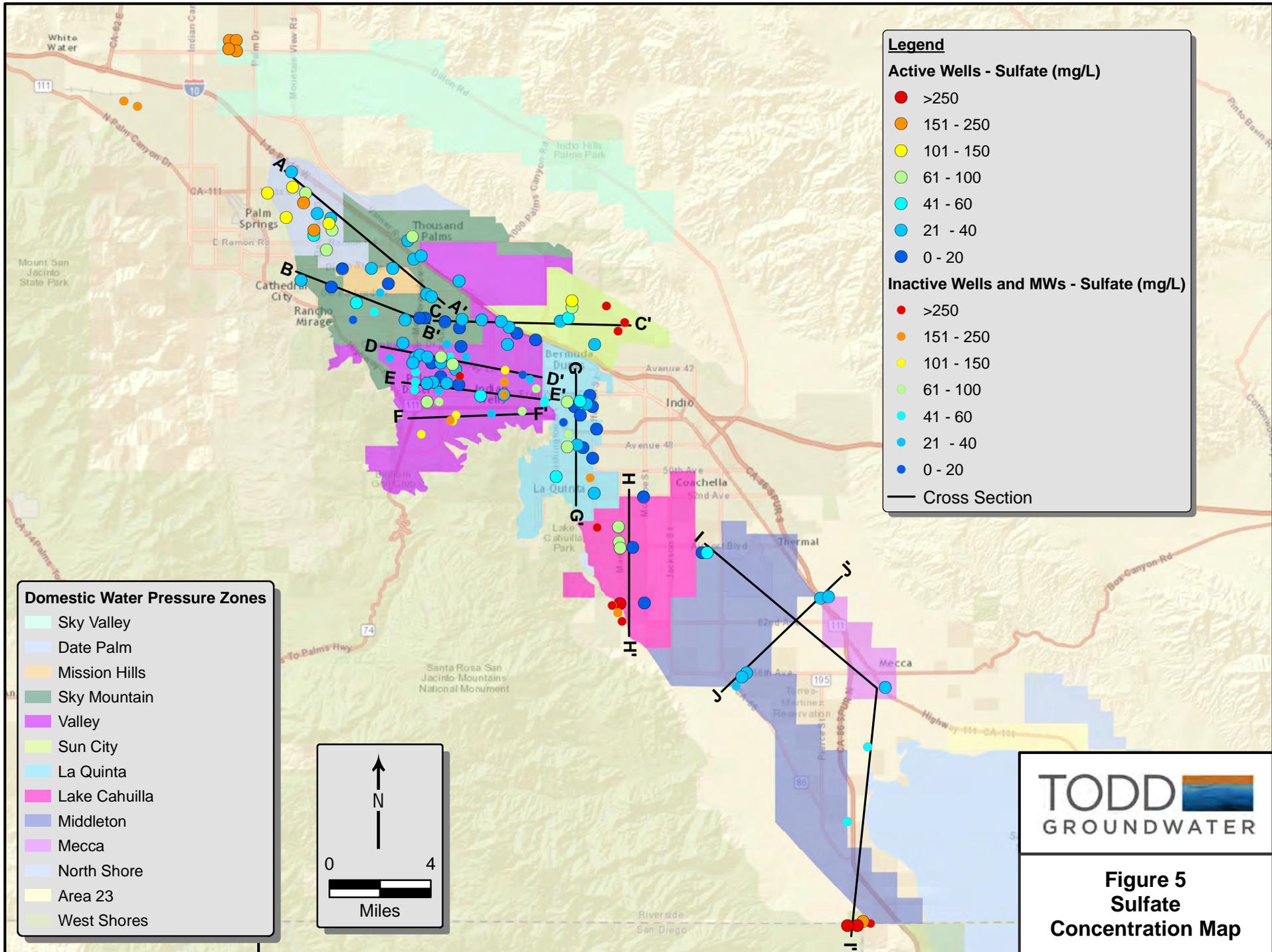


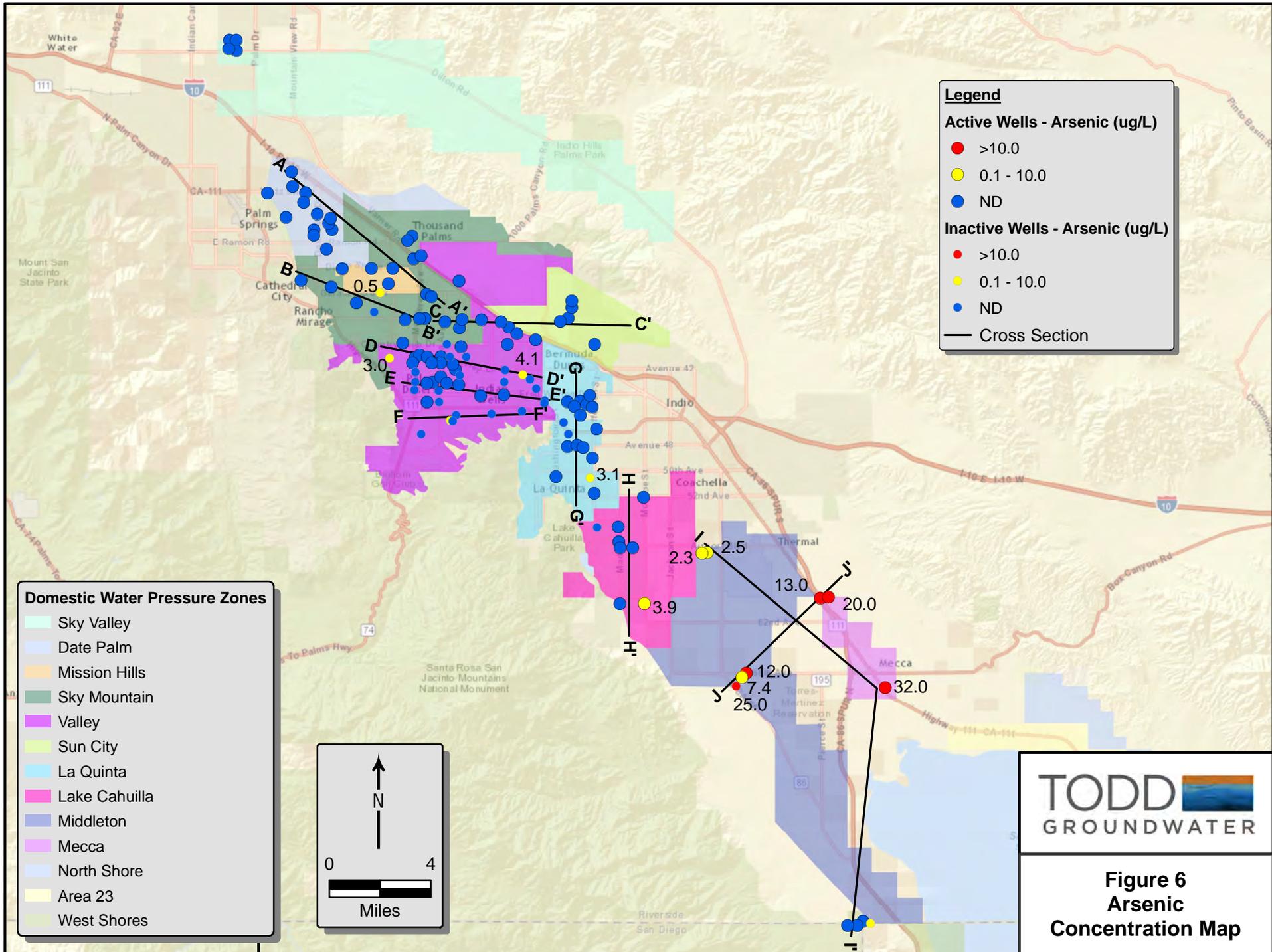
**Figure 1
CVWD Wells
and Cross Section
Locations**





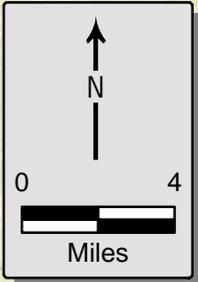




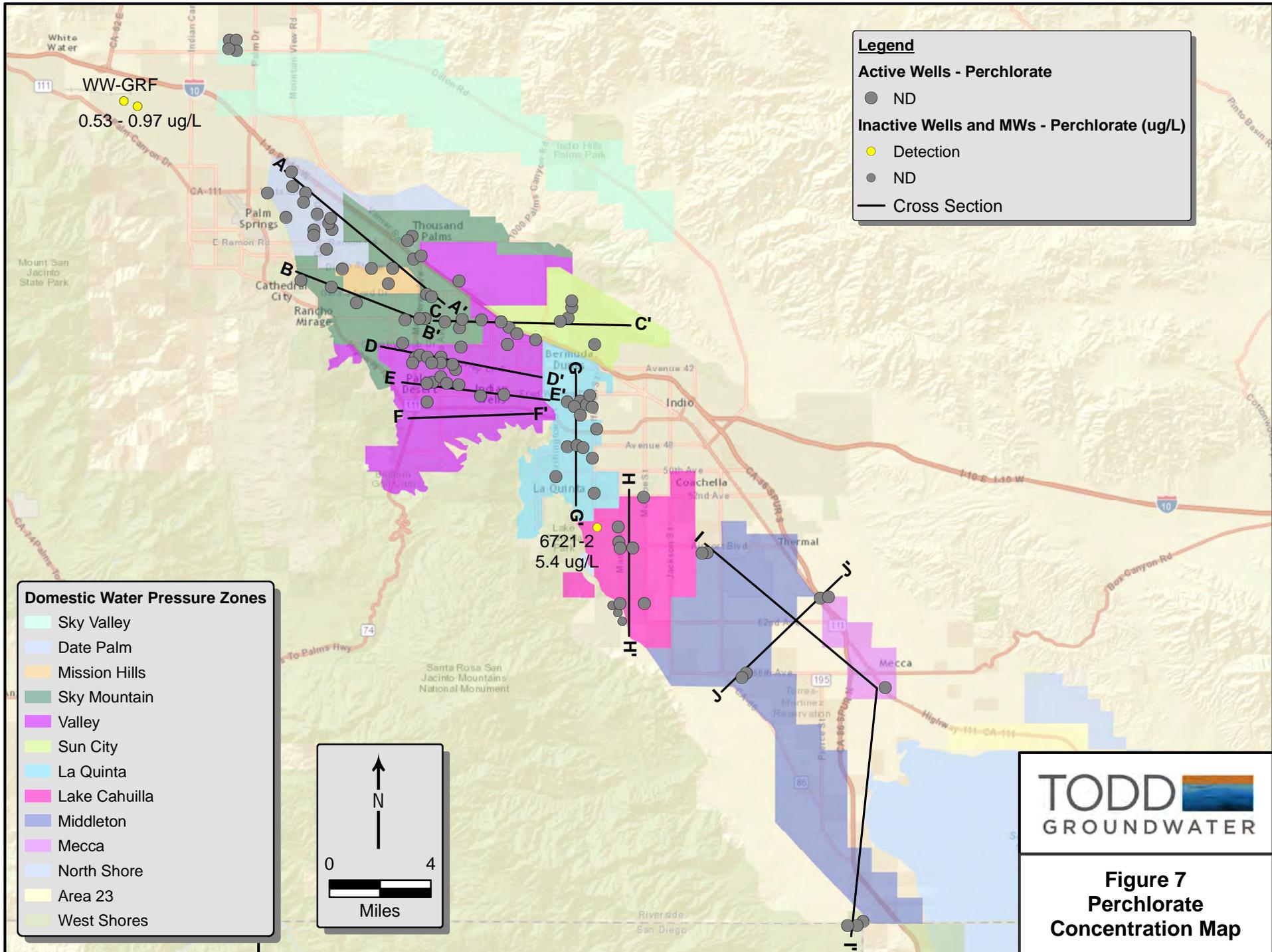


- Domestic Water Pressure Zones**
- Sky Valley
 - Date Palm
 - Mission Hills
 - Sky Mountain
 - Valley
 - Sun City
 - La Quinta
 - Lake Cahuilla
 - Middleton
 - Mecca
 - North Shore
 - Area 23
 - West Shores

- Legend**
- Active Wells - Arsenic (ug/L)**
- >10.0
 - 0.1 - 10.0
 - ND
- Inactive Wells - Arsenic (ug/L)**
- >10.0
 - 0.1 - 10.0
 - ND
- Cross Section



**Figure 6
Arsenic
Concentration Map**



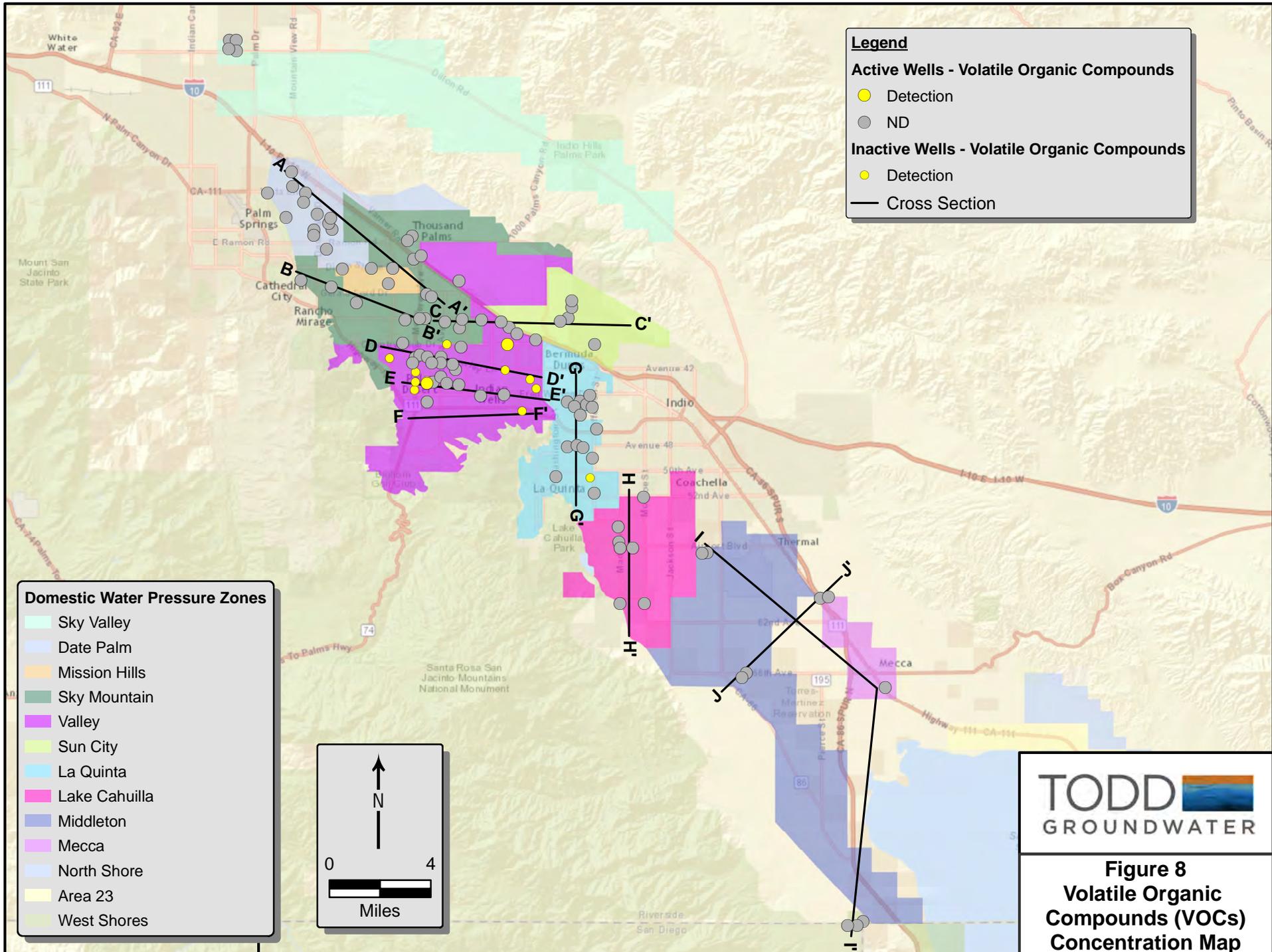
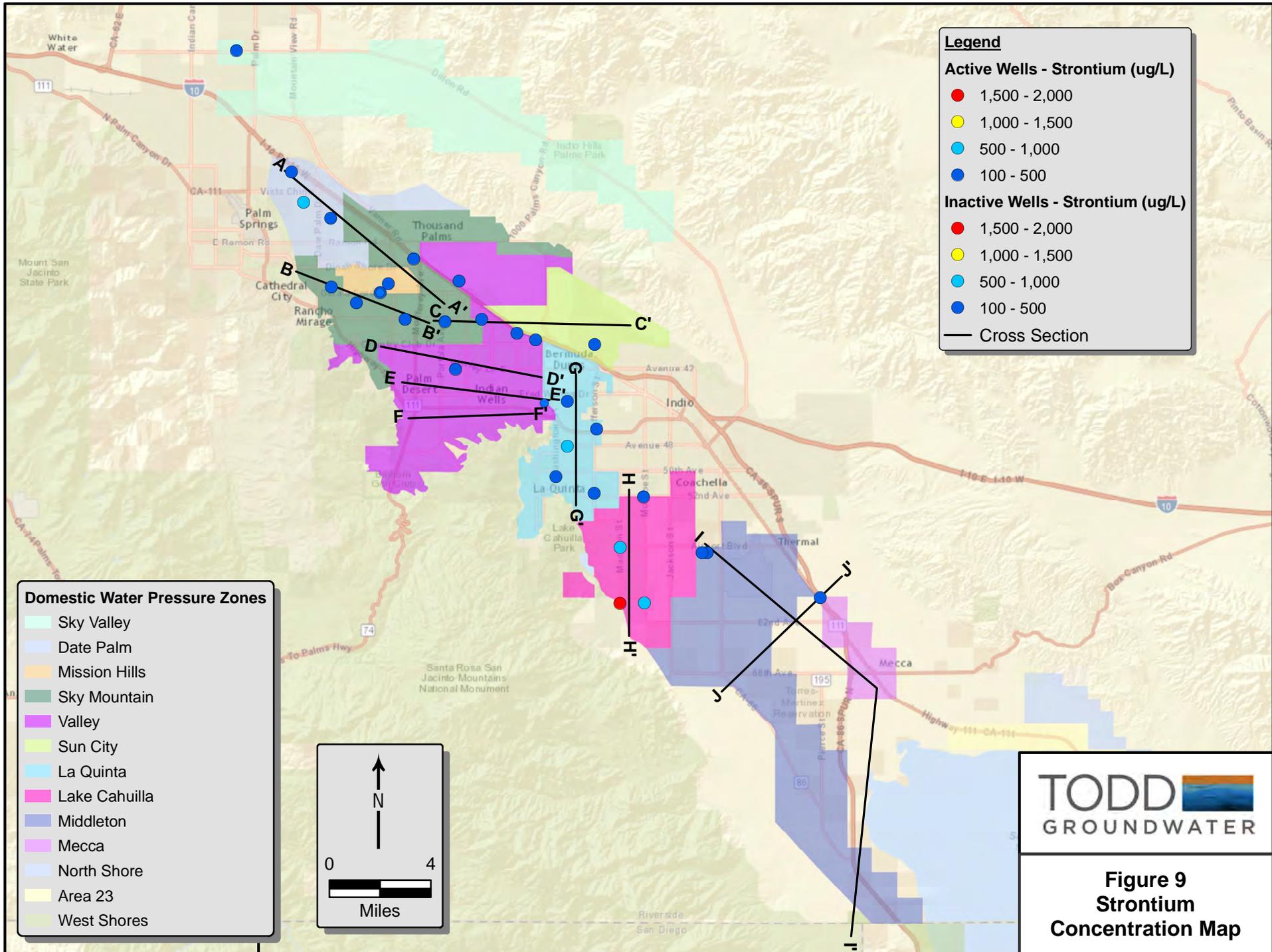
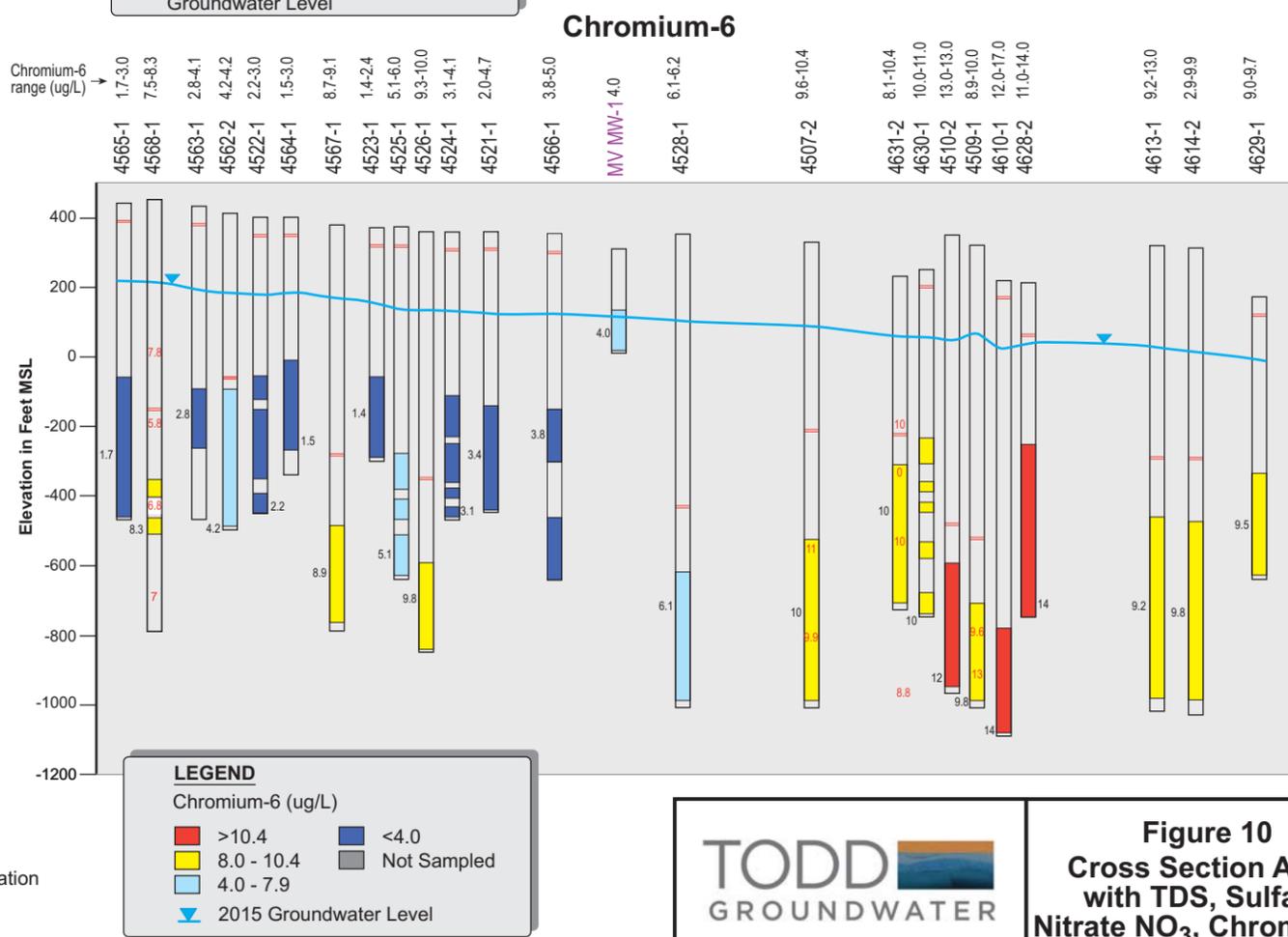
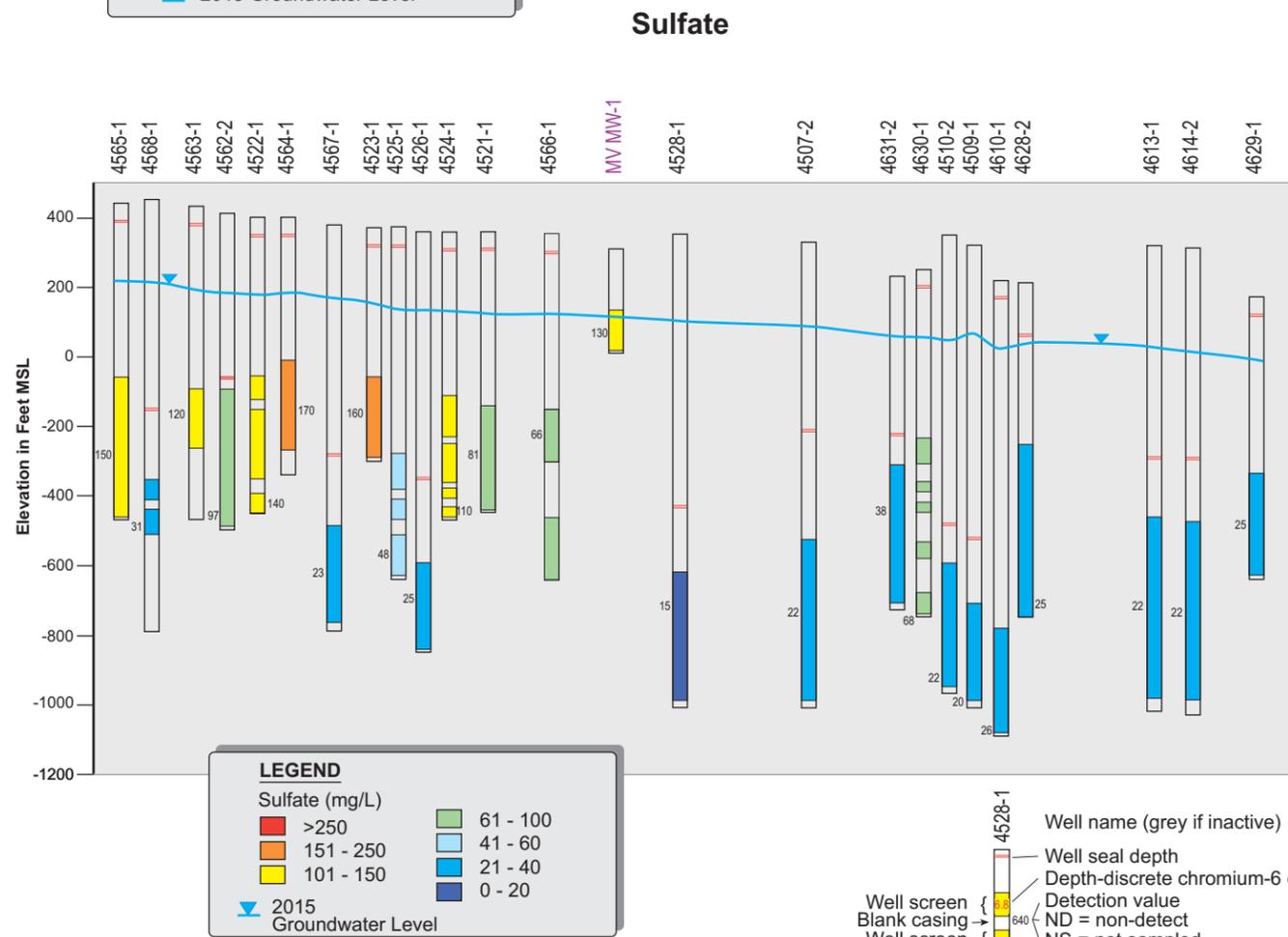
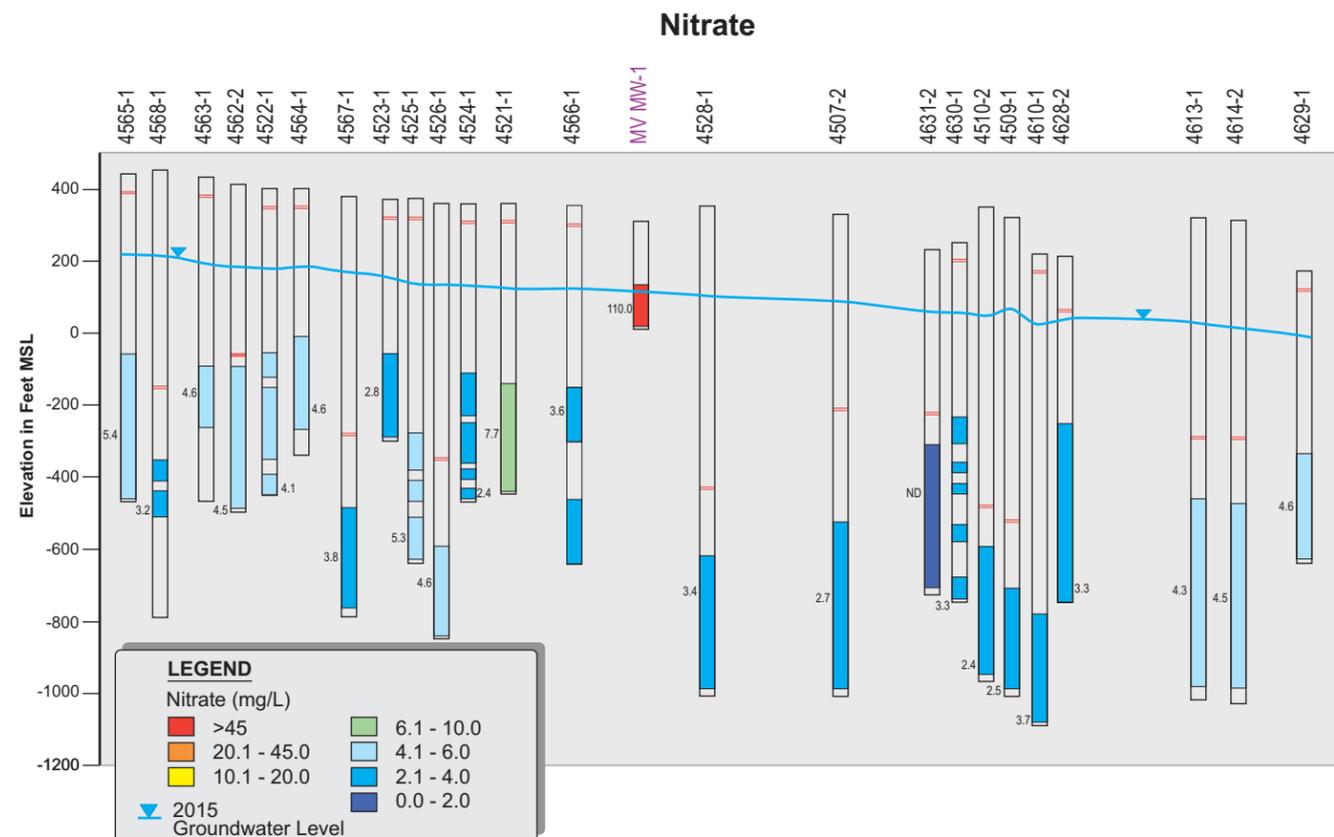
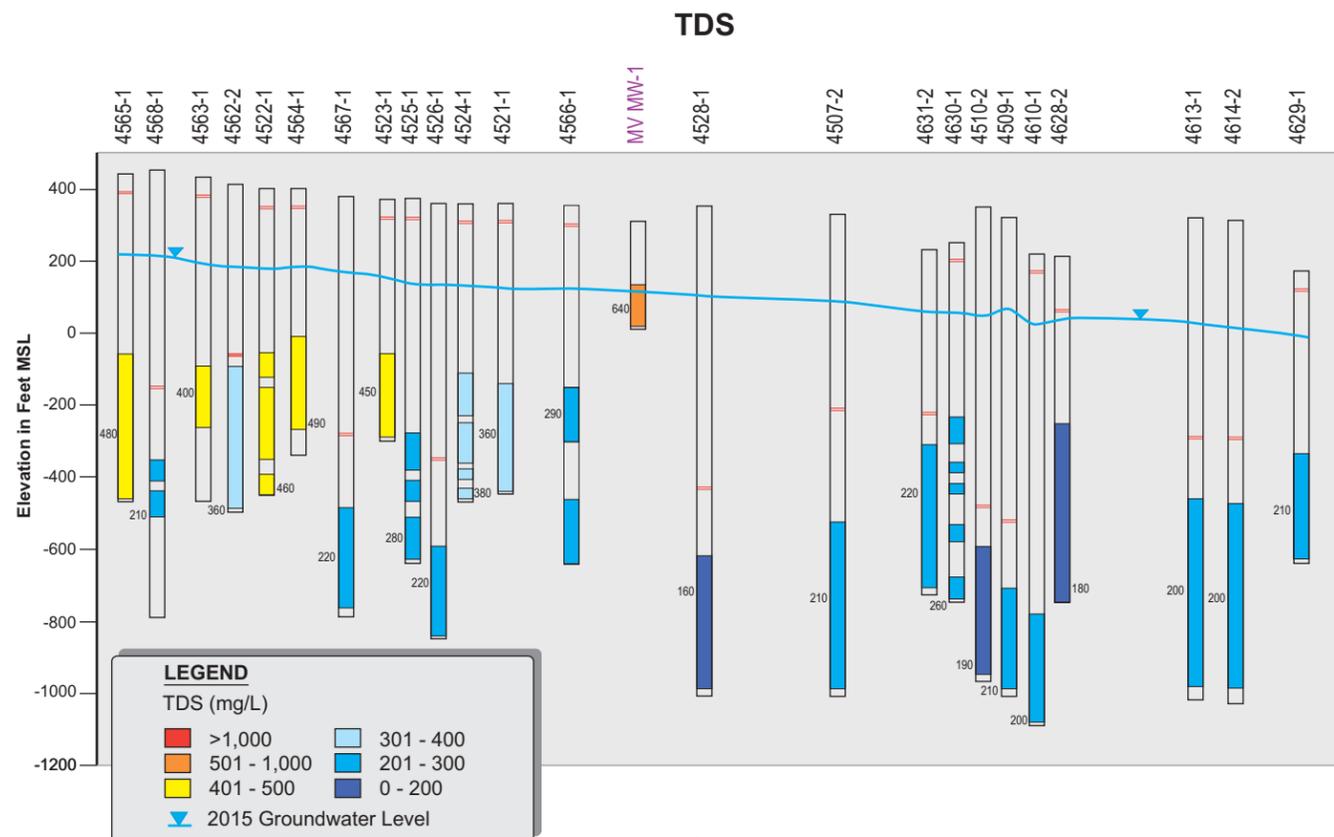


Figure 8
Volatile Organic
Compounds (VOCs)
Concentration Map





Well name (grey if inactive)

Well seal depth

Depth-discrete chromium-6 concentration

Detection value

ND = non-detect

NS = not sampled

Well screen {

Blank casing →

Well screen {



Figure 10
Cross Section A - A'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

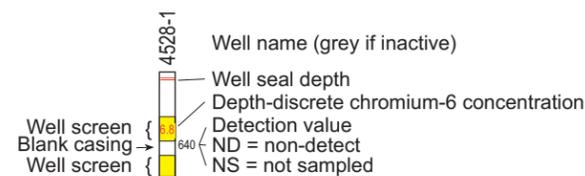
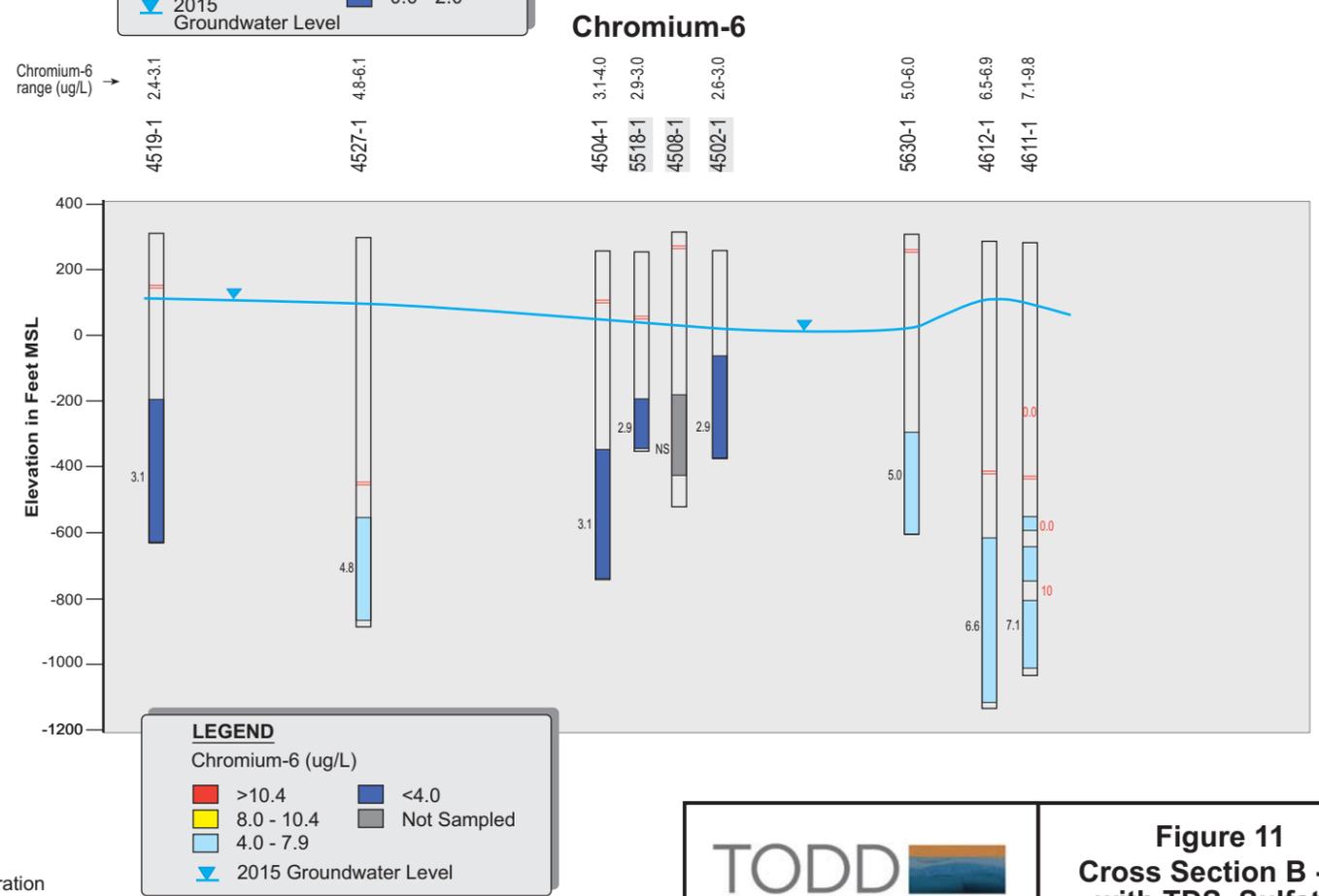
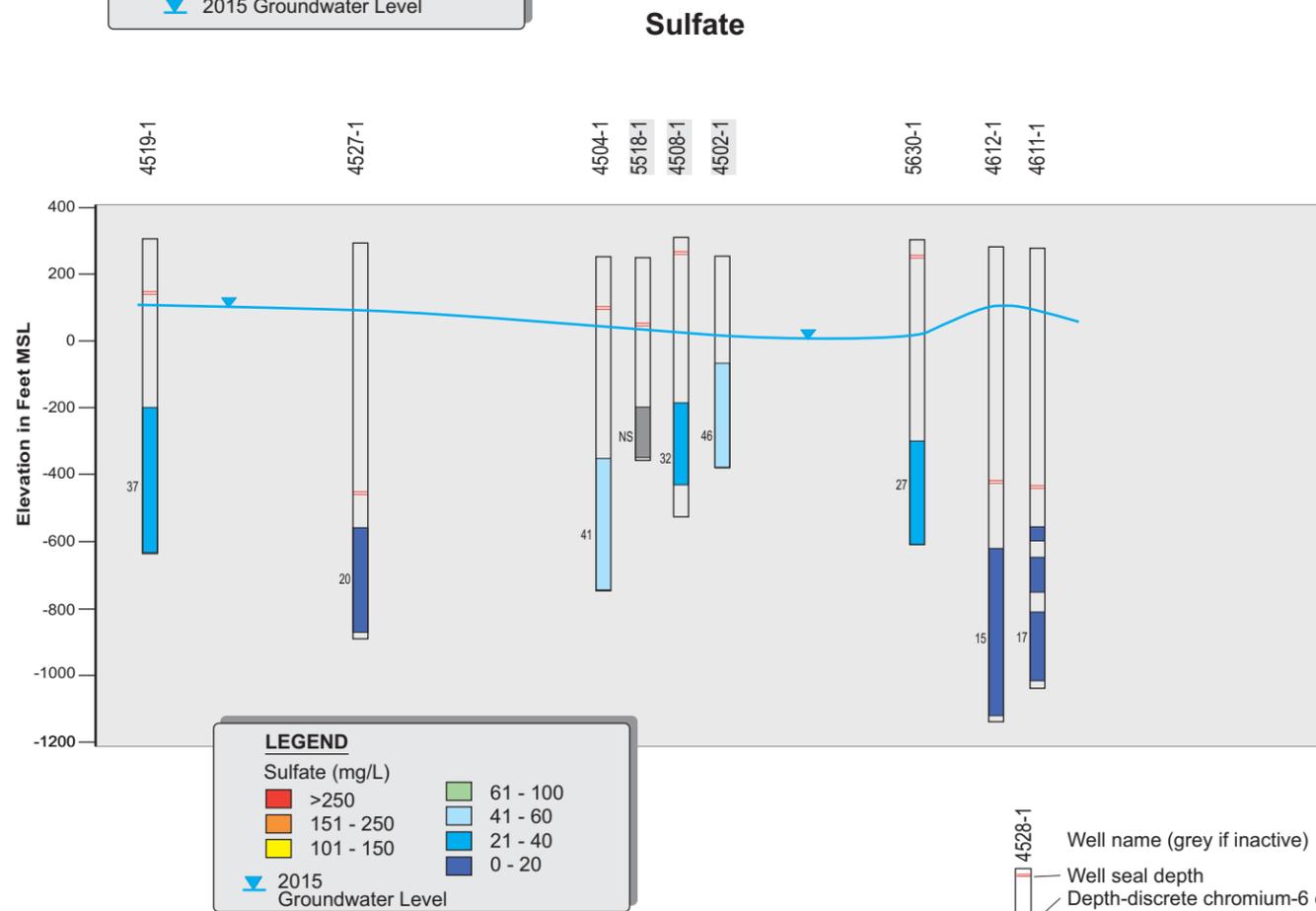
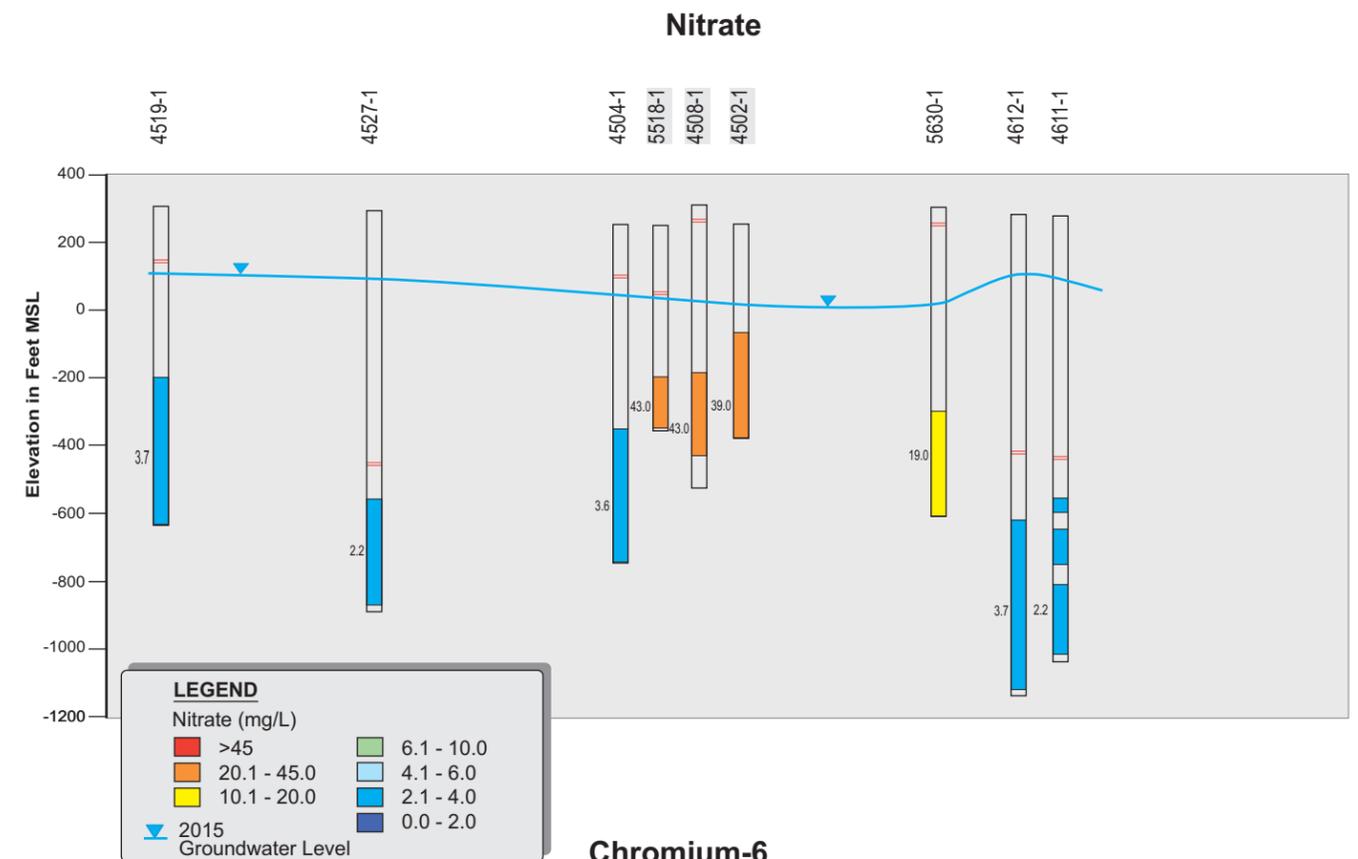
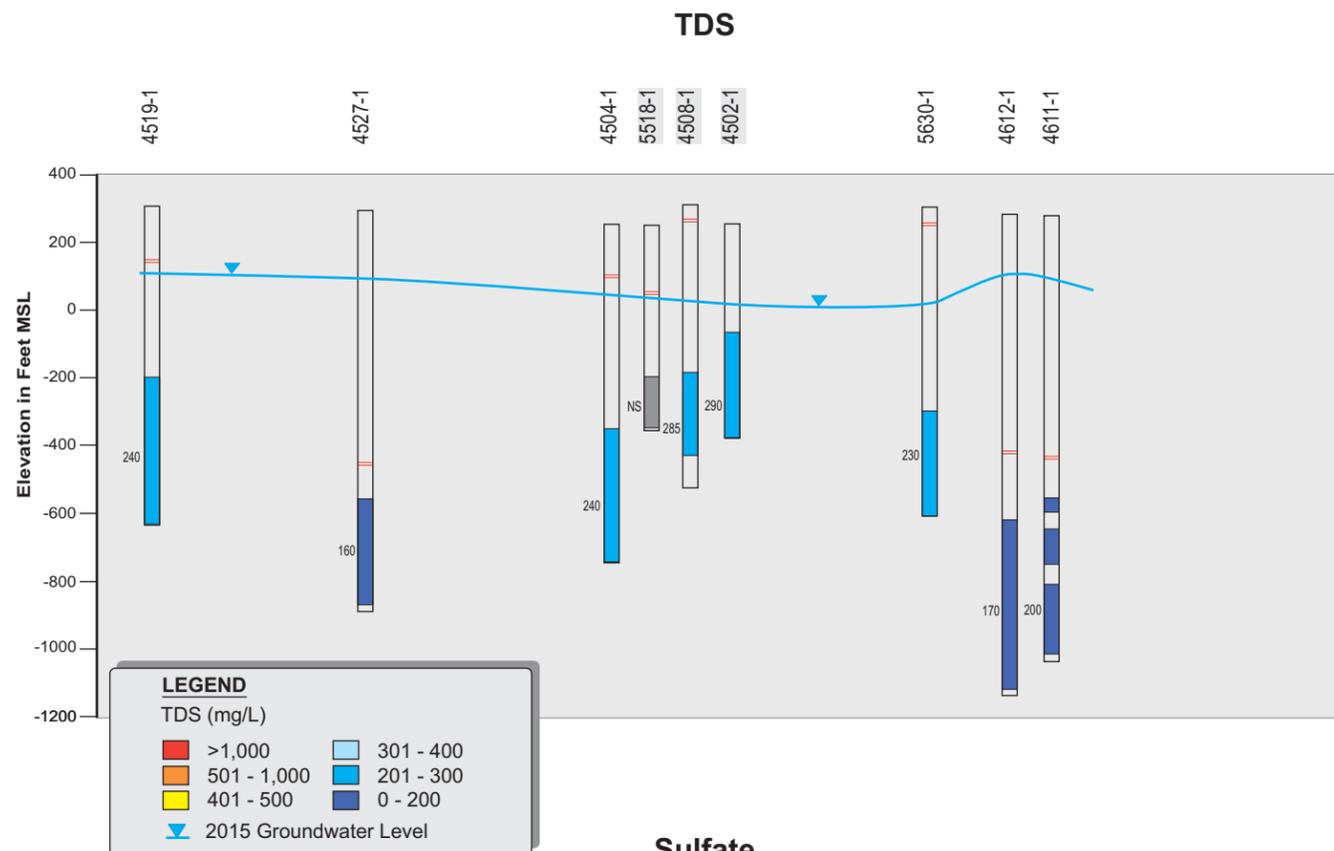


Figure 11
Cross Section B - B'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

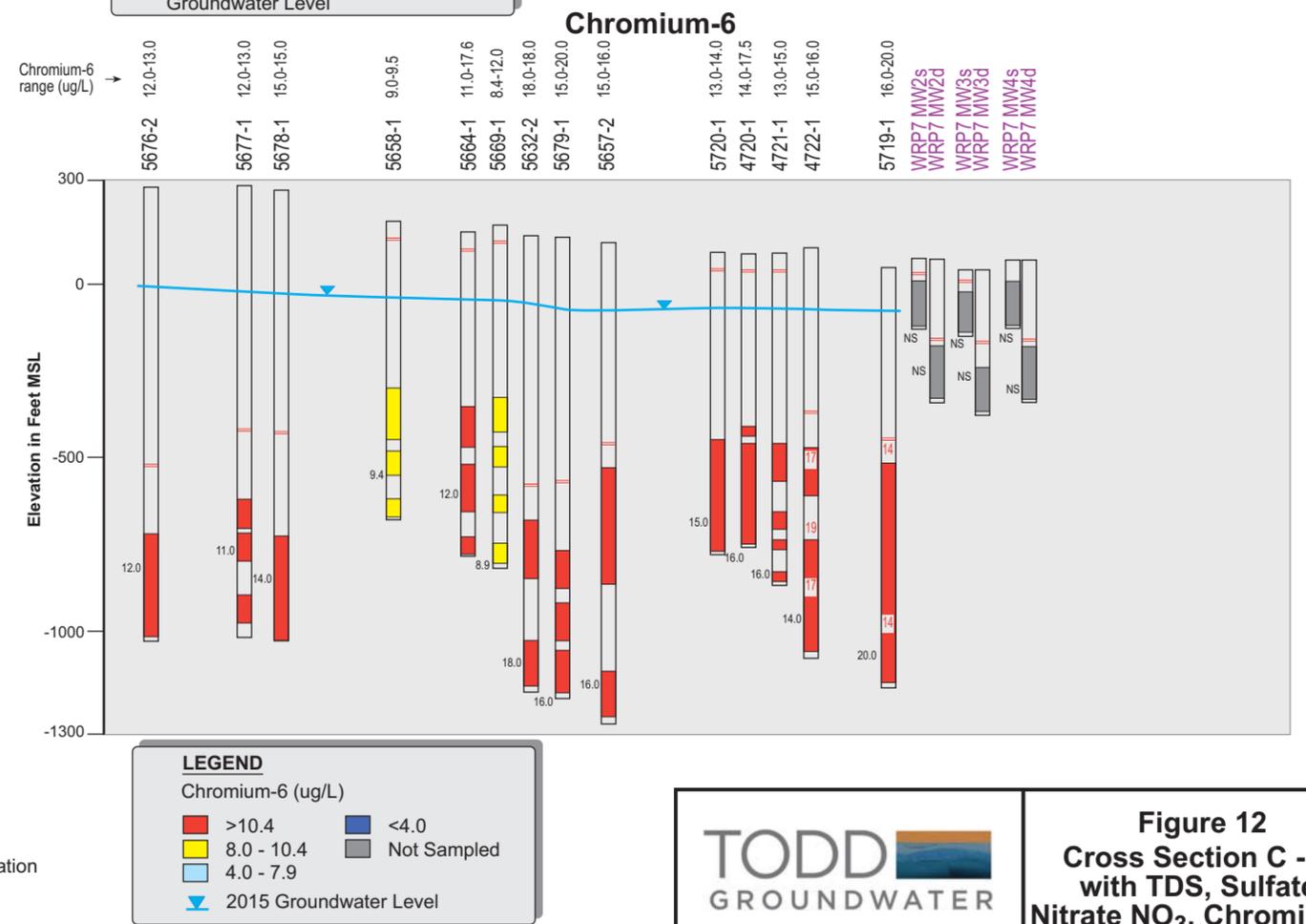
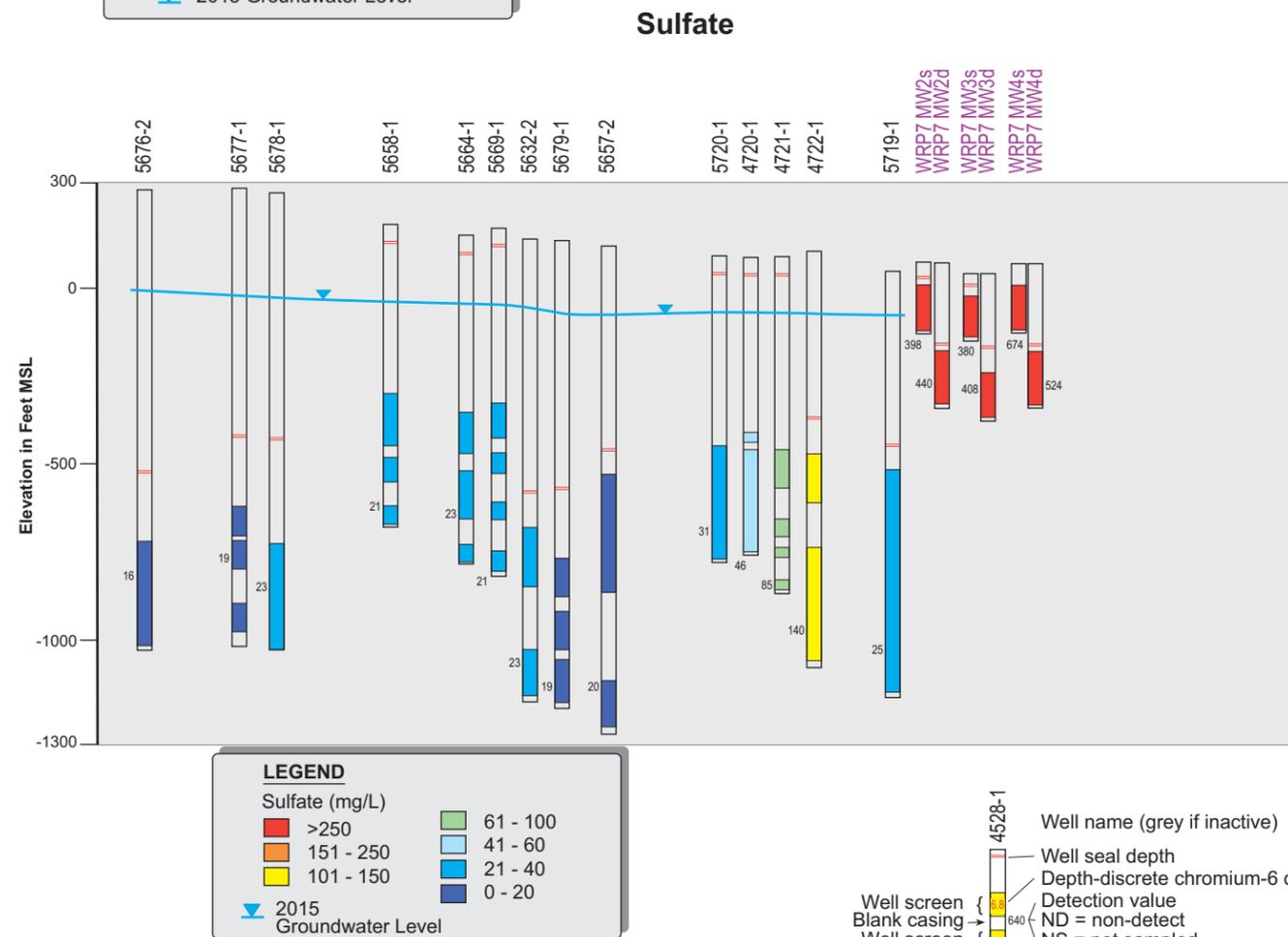
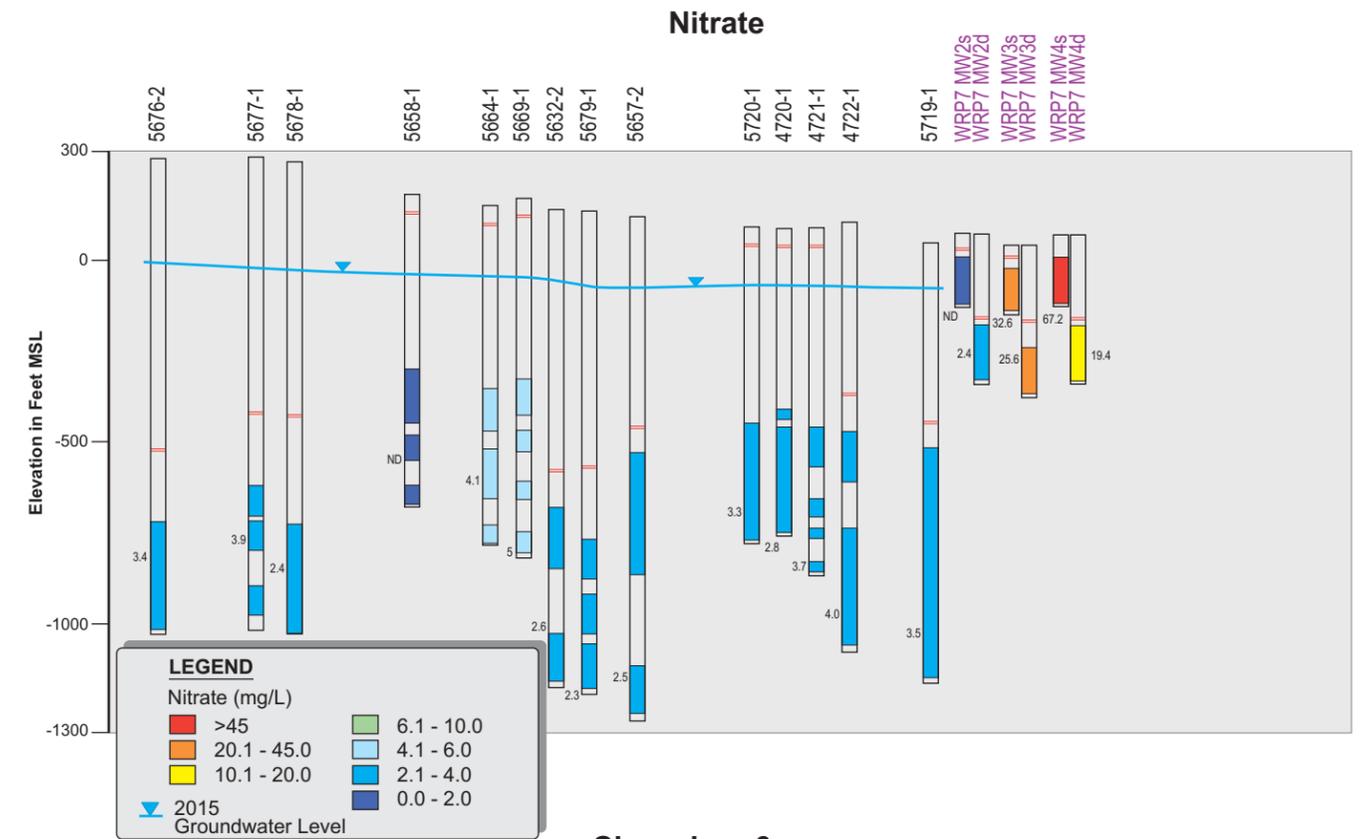
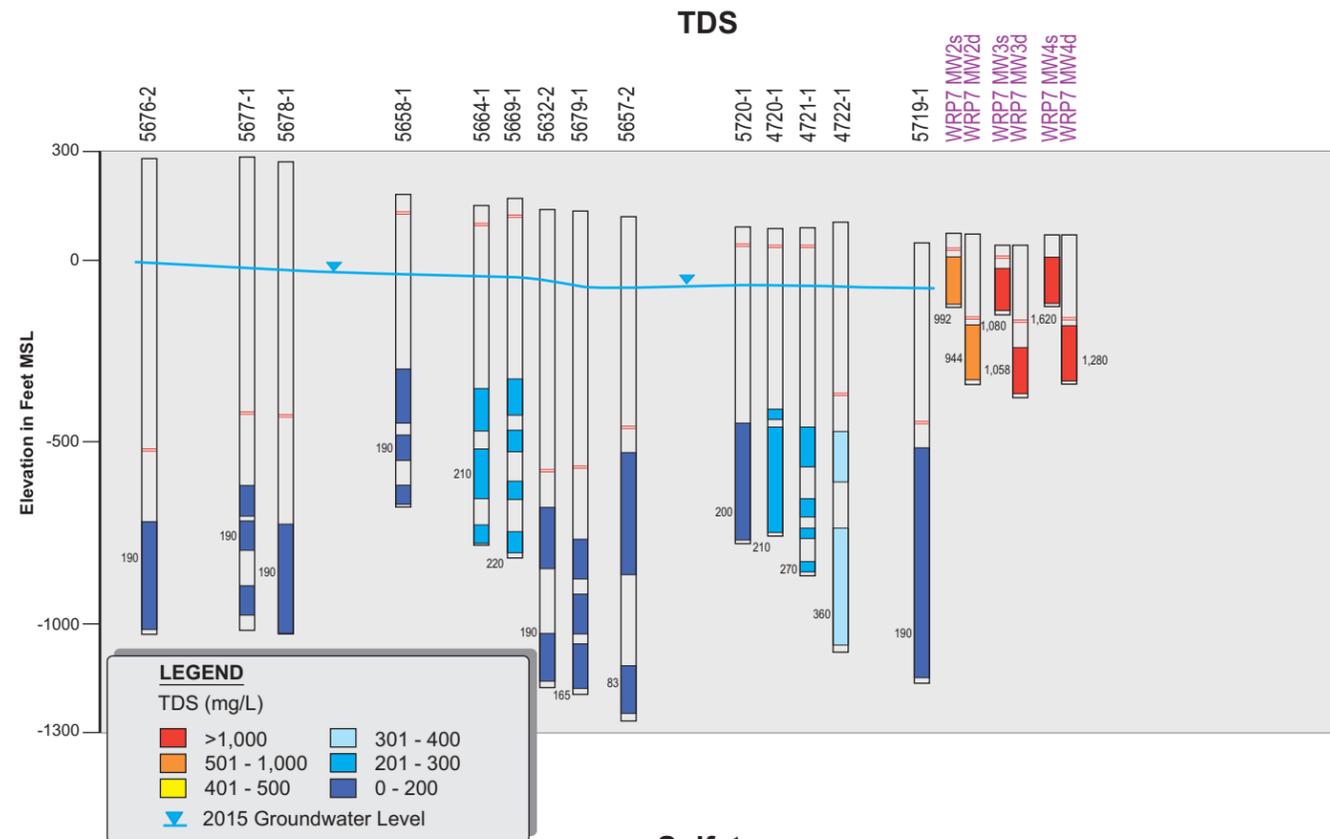


Figure 12
Cross Section C - C'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

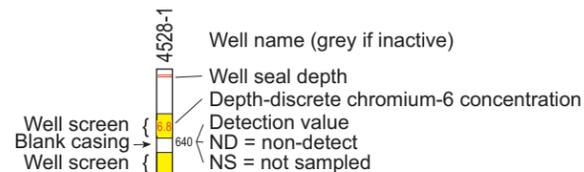
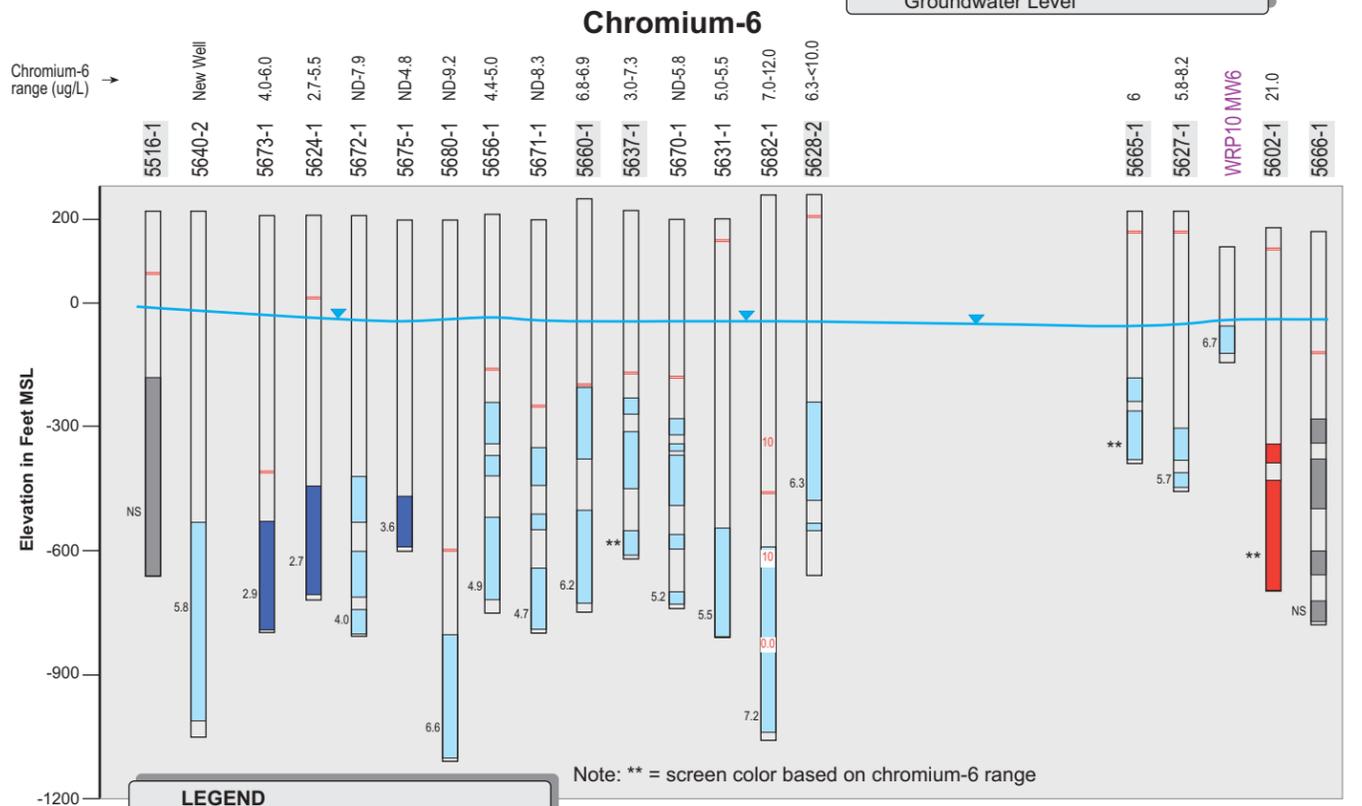
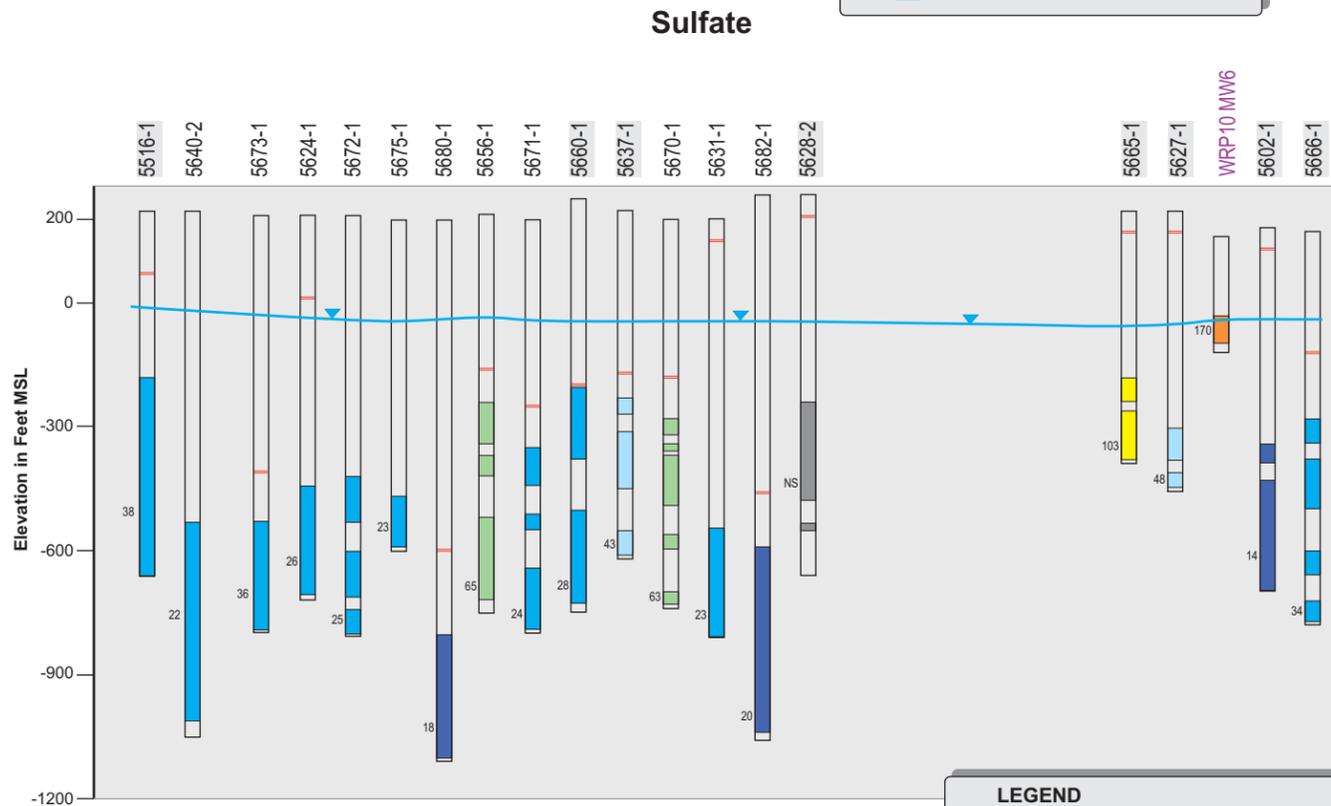
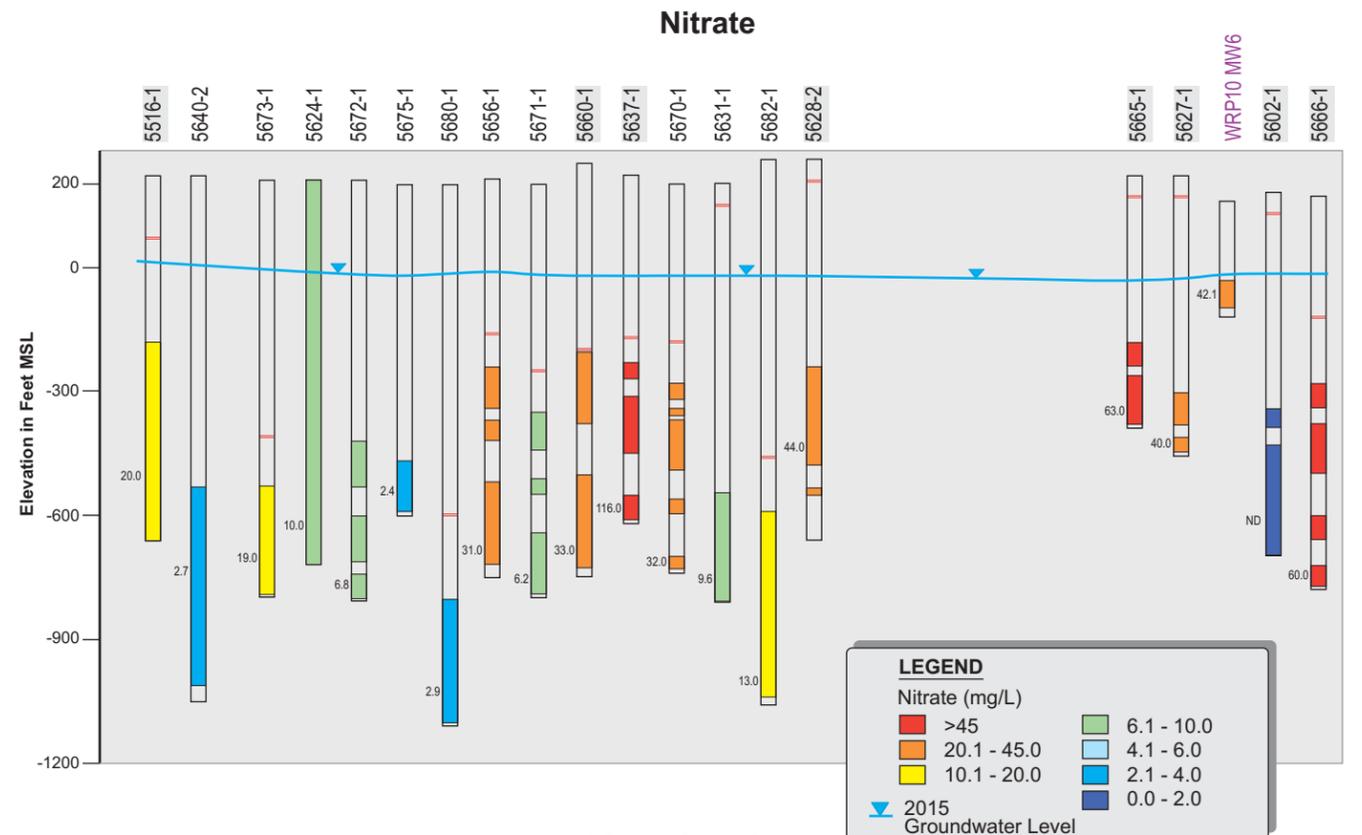
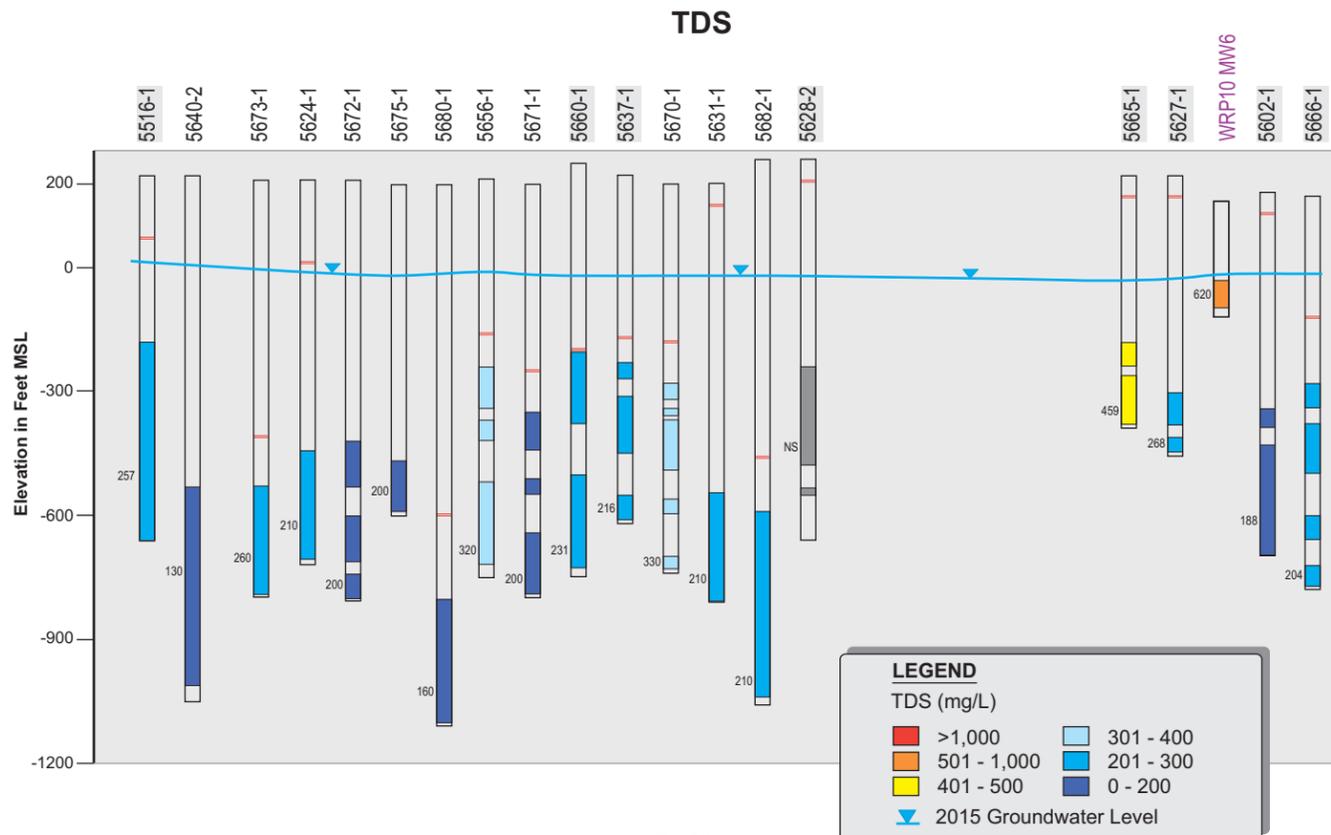


Figure 13
Cross Section D - D'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

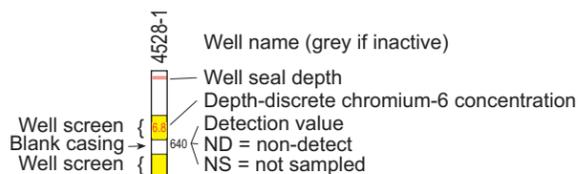
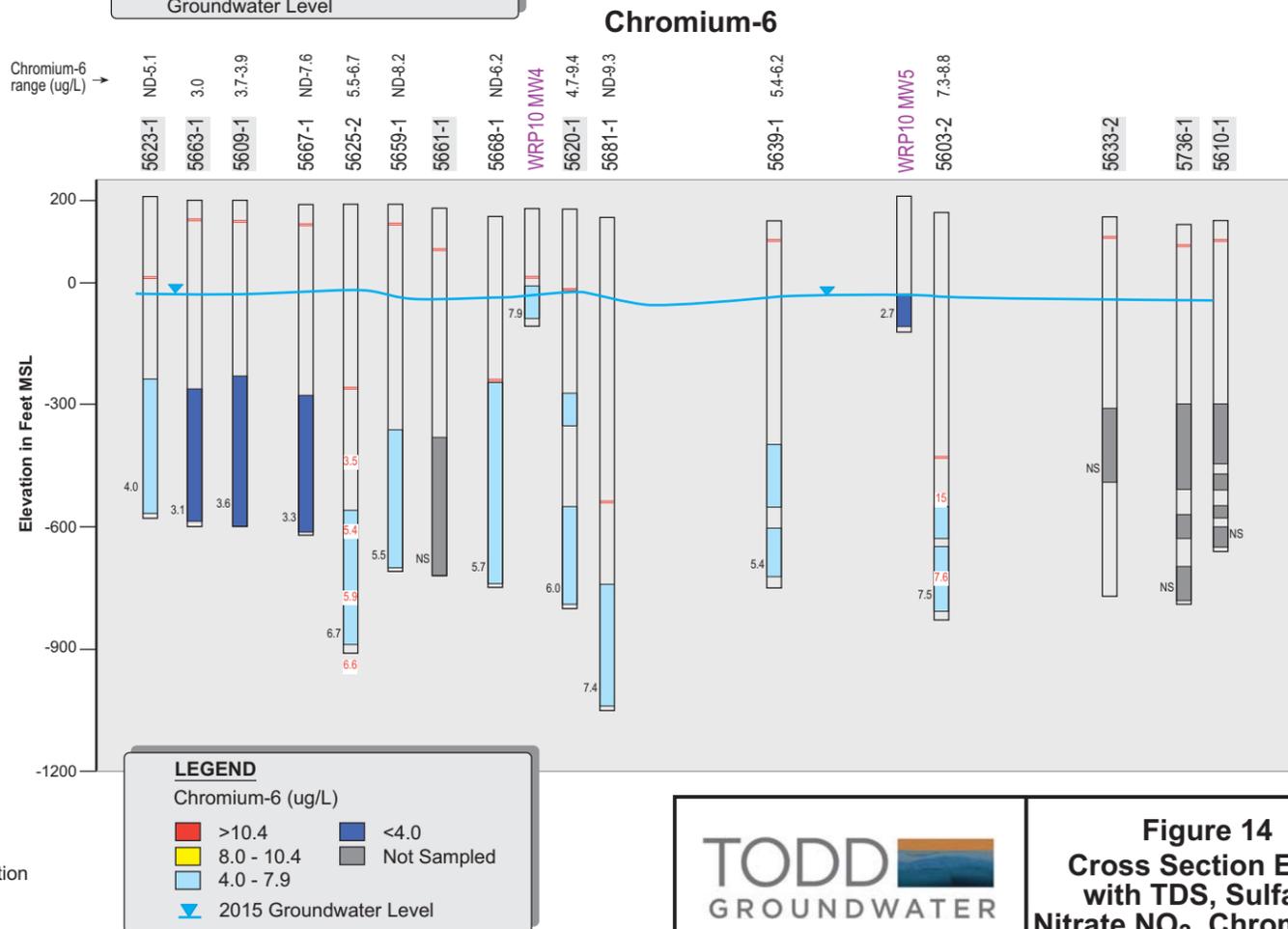
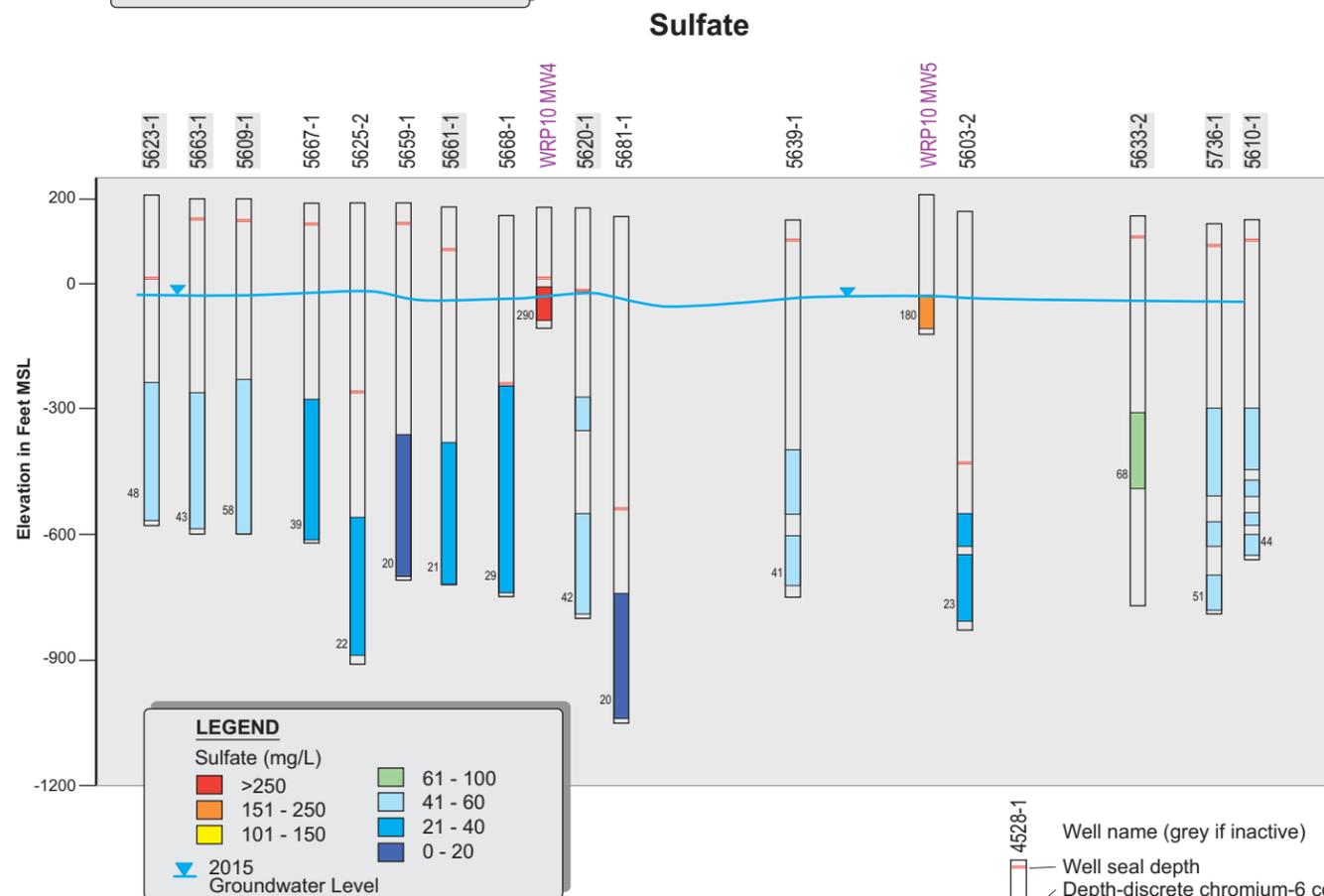
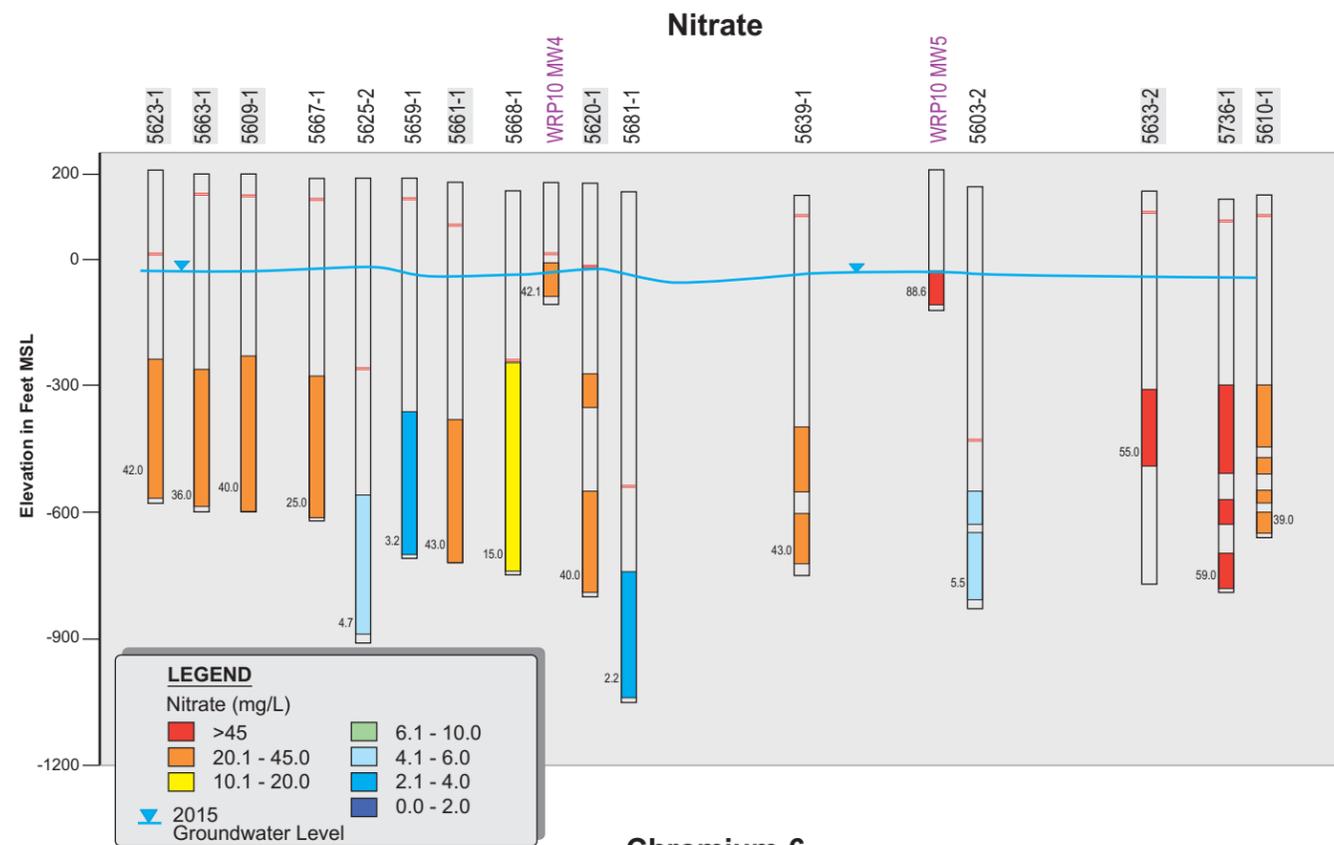
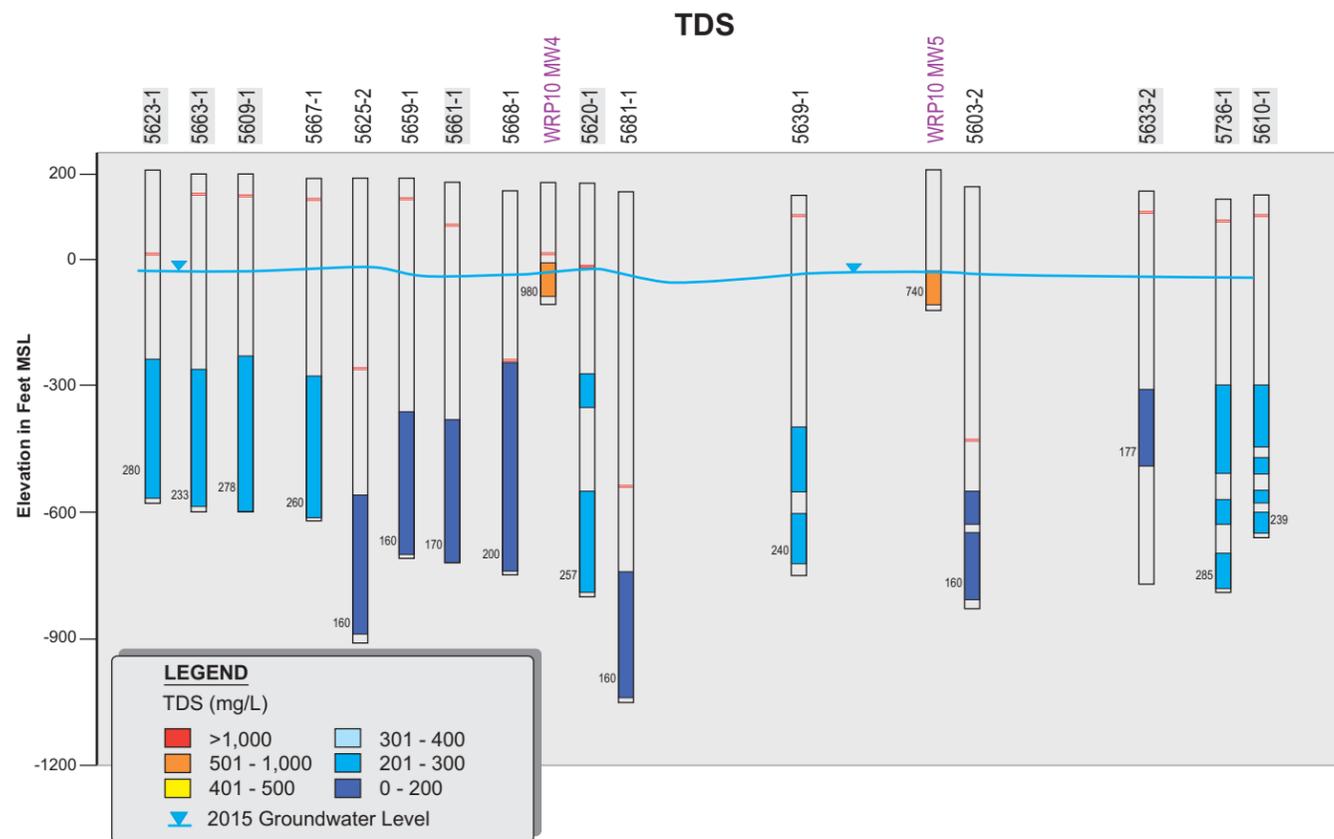
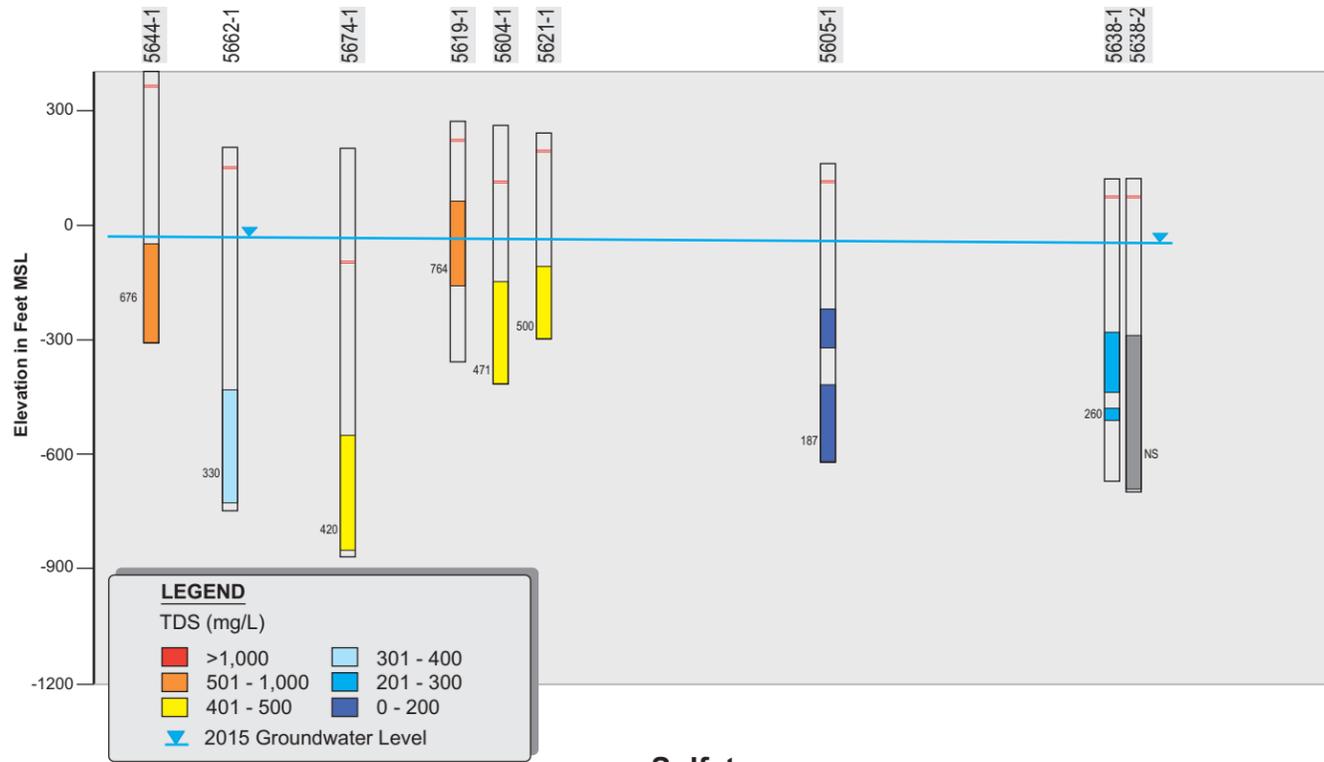
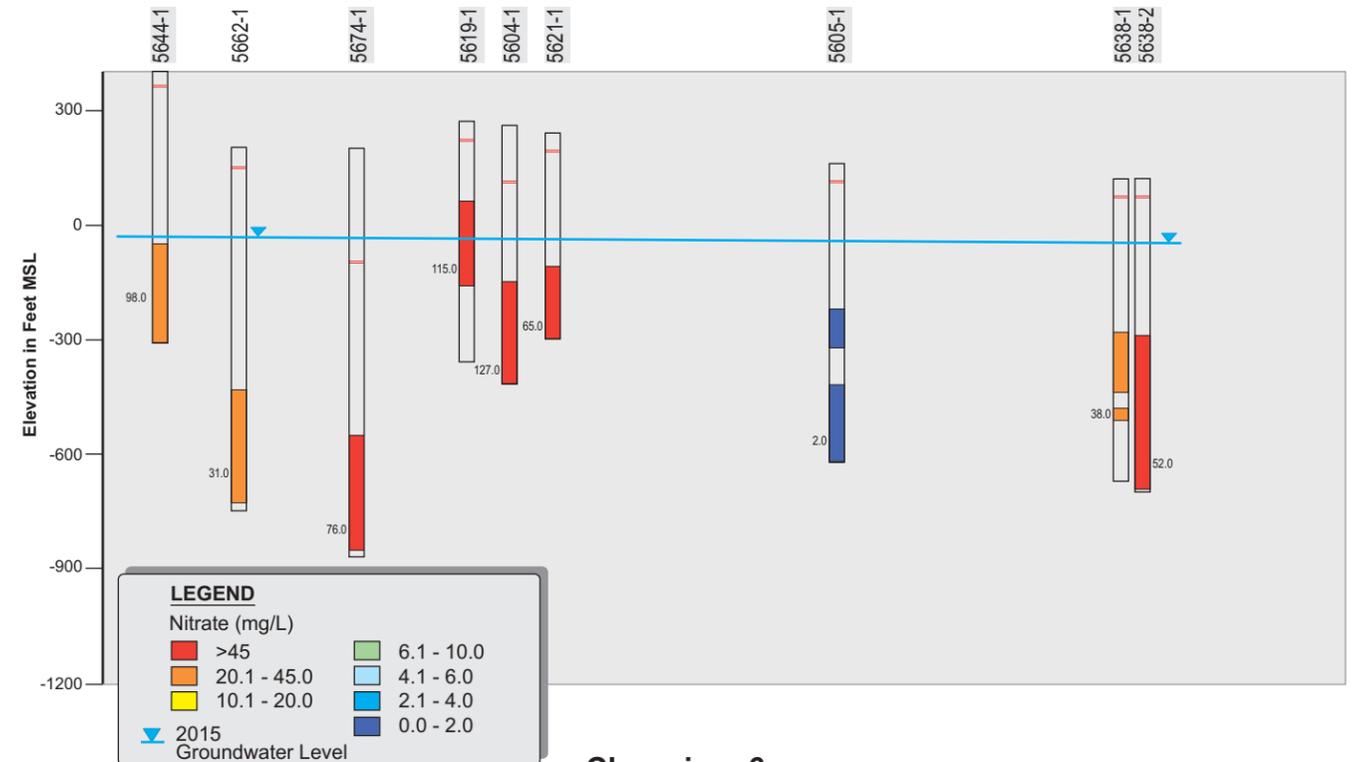


Figure 14
Cross Section E - E'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

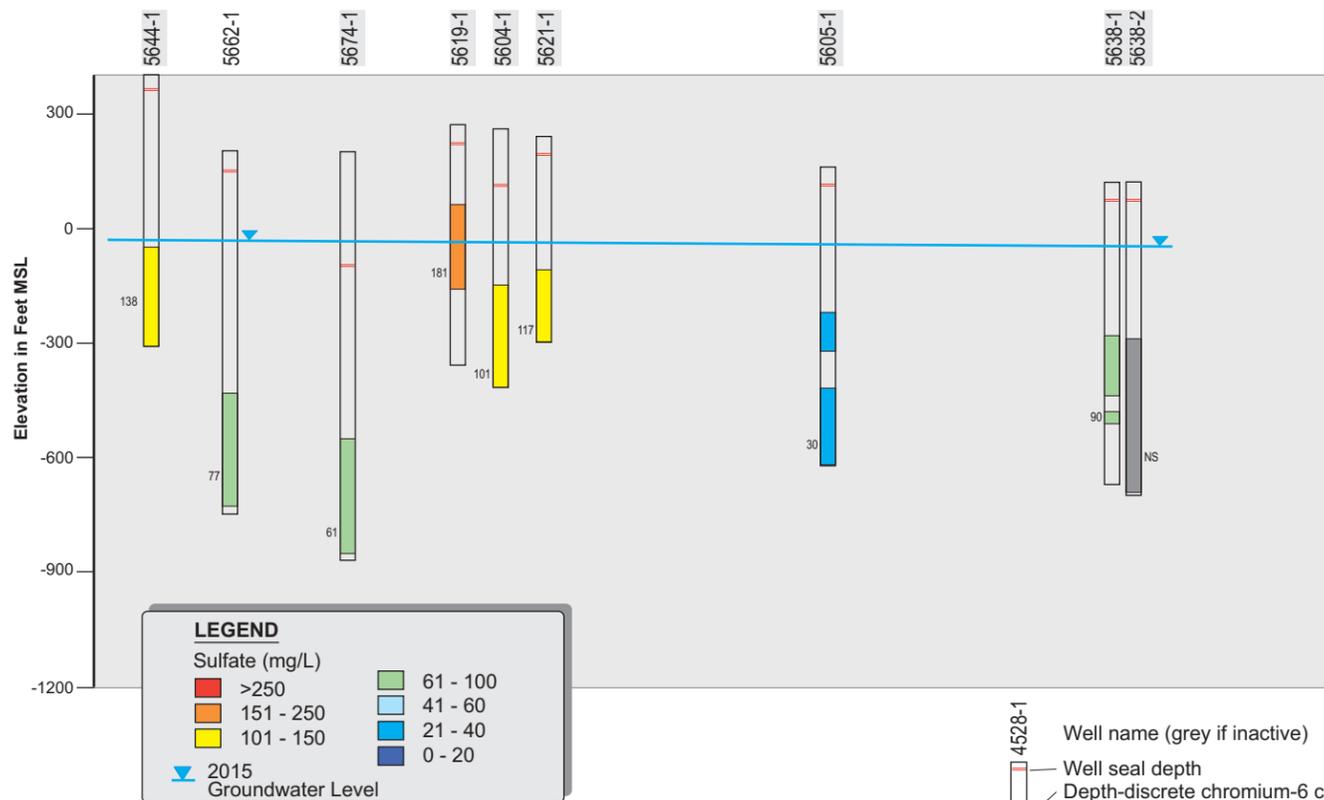
TDS



Nitrate



Sulfate



Chromium-6

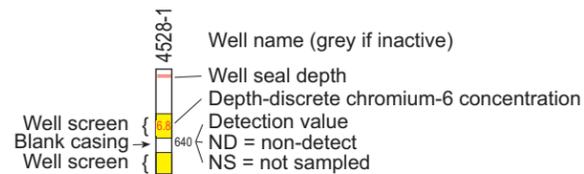
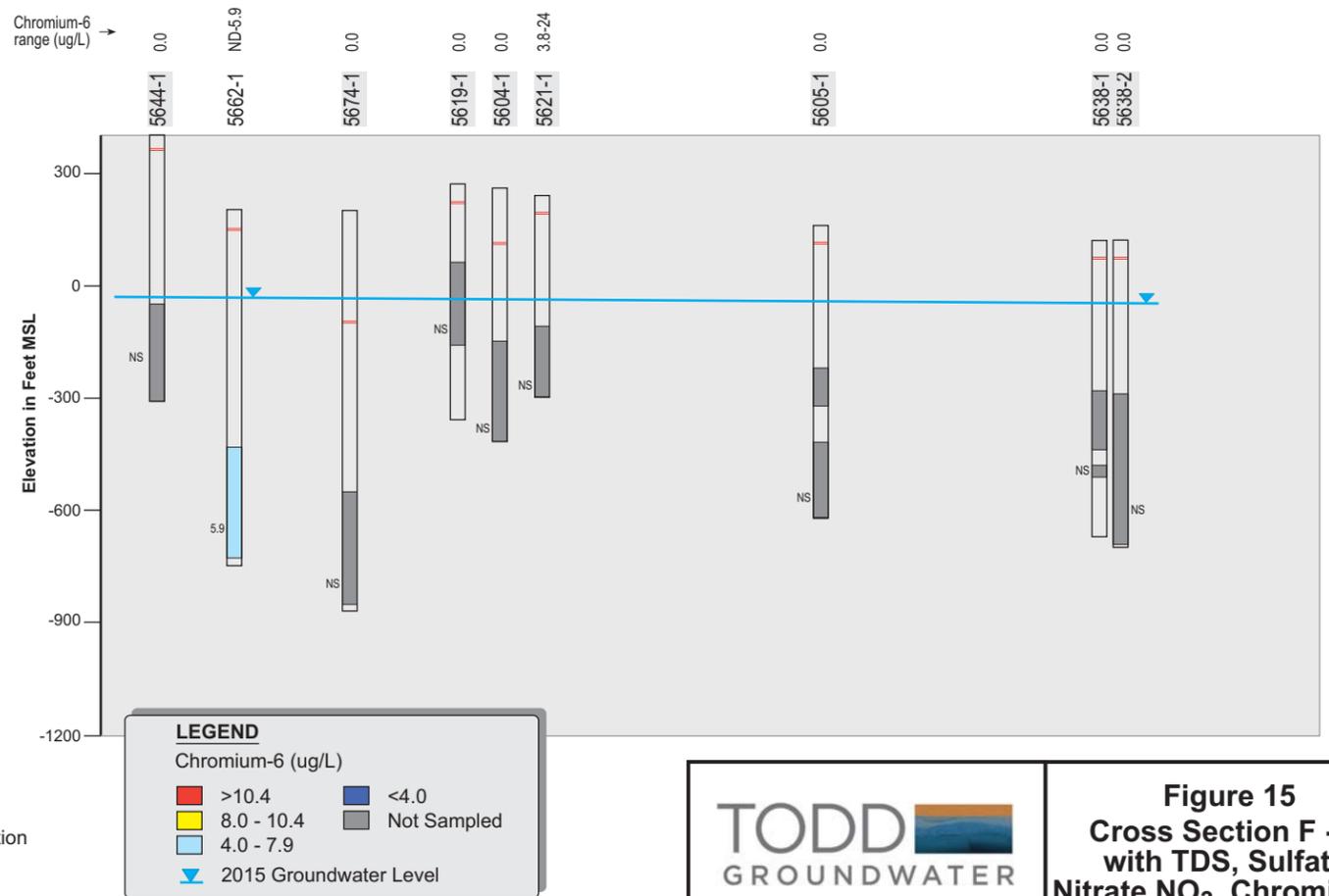
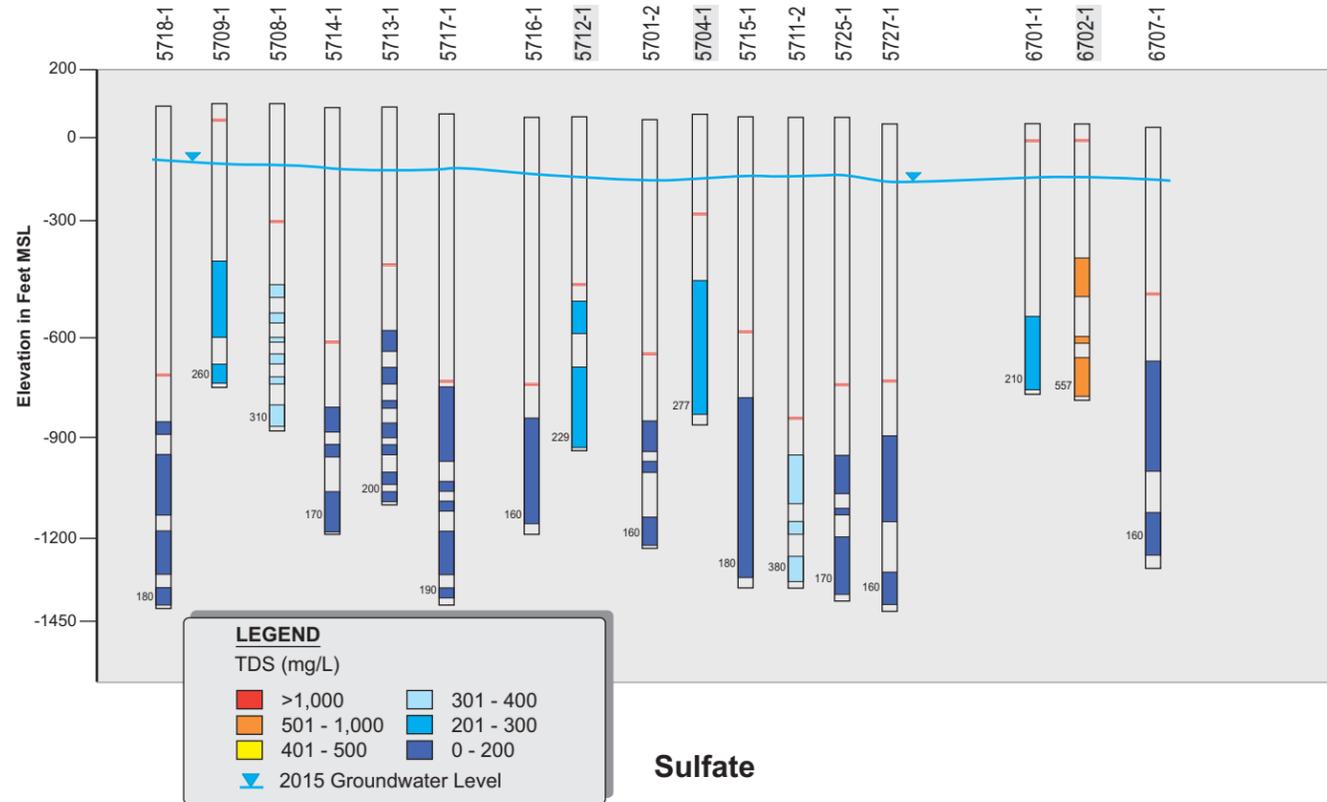
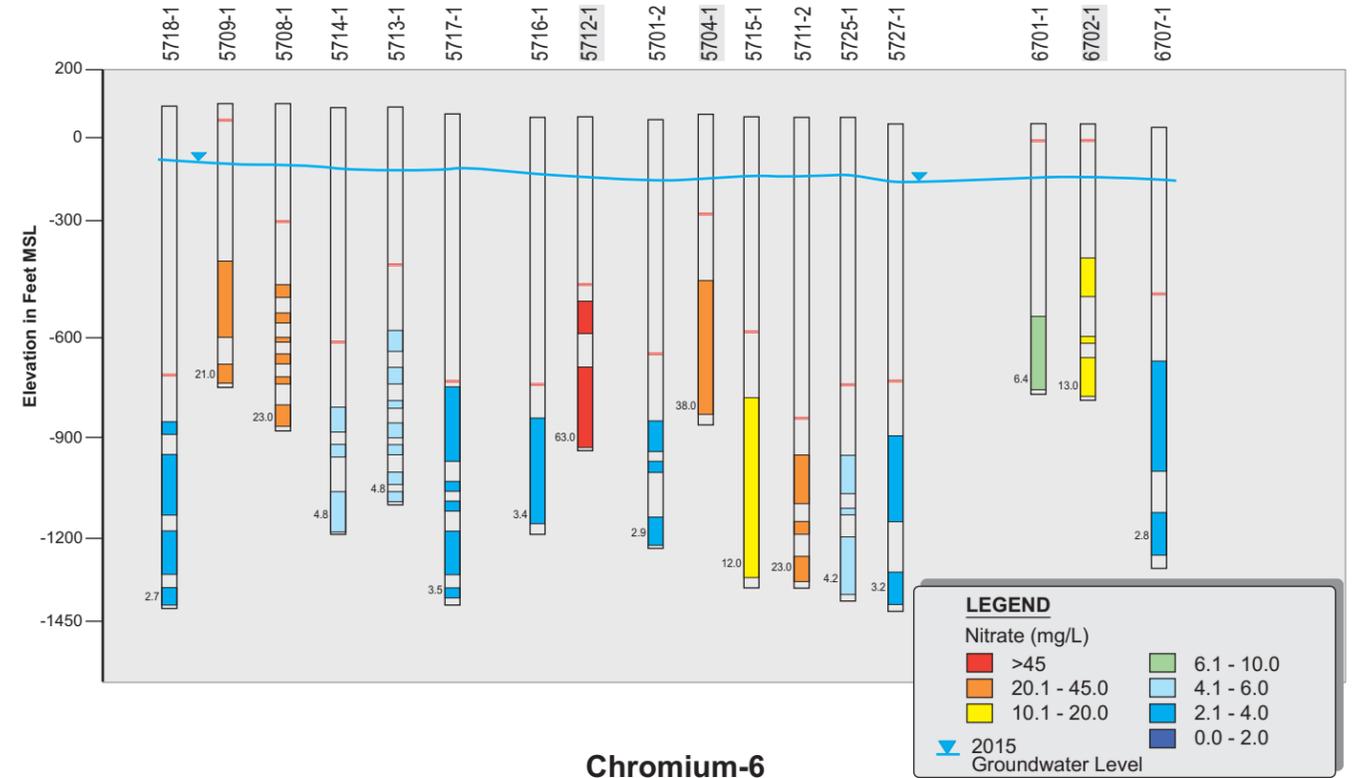


Figure 15
Cross Section F - F'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

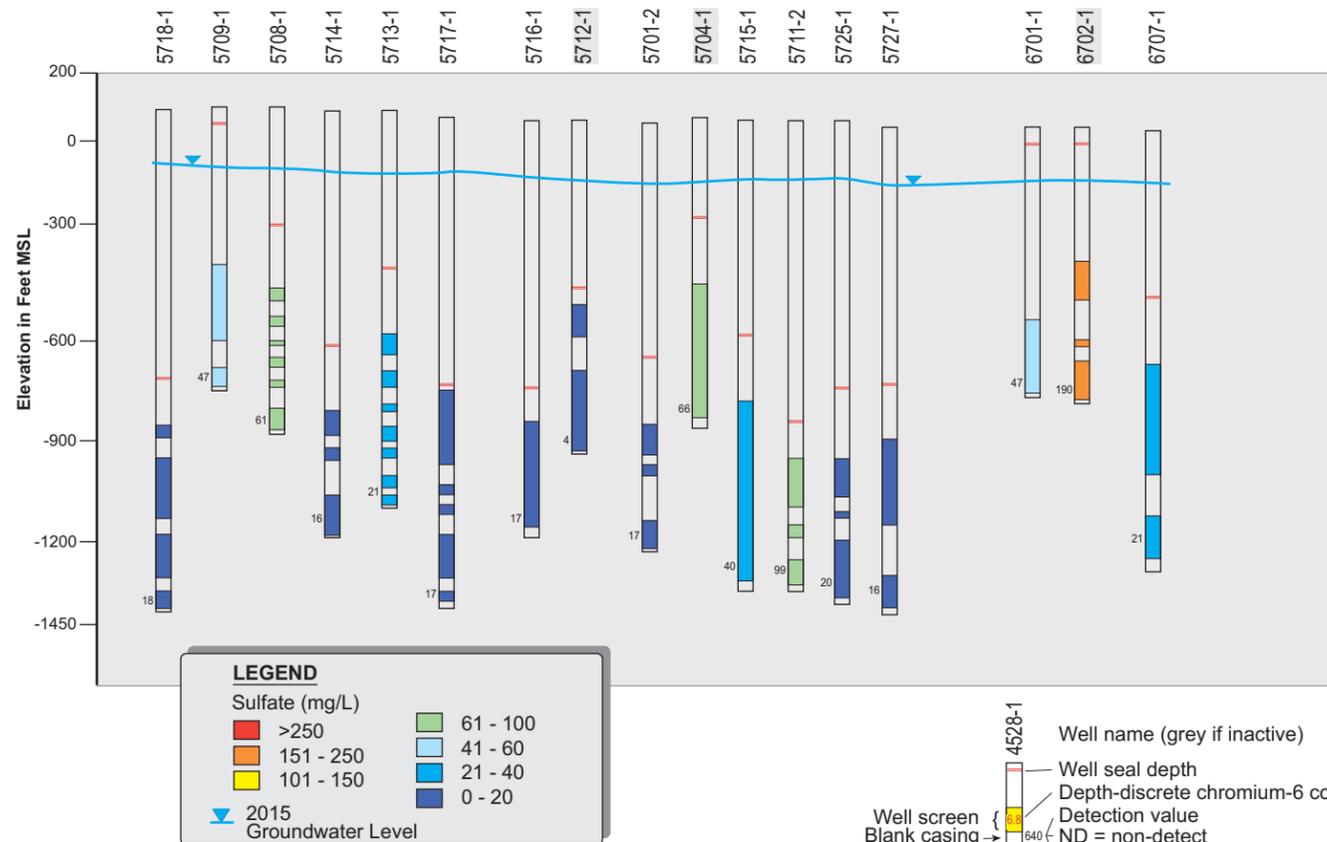
TDS



Nitrate



Sulfate



Chromium-6

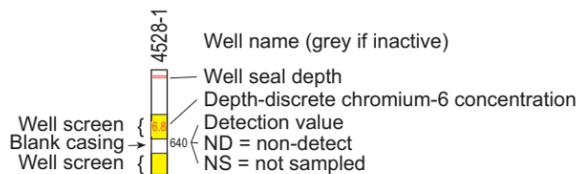
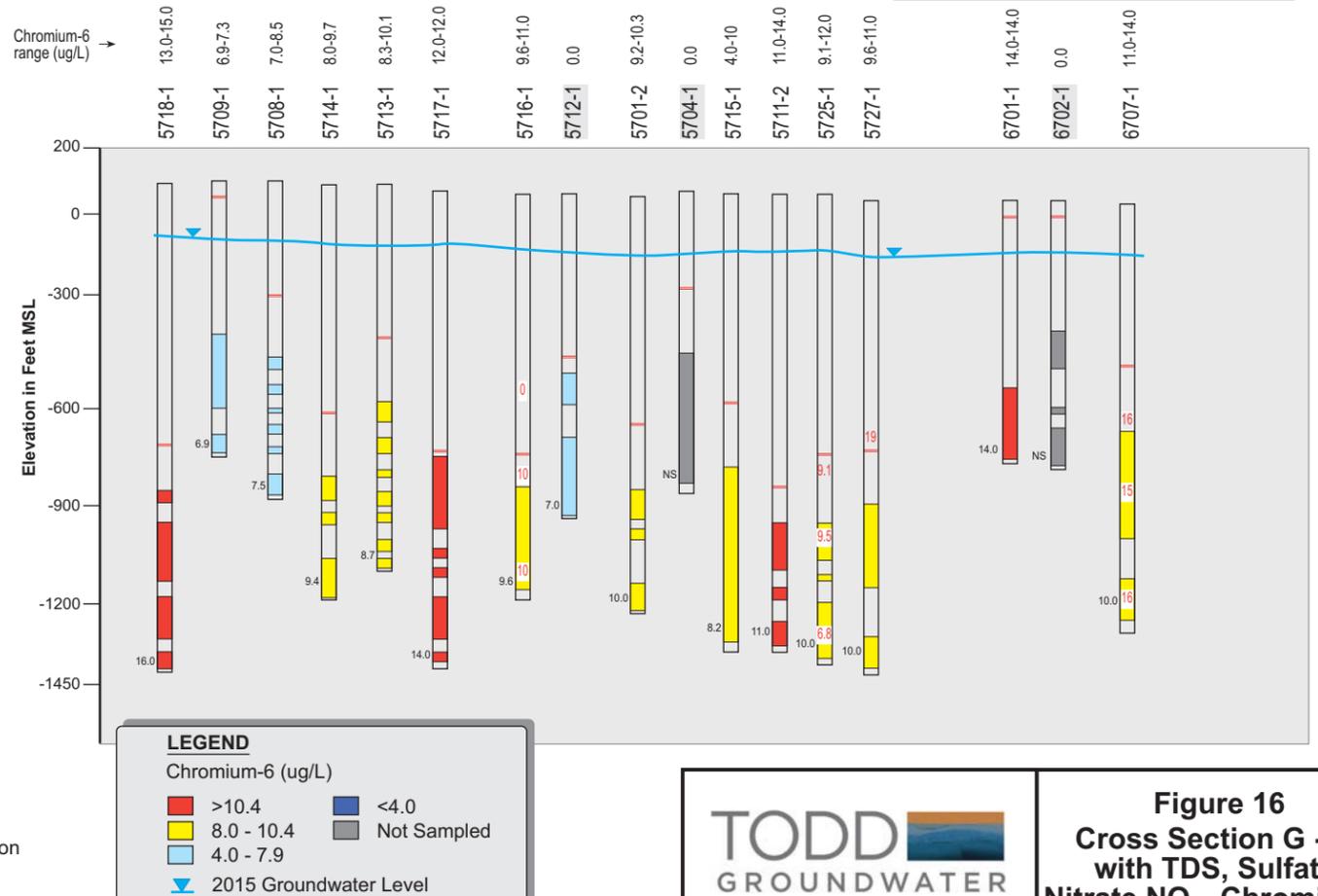


Figure 16
Cross Section G - G'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

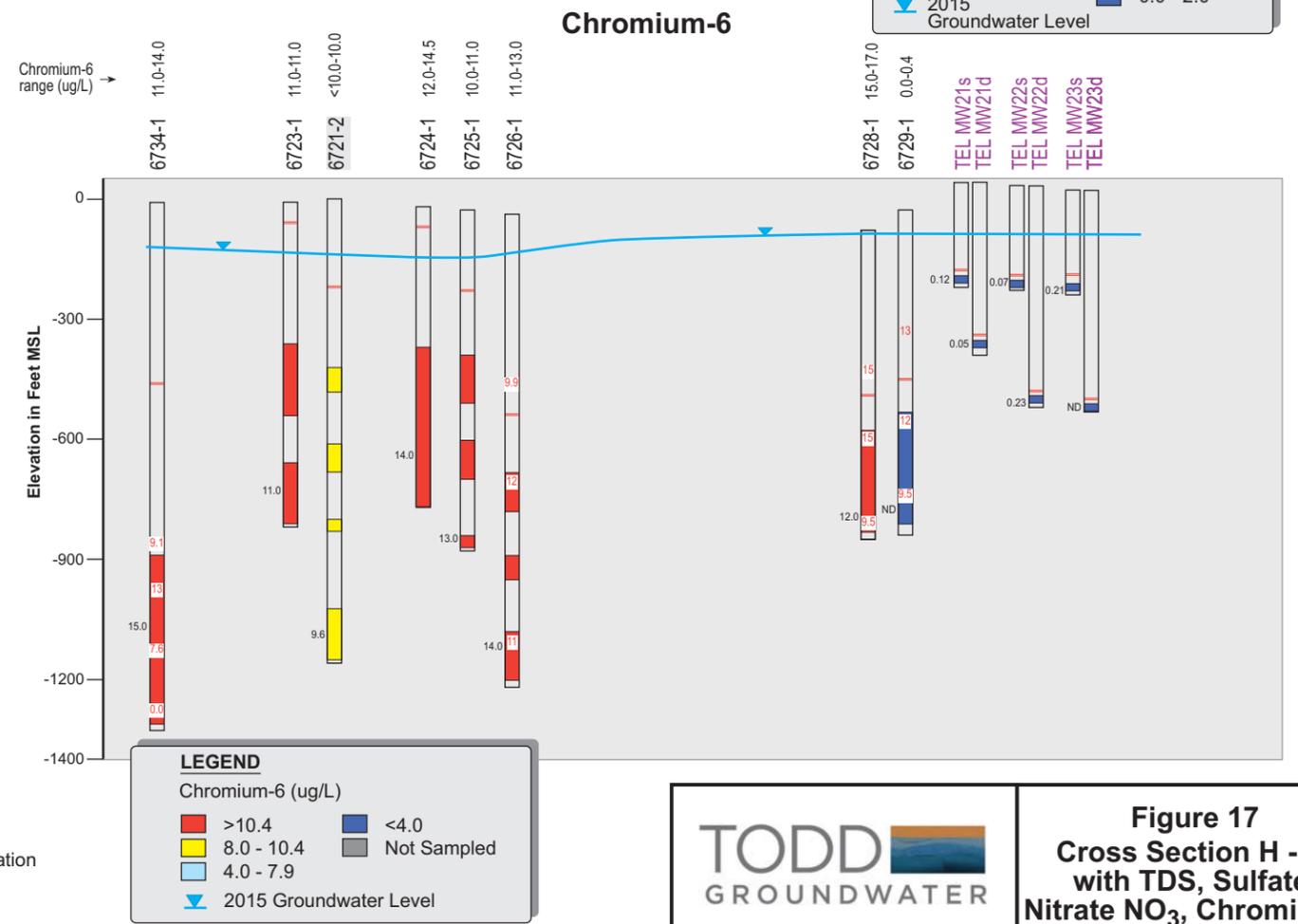
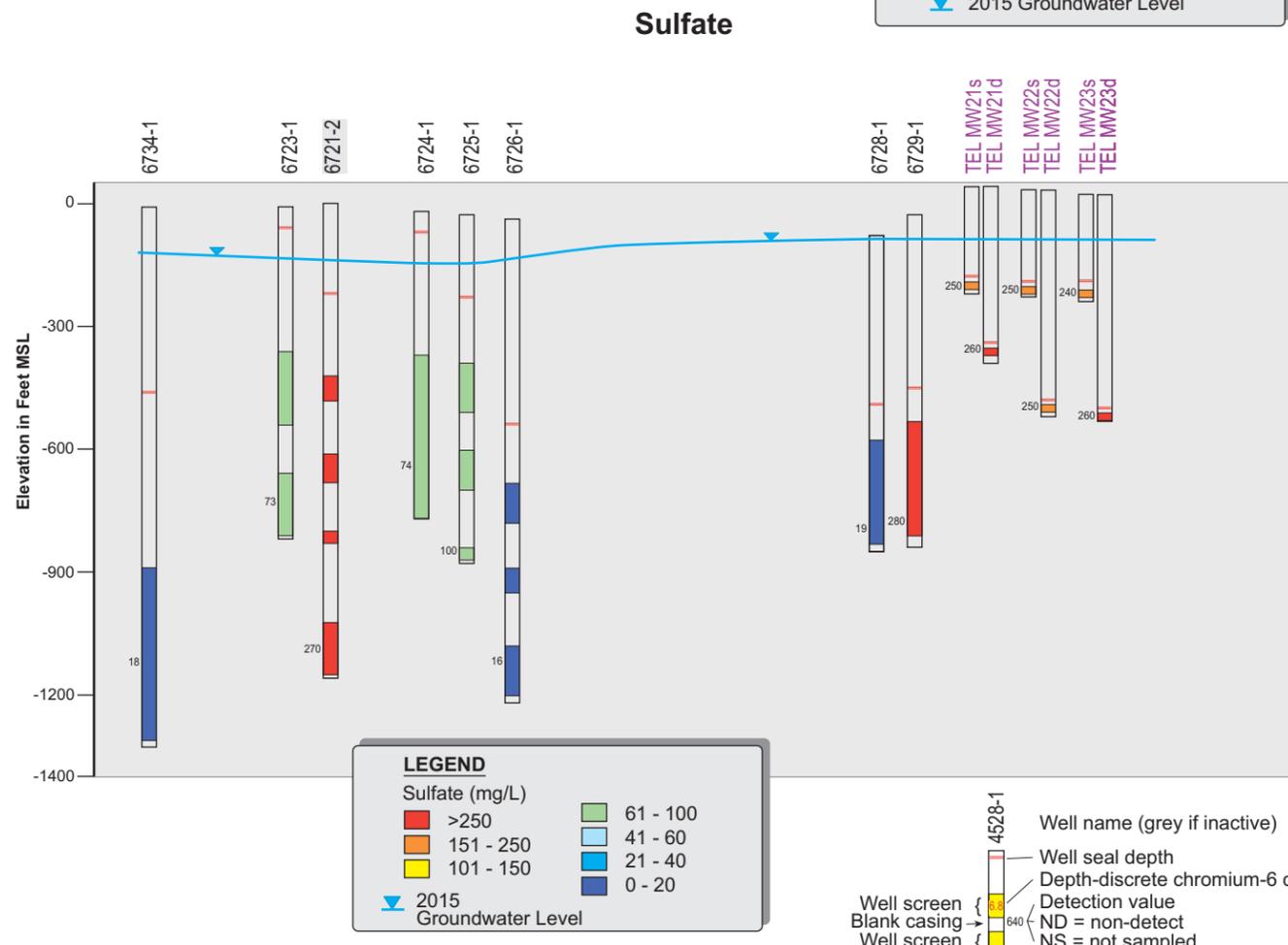
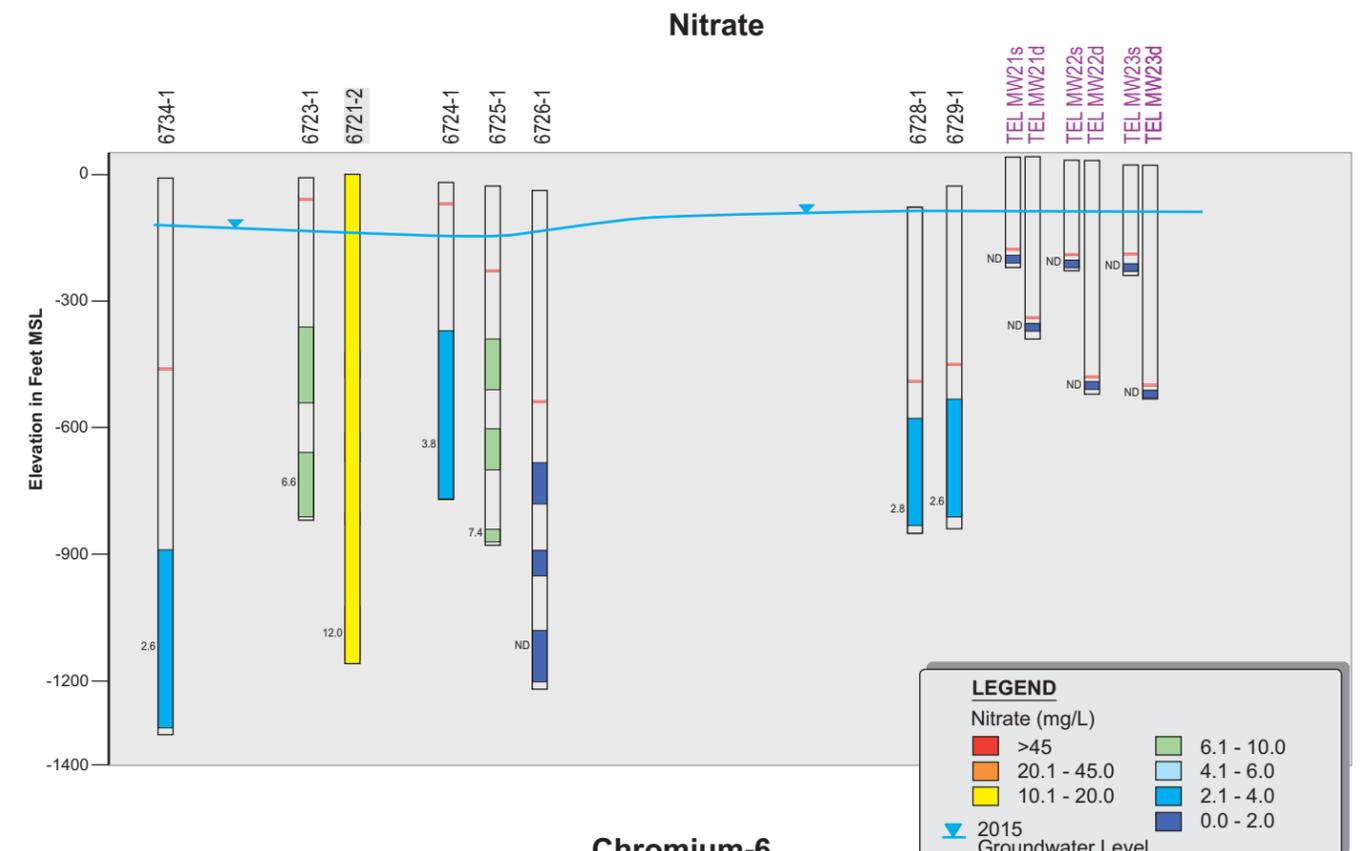
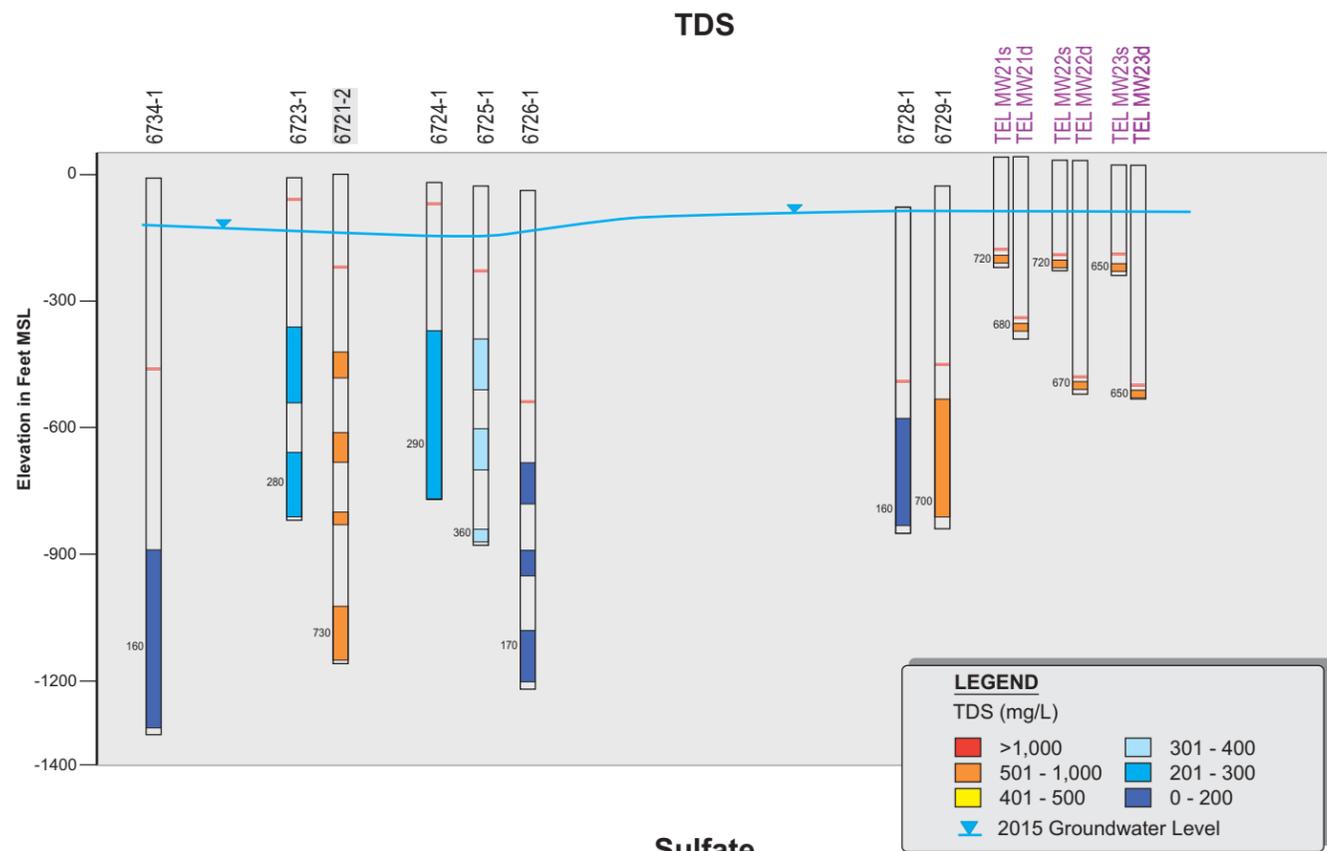


Figure 17
Cross Section H - H'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

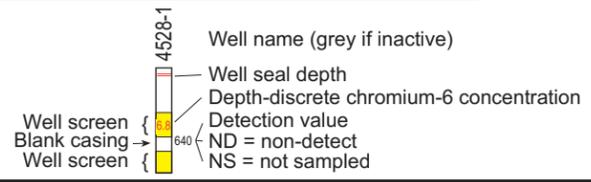
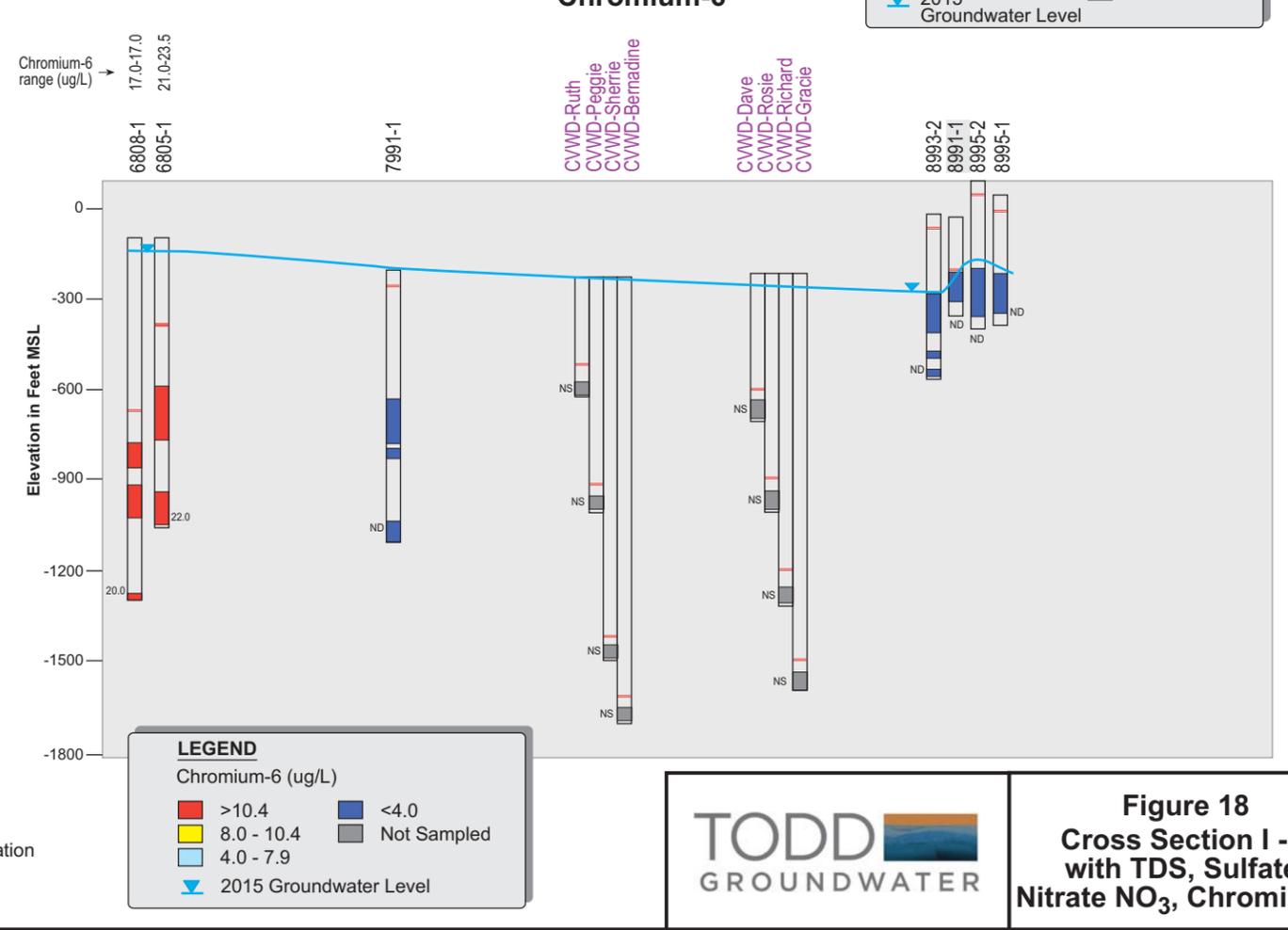
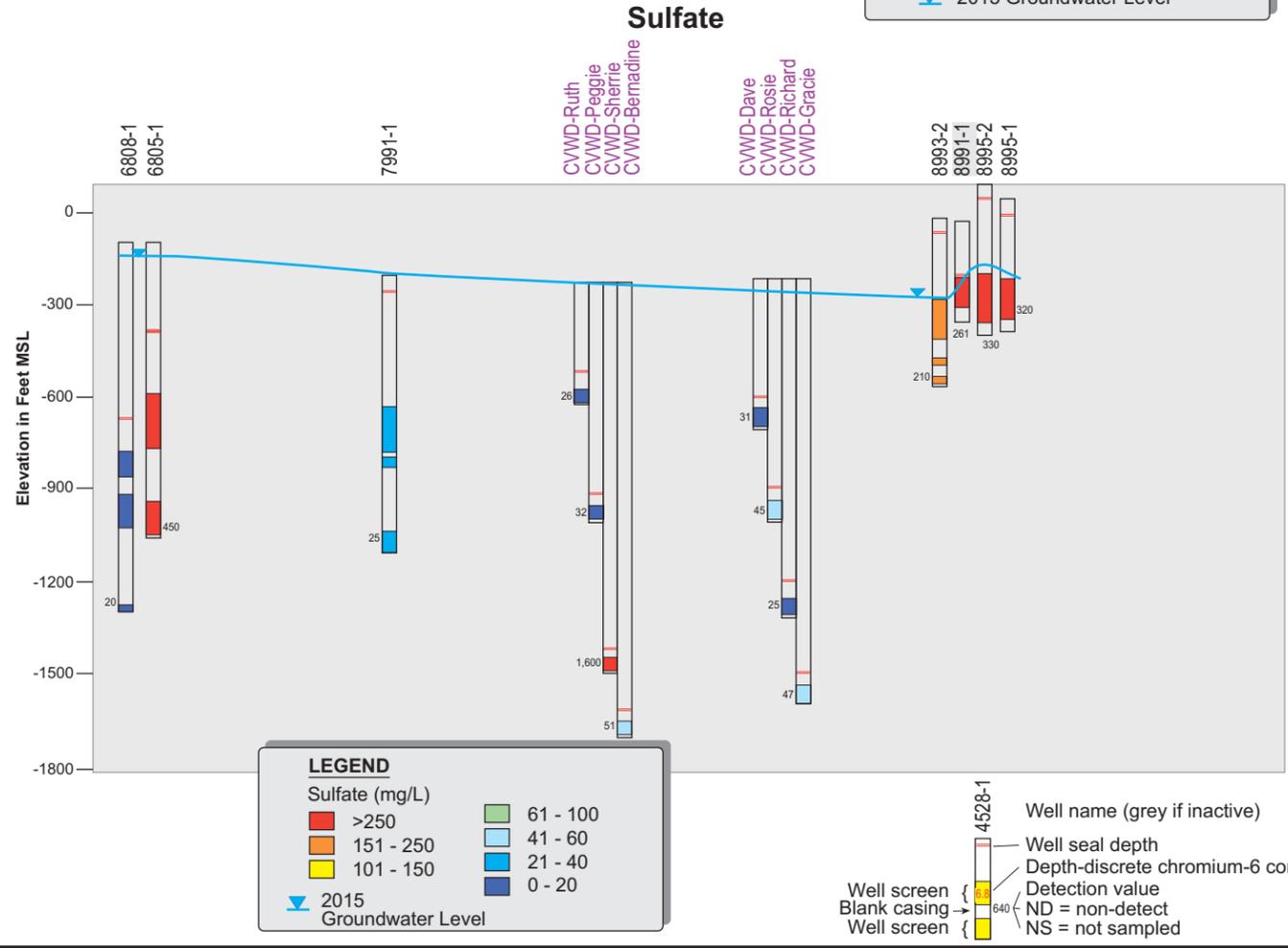
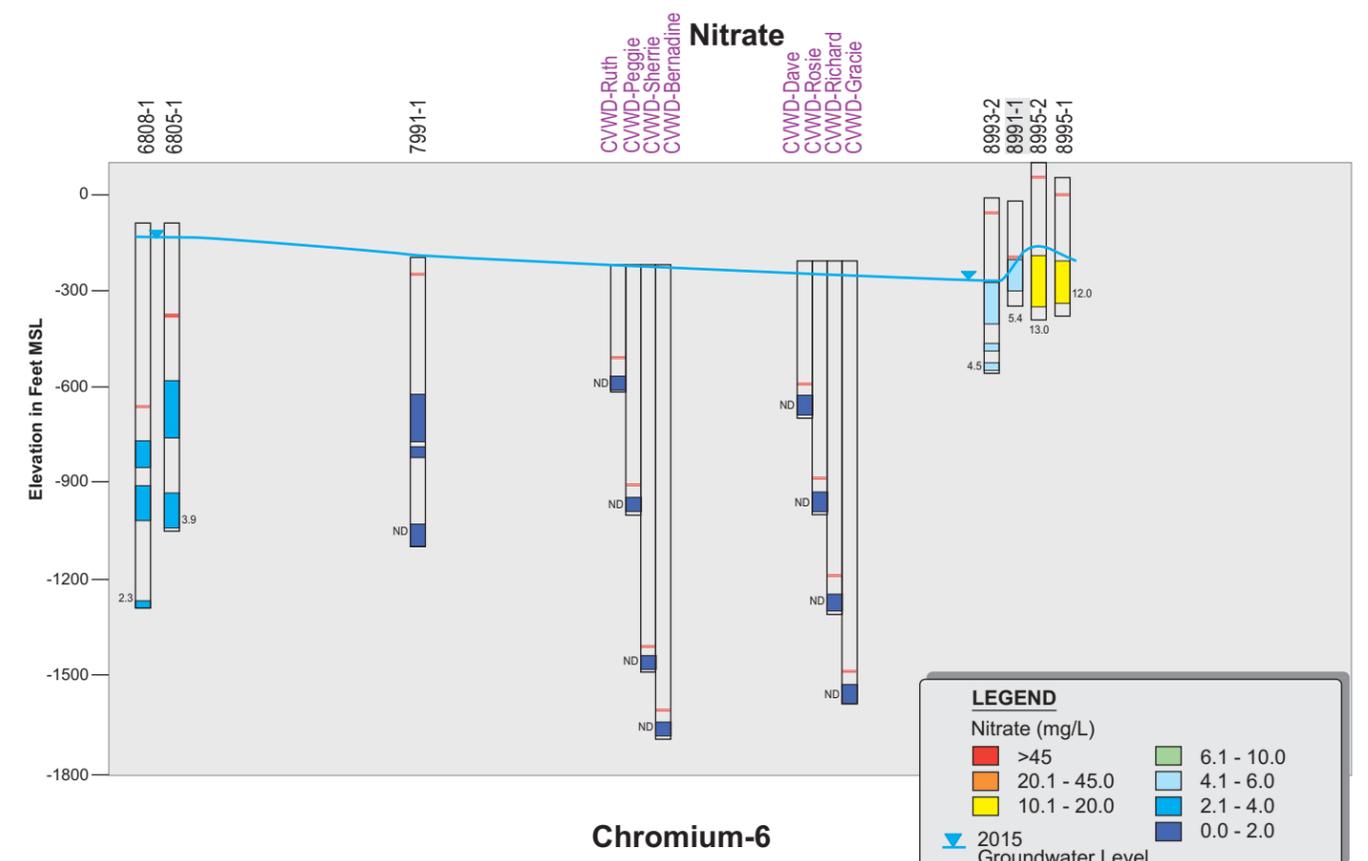
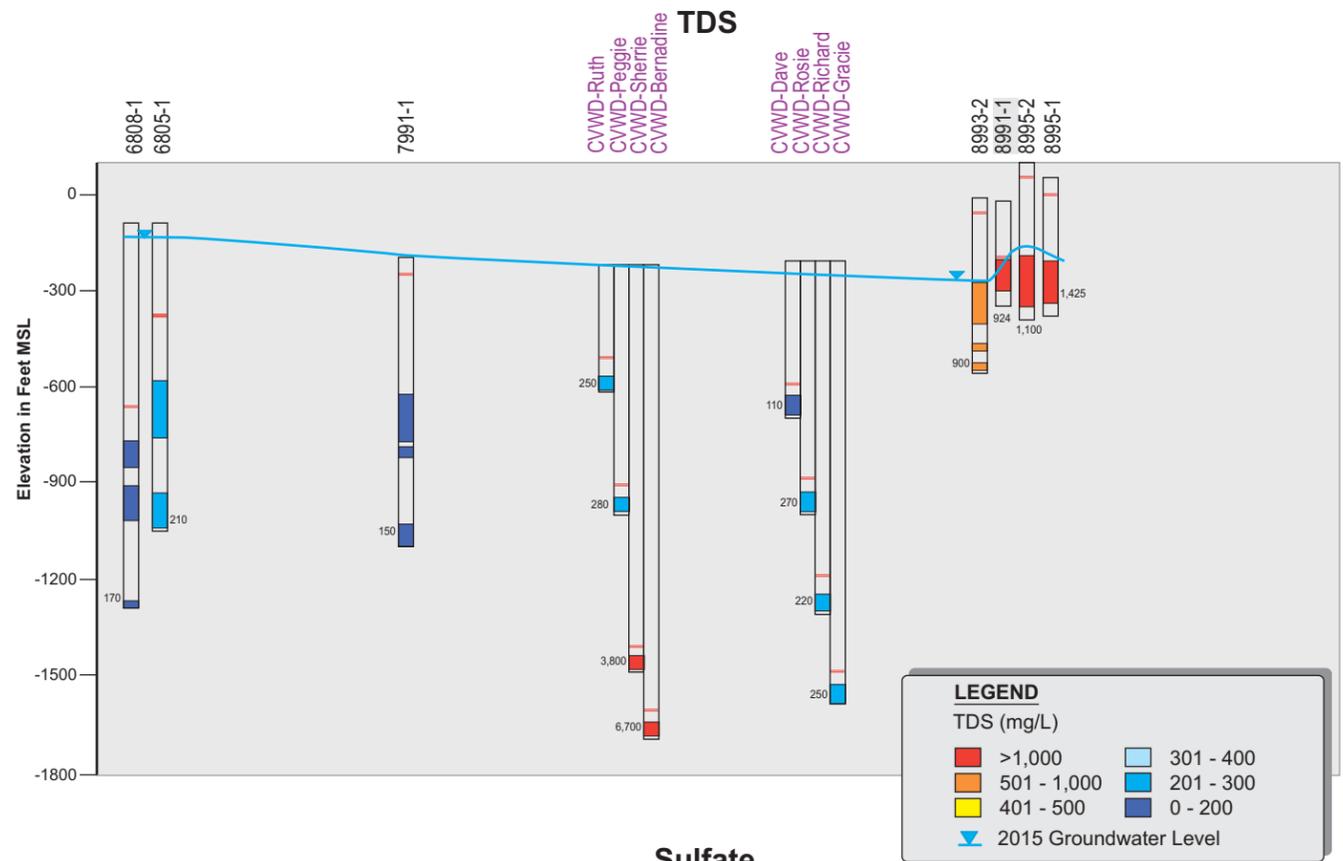
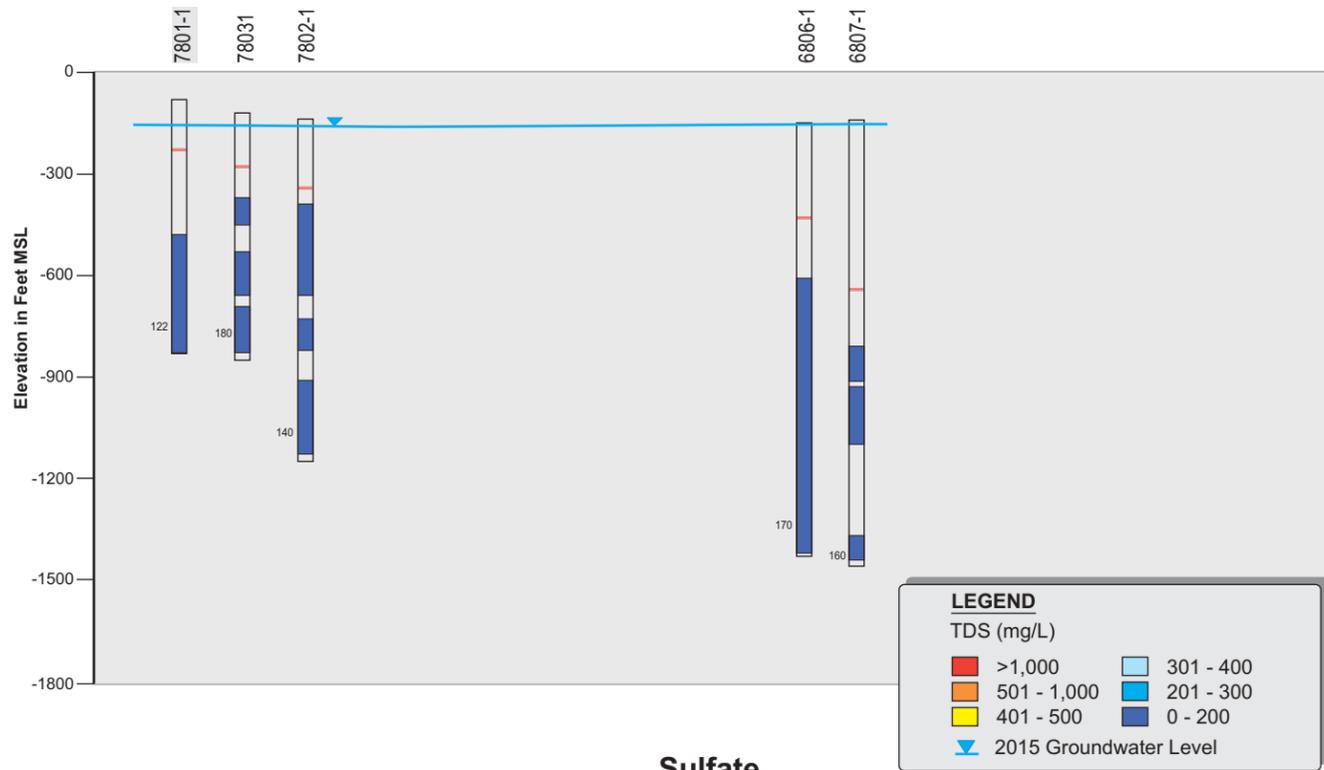
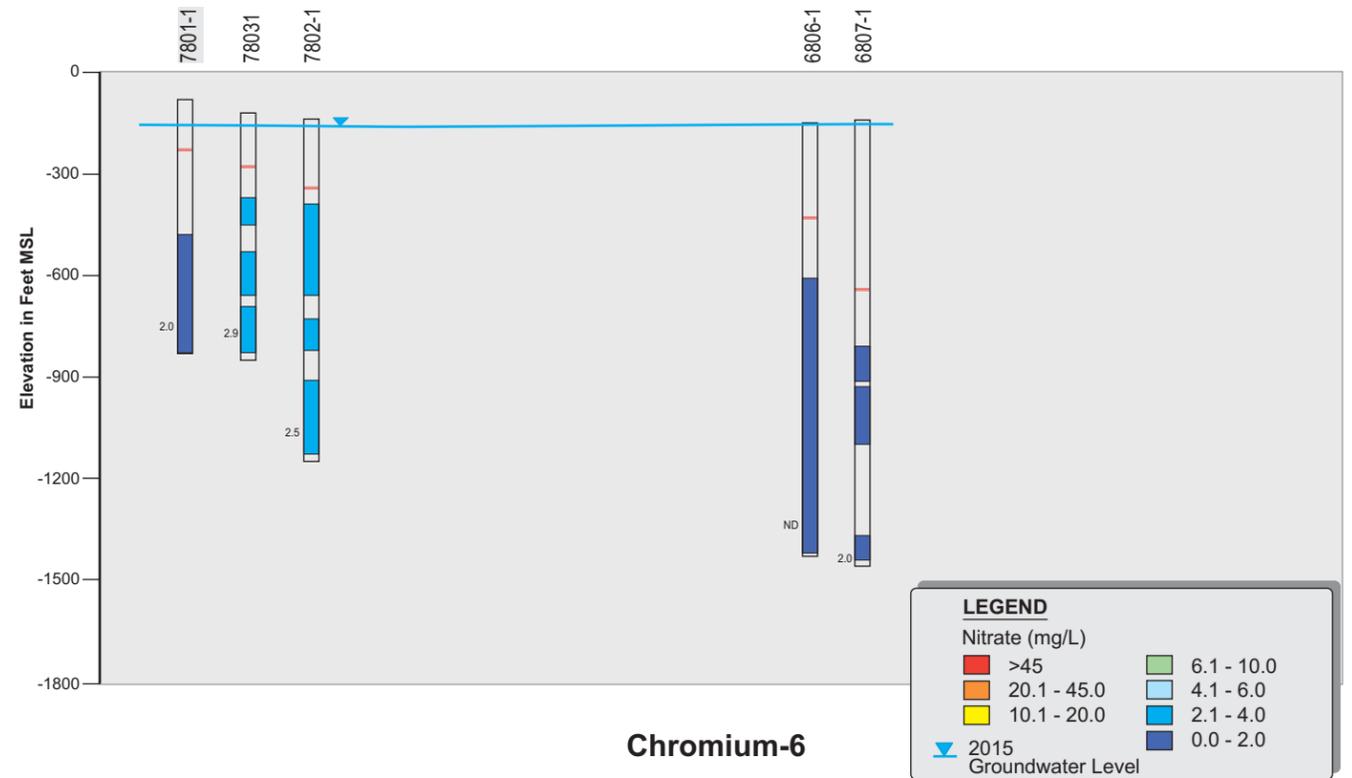


Figure 18
Cross Section I - I'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

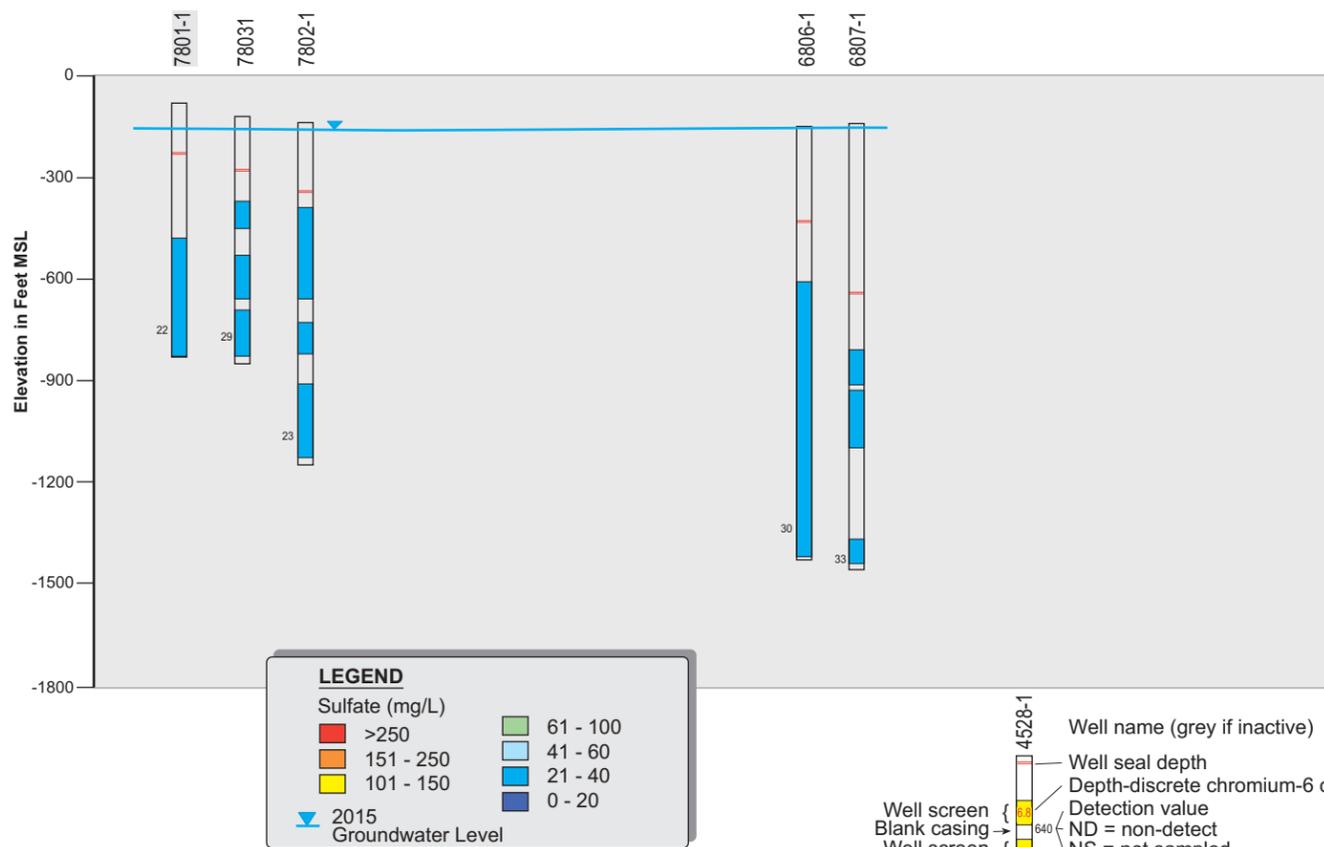
TDS



Nitrate



Sulfate



Chromium-6

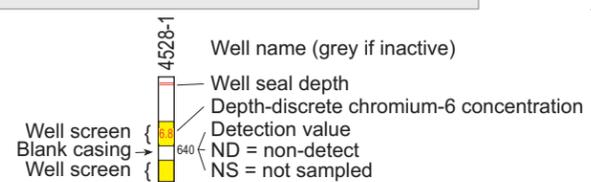
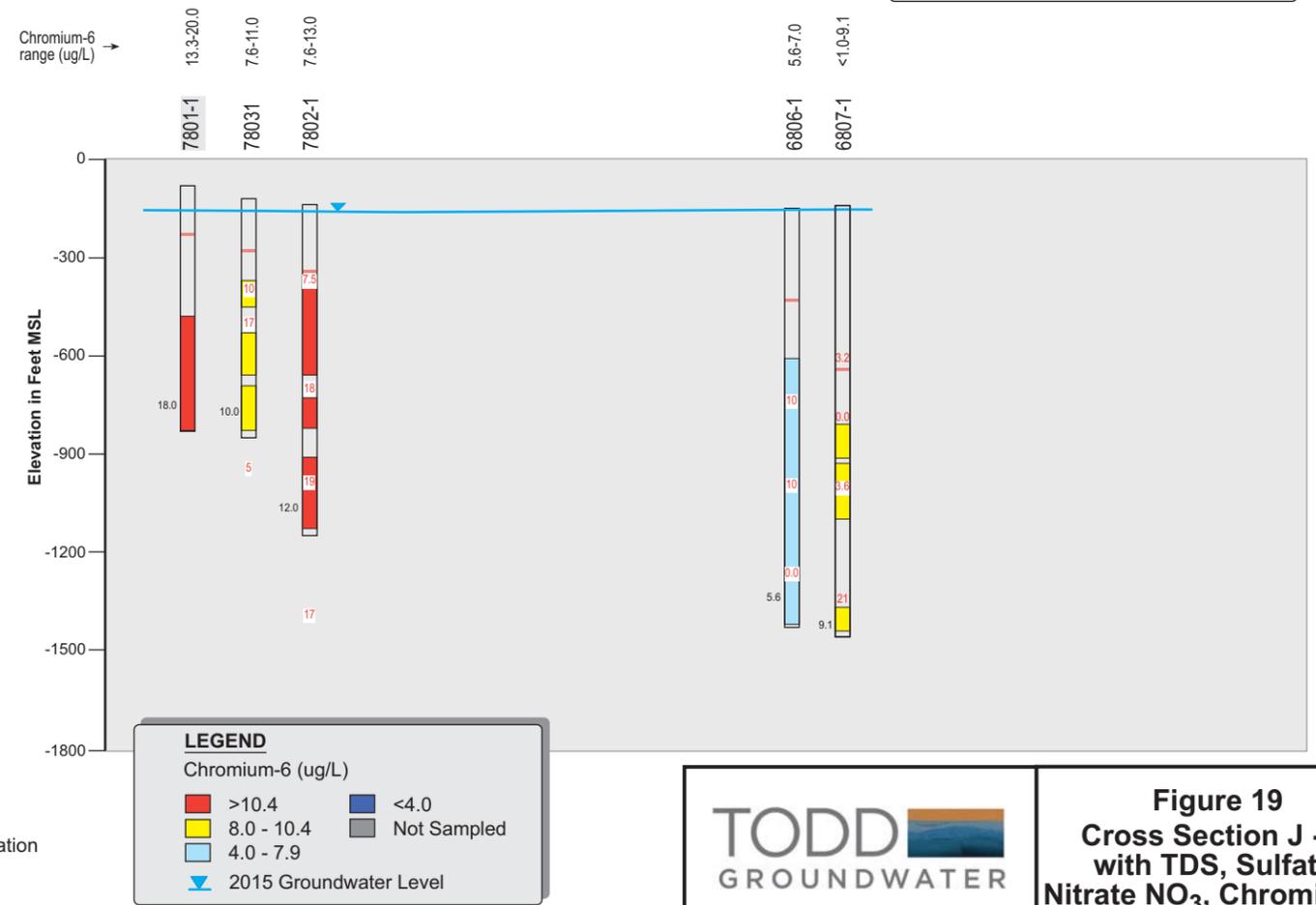
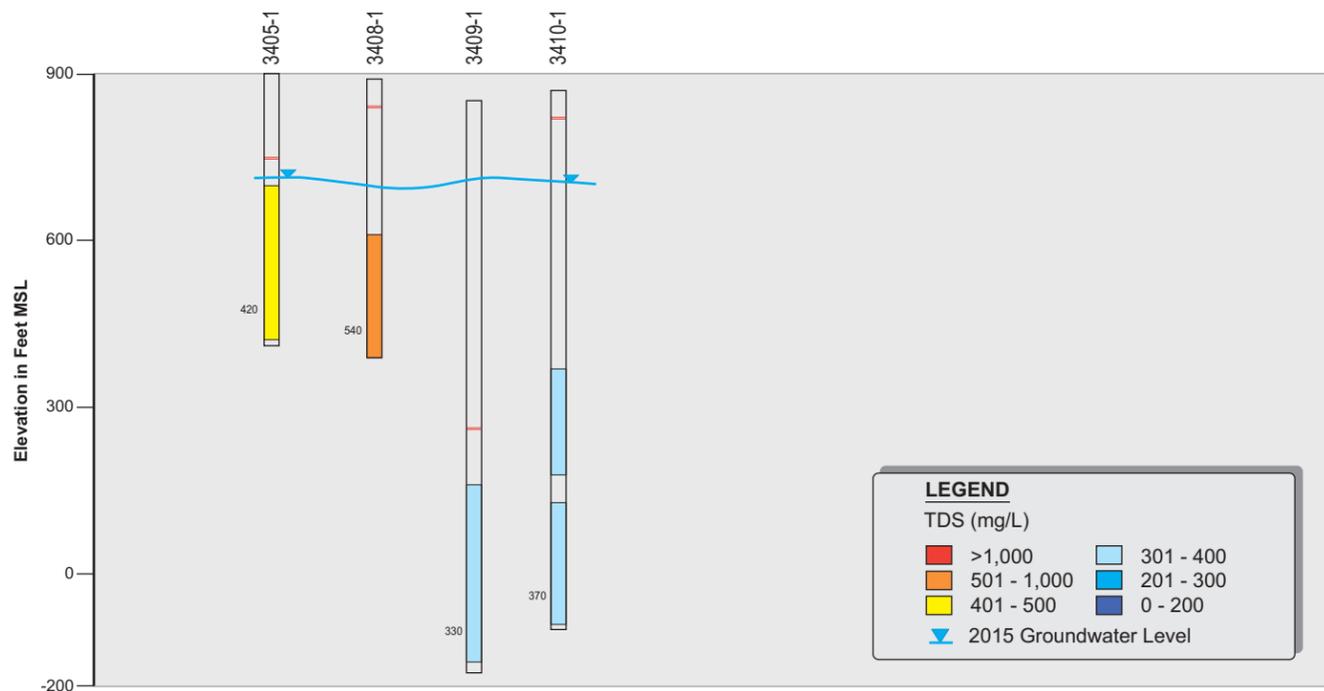
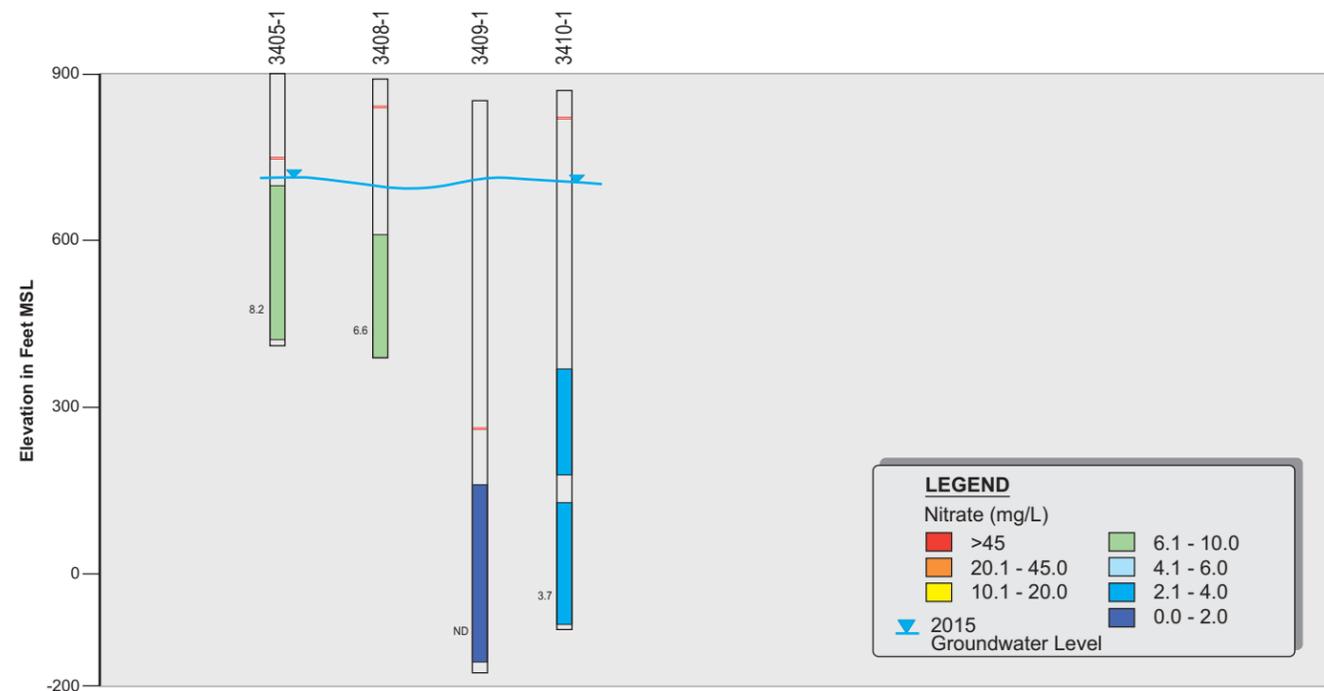


Figure 19
Cross Section J - J'
with TDS, Sulfate,
Nitrate NO₃, Chromium-6

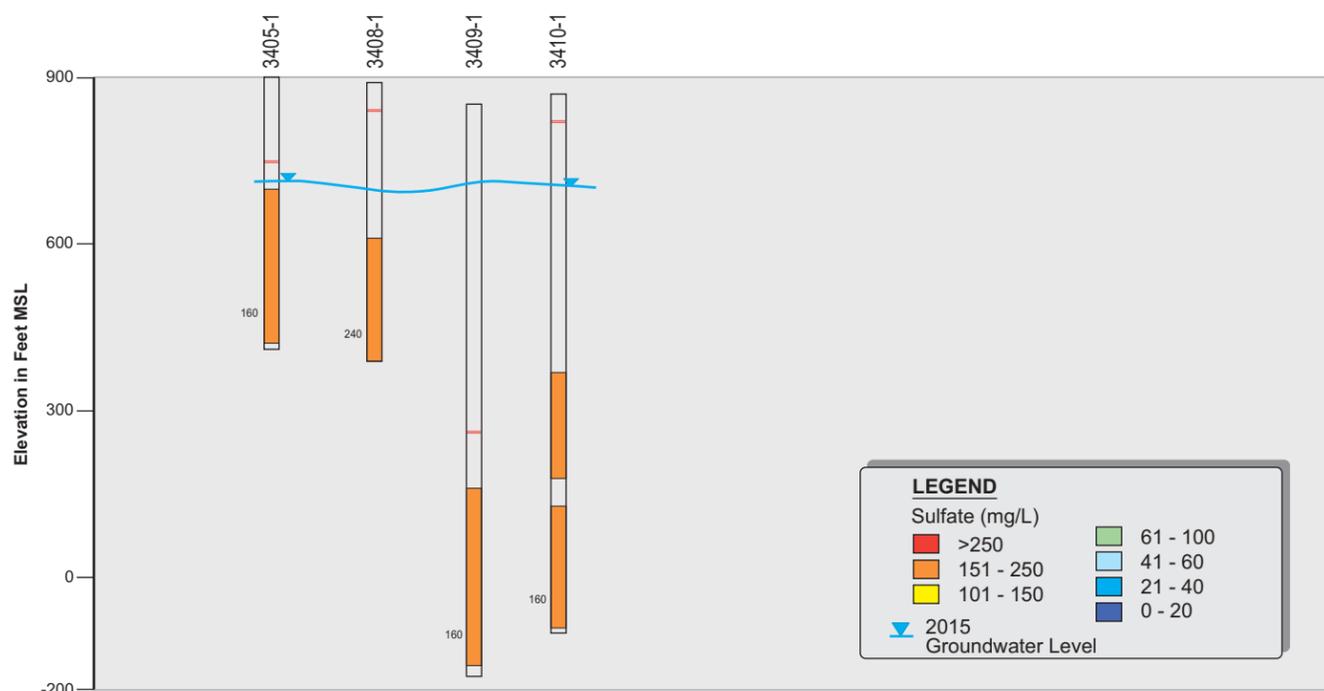
TDS



Nitrate



Sulfate



Chromium-6

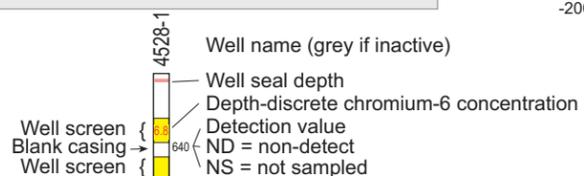
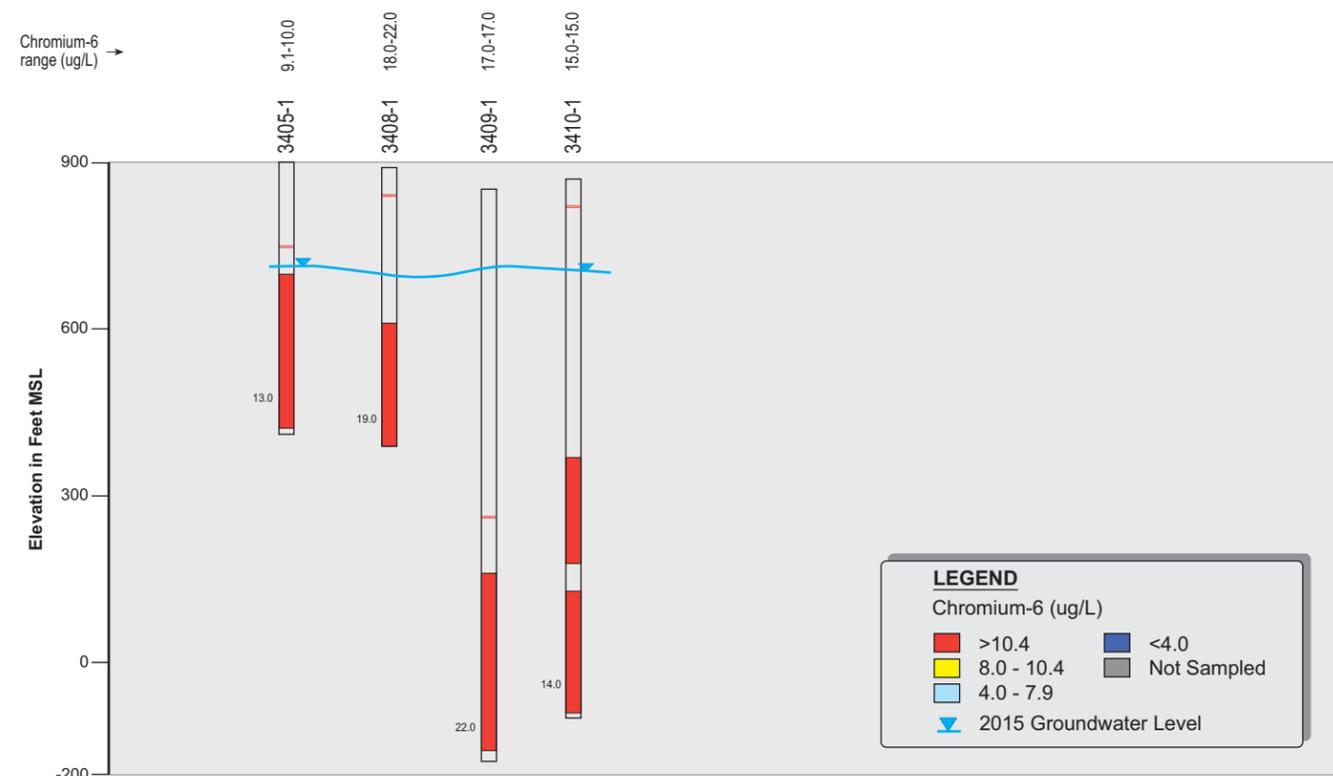
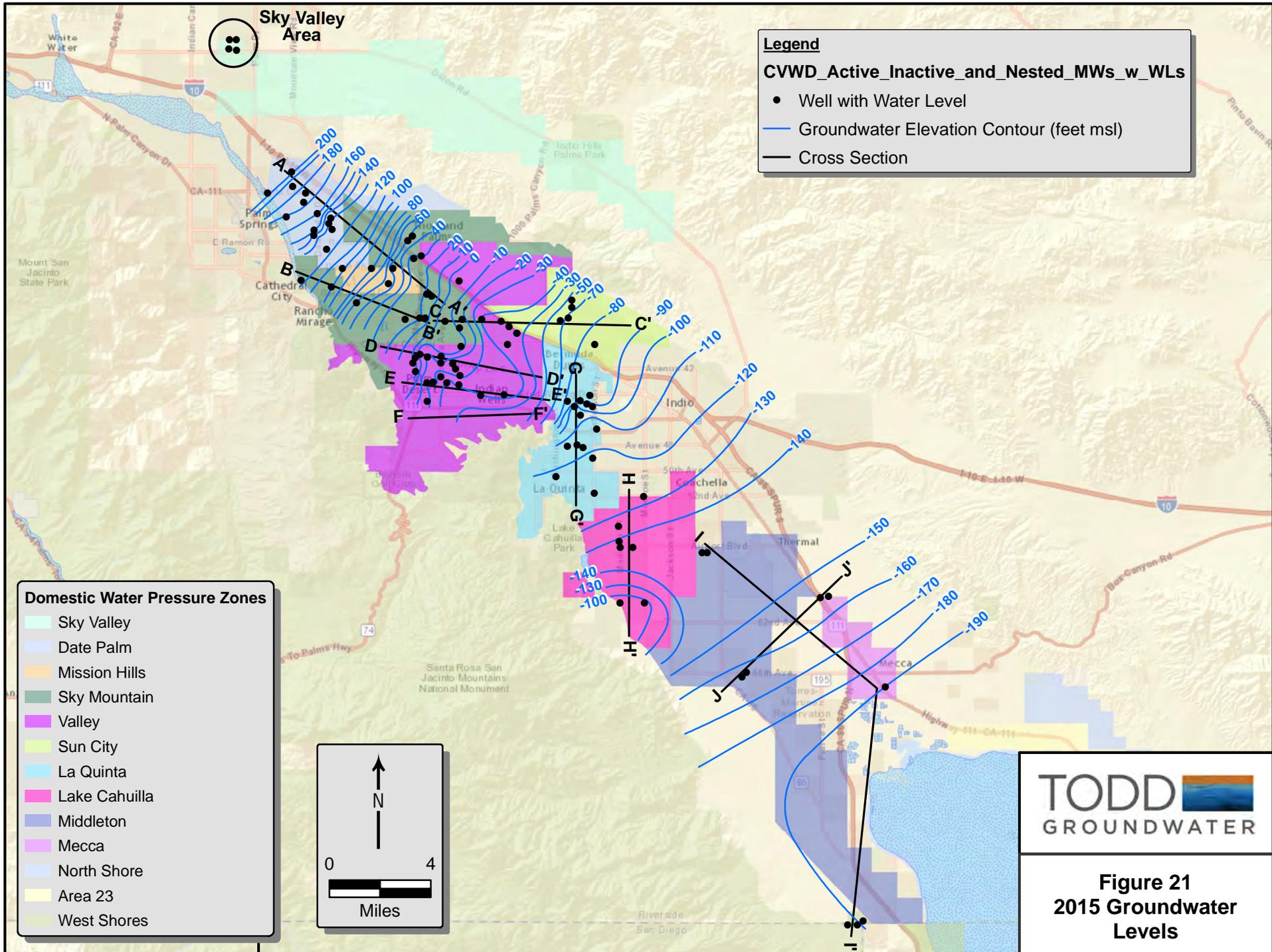
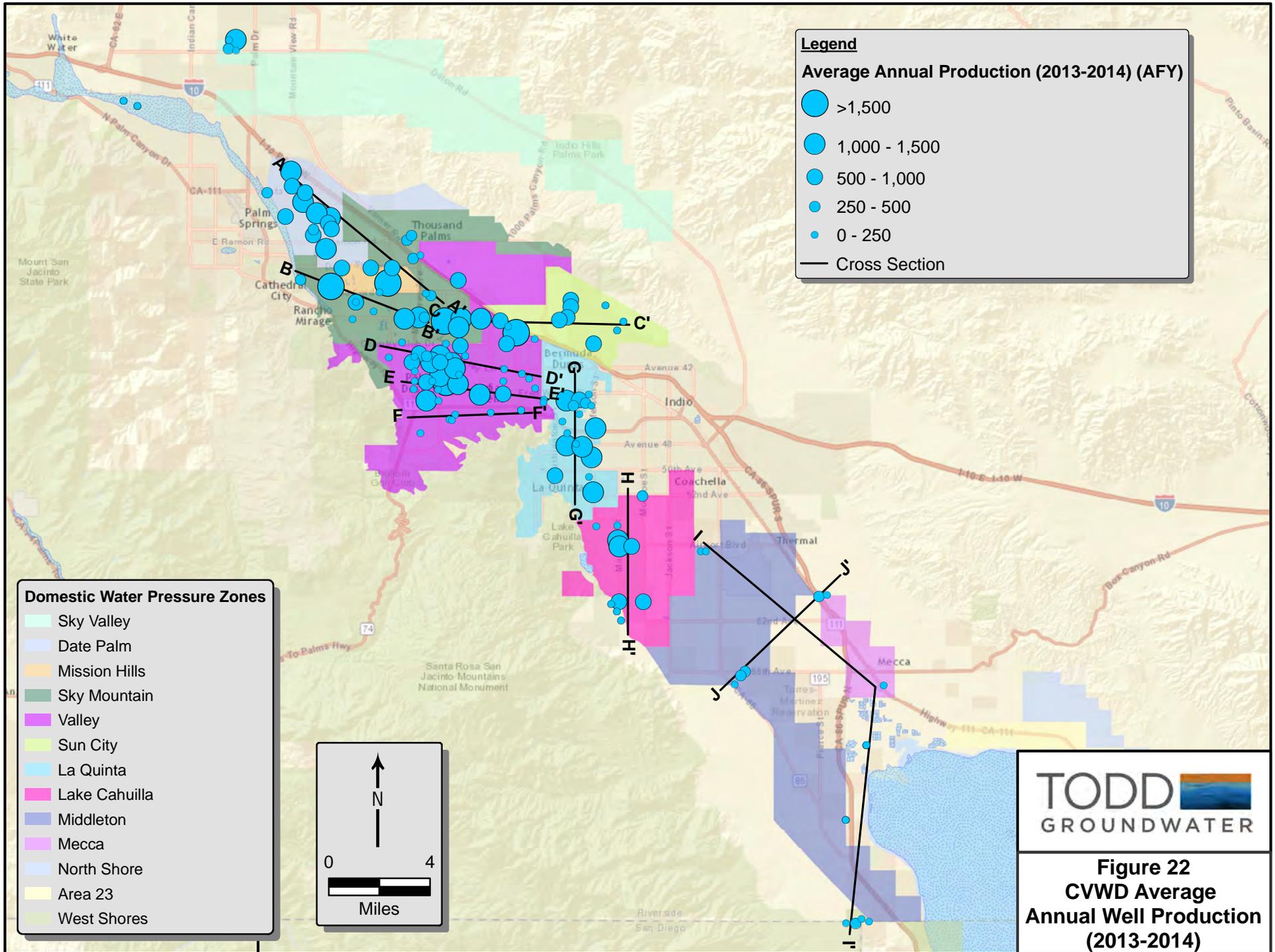
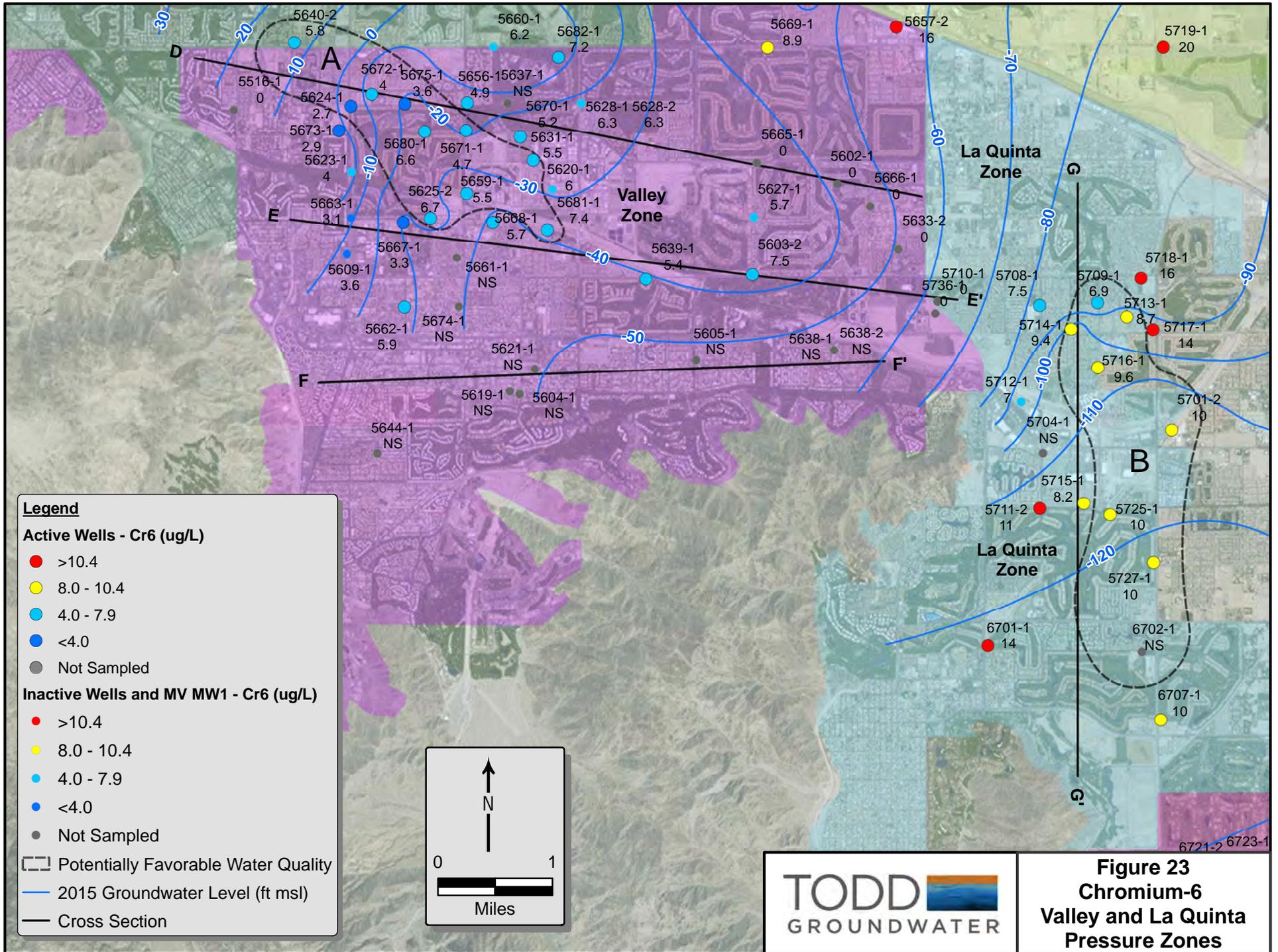
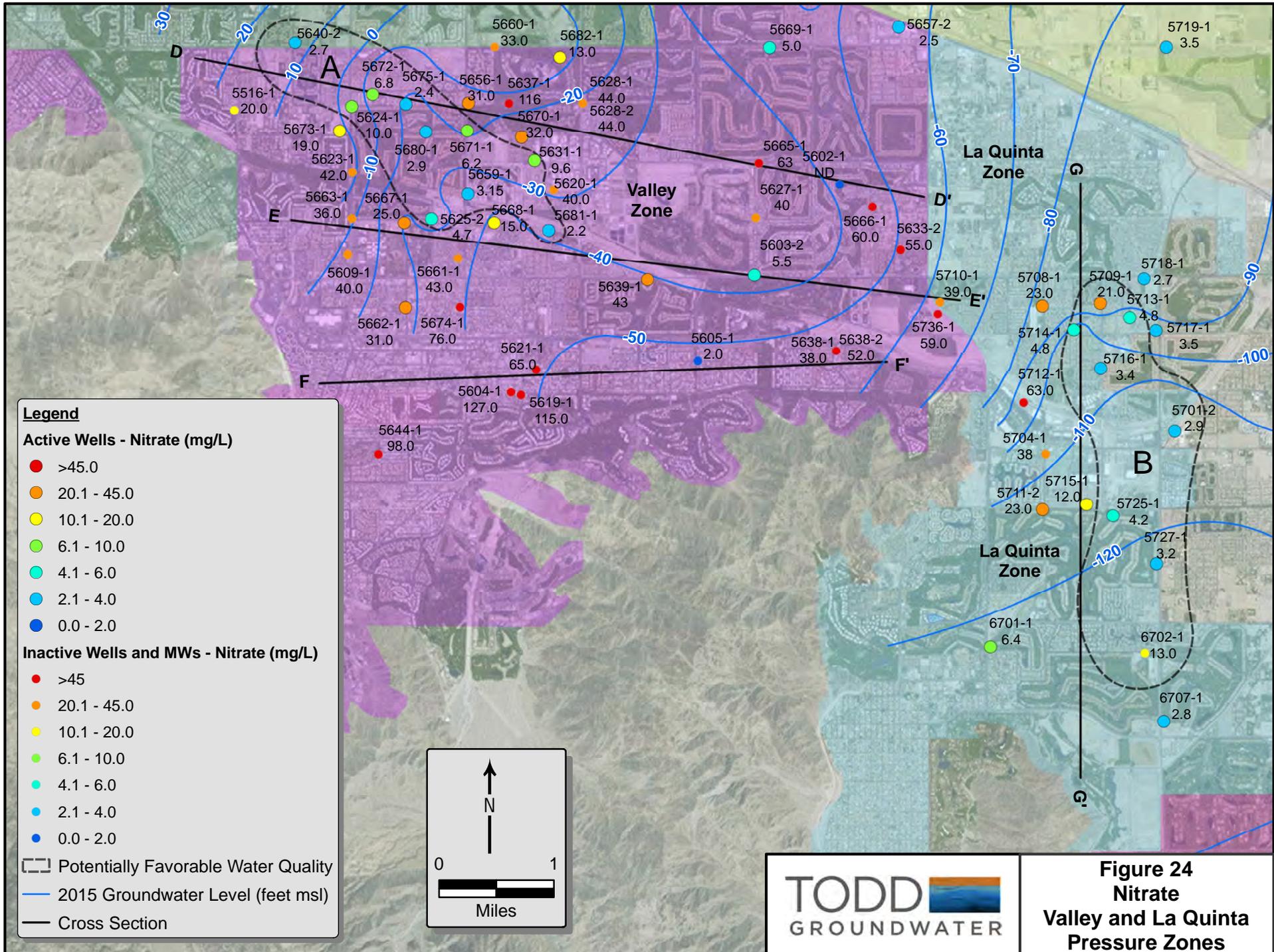


Figure 20
Cross Section Sky Valley with TDS, Sulfate, Nitrate NO₃, Chromium-6

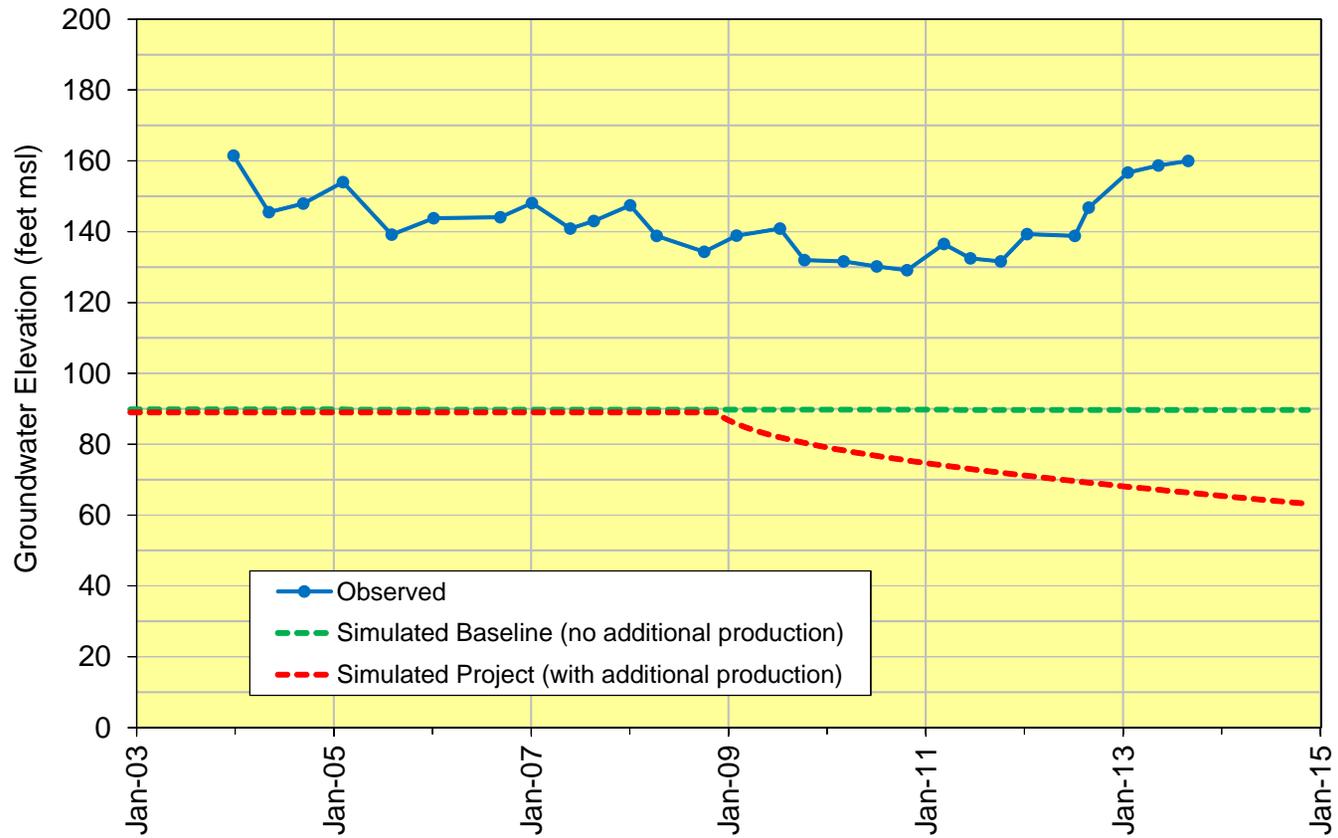








CVWD Well 4567-1
Ground Surface: 377 feet msl



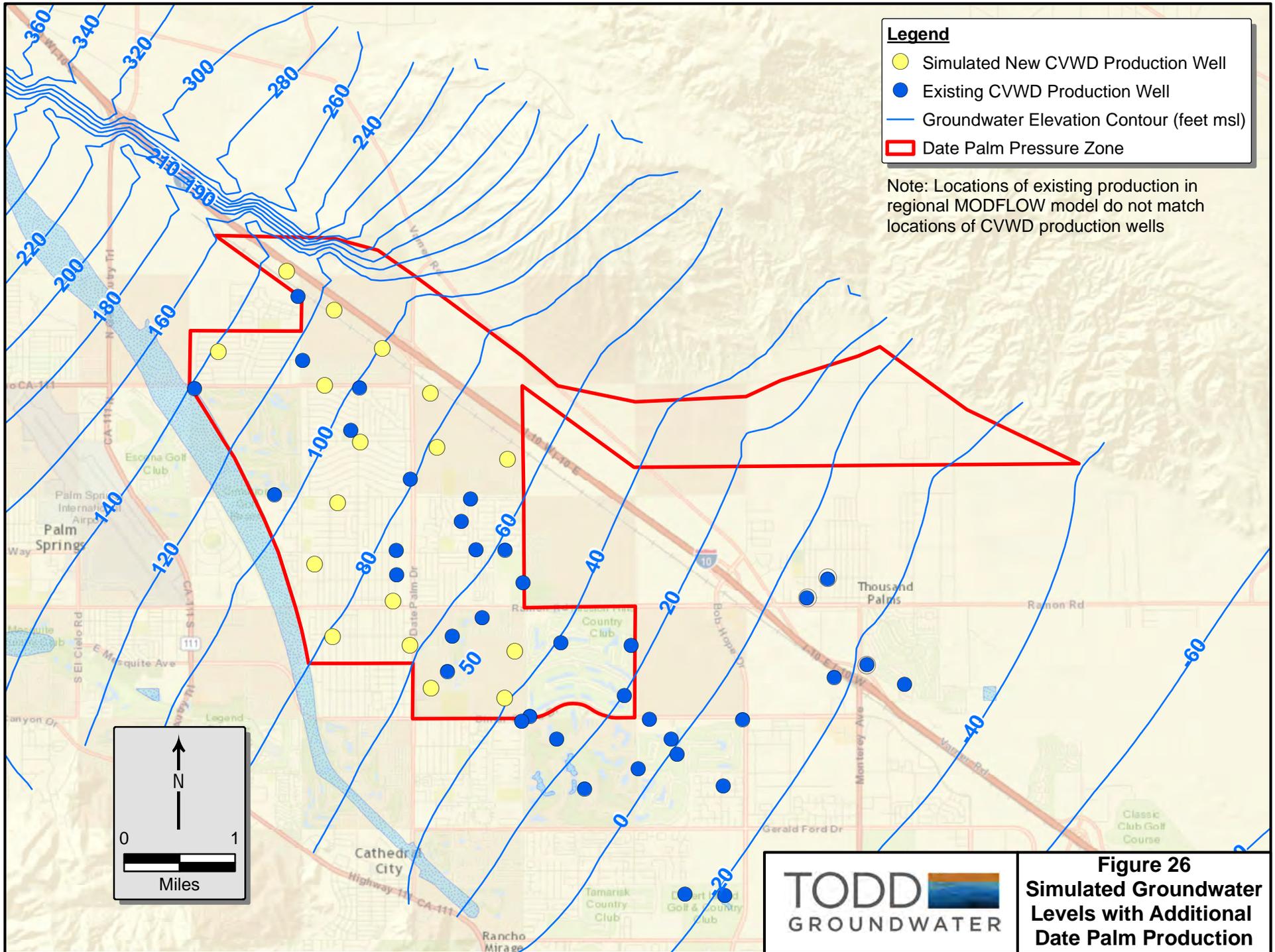


Figure 26
Simulated Groundwater
Levels with Additional
Date Palm Production

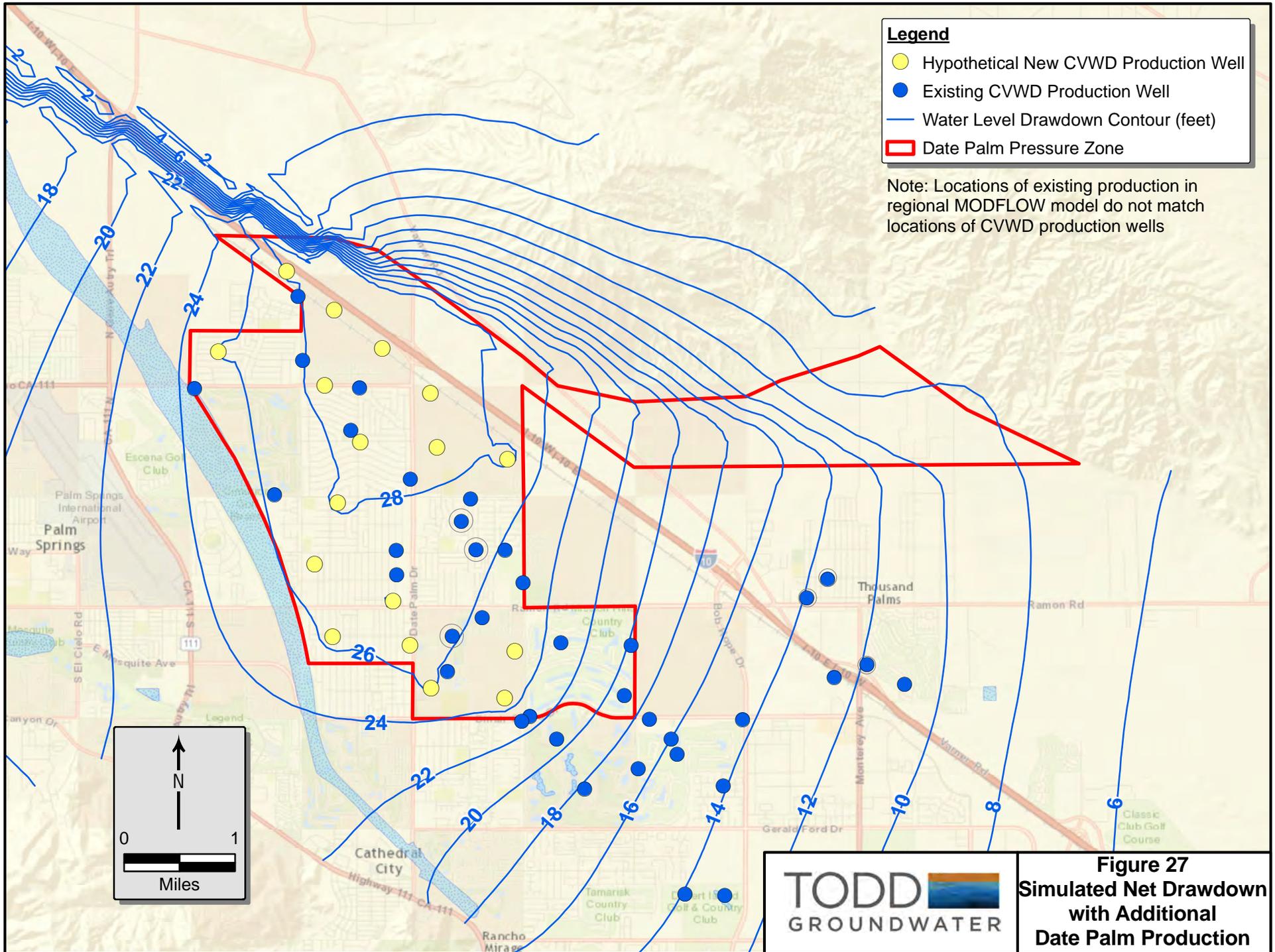


Figure 27
Simulated Net Drawdown
with Additional
Date Palm Production

