Technical Report

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

Prepared for

Montecito Water District

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Executive Summary

This report provides a feasibility analysis of using recycled water to augment the native supply of groundwater to the Montecito Water District (District) by installing injection and extraction wells in areas of the Montecito Groundwater Basin (Basin) that can be identified to meet logistical and regulatory constraints associated with indirect potable reuse (IPR) projects. GSI Water Solutions, Inc. (GSI), teamed with Geosyntec Consultants and Rick Hoffman (Hydrogeologic Consultant) for the data collection and data interpretation aspects of this report.

The team conducted extensive data collection and developed a comprehensive data set of known wells in the primary areas of interest. Three key sources for well data were used: the California Department of Water Resources (DWR) online inventory of well completion reports, the Santa Barbara County Environmental Health Service (EHS) paper well records, and data supplied by the District. The data were used to develop an online, browser-based, interactive web map and a 3-D geologic model illustrating the hydrogeologic conditions present within the District. From these data sets, important well information for the IPR evaluation were extracted, including well locations and ownership, specific capacity, and historical water levels.

This study reviewed the potential for implementing IPR projects generally throughout the District's service area. Particular focus was directed to specific areas of interest identified by the District where it owns groundwater rights, namely the Birnam Wood Development and Ennisbrook areas. A third area of interest—though the District does not explicitly own the groundwater rights—is the Toro Canyon area. Outside of these preferred areas, IPR opportunities were also considered and determined to be infeasible given the generally low permeabilities of the underlying aquifer and proximity to existing wells.

Based upon the work conducted in this technical study, two areas are identified where injection of recycled water could theoretically be accomplished: the south-central portion of Storage Unit 1 near the District/San Ysidro Road corridor and Jelinda Drive, and the eastern portion of Storage Unit 3 near the western edge of the Area of Interest (see Figure 3 and Figure 5). Based on a series of hydrologic assumptions, the injection and recovery capacity of these areas is estimated to be approximately 35 and 75 acre-feet per year (AFY), respectively. Importantly, these capacity values are likely not achievable in all years because of the tendency of the Basin water levels to be quite shallow following normal to high rainfall years. The potential exists for the lack of storage capacity to persist for several years in a row during some periods. If the District chooses to move forward with either or both of these locations, additional site characterization would be required to more accurately determine potential injection rates and other site-specific information, including installation and testing of temporary wells and further identification of nearby existing wells. Based upon the presence of private homes throughout the areas, site access and permissions for this testing could represent a significant challenge.

Except for the two areas identified in Storage Units 1 and 3, the remainder of the District is dominated by the presence of low-yielding wells (and therefore poor aquifer characteristics) and/or insufficient offset distance from existing wells that preclude further consideration for IPR potential.

SECTION 1: Introduction

1.1 Background

In an effort to continue the pursuit of local, drought-resistant water supplies, Montecito Water District (District) recently developed a Recycled Water Facilities Plan (Woodard & Curran, 2019) to evaluate recycled water as one of the options being considered to meet future water supply needs. At the request of the District, this report provides a feasibility analysis of using fully advanced treated recycled water[1] to augment the native supply of groundwater by installing injection and extraction wells in areas of the Montecito Groundwater Basin (Basin) that can meet logistical and regulatory constraints. The preferred aquifer characteristics are sufficiently high injection rate potential, available storage capacity, and adequate offset distances from existing wells. The District's recent Recycled Water Facilities Plan identified the potential availability of 500 acre-feet per year (AFY) of recycled water that could be used for both non-potable and indirect potable reuse (IPR) purposes (Woodard & Curran, 2019). Further, the District has expressed an interest in assessing the future potential of up to 1,000 AFY of groundwater augmentation capacity.

The District encompasses an area of 9,900 acres and serves a population of approximately 11,400 residents. The District's service area consists primarily of single-family residential homes located in the unincorporated communities of Montecito and Summerland, California. This report details the hydrogeological investigation that was performed to evaluate whether the Basin has the hydrogeologic characteristics necessary to implement an IPR program.

1.2 Current Use of Groundwater Basin

The Basin is highly utilized and has hundreds of existing water wells within a moderately dense suburban and rural environment. The District has 12 active wells located across the Basin that provide potable and non-potable water for the District's customers. Throughout the Basin, a large number of private domestic wells are used on individual parcels; most of these wells have low yields (10 gallons per minute [gpm] or less is common) and many are used for irrigation.

1.3 Areas of Montecito Water District Control (Areas of Interest)

This study addresses the feasibility of groundwater augmentation projects throughout the entire District, including particular focus on specific areas of interest identified by the District where it owns groundwater rights, namely the Birnam Wood Development and Ennisbrook areas. A third area of interest is the Toro Canyon area, although the District does not own the groundwater rights there. These three areas are highlighted in blue on Figure 1. Outside of these areas, IPR opportunities were also considered. The Birnam Wood Development and Ennisbrook Development areas and the Toro Canyon area are the primary focus of this feasibility study.

[1] Fully advanced treated recycled water, as specified in Woodard & Curran (2019), can be defined as follows: "The common advanced treatment train consists of microfiltration (MF) or ultrafiltration (UF), reverse osmosis (RO), and an advanced oxidation process (AOP) and is designed to meet DDW 12/10/10 (enteric viruses/cryptosporidium/giardia) log removal requirements. MF or UF removes residual particulate matter, RO demineralizes and removes chemical constituents, and AOP is used to destroy or alter chemical constituents that are not oxidized completely by conventional biological treatment processes or removed by filtration; AOP also provides disinfection benefits. AOP includes ultraviolet (UV) disinfection with hydrogen peroxide, ozonation, or chlorination."

1.4 Collaboration with Geosyntec and Rick Hoffman

GSI Water Solutions, Inc. (GSI), teamed with Geosyntec Consultants (Geosyntec) and consultant Rick Hoffman for the data collection and data interpretation aspects of this report. Geosyntec led the data-gathering effort, which focused on the acquisition of readily available groundwater data in the vicinity of the Birnam Wood and Ennisbrook areas, Toro Canyon, and to a lesser degree in the surrounding areas of the District. With the intention of creating a more comprehensive compilation of known well data for the District, Geosyntec compiled well construction, production, and water level data from records available from the District, the Department of Water Resources (DWR) and Santa Barbara County Environmental Health Service (EHS). This comprehensive well data set, including other informative spatial data sets such as surface geology and faults, were used to develop an online, browser-based, interactive web map. Geosyntec also developed a 3-D geologic model of the District using a digital elevation model (DEM) in conjunction with existing cross sections and maps from various reports, such as the Safe Yield Evaluation of the Montecito Basin and Toro Canyon Area by Hoover (1980). The model allows the user to see the spatial extent and depth of the known wells in the District, view interpretations of the subsurface geology, and map groundwater elevations during various years.

Rick Hoffman provided valuable support in well log interpretation and hydrogeologic characterization of the District areas. Having worked extensively in the Basin over the past 30 or more years, he was able to supplement the publicly-available well data with data from his private data sets. No confidential data were used in Geosyntec's database nor in this report, but the data did beneficially inform the hydrogeologic interpretations of many key areas throughout the Basin.

SECTION 2: Basin Characteristics Essential for IPR

There are a number of hydrogeologic characteristics that a basin must demonstrate for an IPR project to be feasible.

1. **Aquifer Transmissivity and Specific Capacity** – The *transmissivity* of the target aquifer is one of the main factors determining the amount of water that can be injected into the target aquifer. Transmissivity, similar to hydraulic conductivity or permeability, is a measure of the ability of an aquifer to transmit groundwater horizontally through the aquifer. Another hydrogeologic term used in the analysis is *specific capacit*y, which is defined as the ratio of flow rate of a well to the water level drawdown measured in the well during pumping, expressed as gpm/foot of drawdown. For both transmissivity and specific capacity, higher values are more favorable for both pumping and injection. Only a small number of wells (fewer than 10) in the Basin exhibit flow rates, transmissivity, and specific capacity values in excess of 75 gpm, 1,000 gallons per day per foot [gpd/foot] and/or 0.75 gpm/foot of drawdown, respectfully. While these figures are not absolute values to be used as a basis for implementing a successful IPR program, they provide a measure for determining which areas can be demonstrated to have relatively better hydrologic characteristics.[2]
2. **Water Levels and Storage Capacity** – Existing water levels in the target aquifer are another key factor in determining the aquifer's capacity to accept injected water. The higher the water table, the less water can be injected due to mounding (drawup, i.e., the opposite of drawdown created during well pumping) of water at the point of injection. Greater depths to water are more favorable for IPR because there is more space to store the water. Another important consideration is the aquifer response to seasonal wet and dry periods. Due to the continuous supply of recycled water, an IPR project will not be effective if the target aquifer partially or completely fills up during the rainy season, meaning it cannot accept IPR water year-round. The Basin generally responds rapidly to recharge during periods of above average rainfall and runoff. As shown in Section 5 below, our review of area hydrographs show that there are long periods when the Basin has minimal amounts of available storage due to high water table conditions.
3. **Existing Well Locations** – The Basin is a mature basin with hundreds of private, shared, and public domestic and irrigation water wells. Areas with a high density of production wells can be problematic for IPR projects. Replenishment wells and local domestic, irrigation or municipal supply wells must be far enough apart to allow adequate retention time, or residence time, in the aquifer to meet regulatory requirements for injection of advanced treated recycled water. A minimum of two to four months of groundwater retention time is required for recharge projects using advanced treated recycled water.

[2] By comparison, the successful Orange County Groundwater Basin recharge injection project has wells that produce at flow rates in excess of 2,000 gpm, have transmissivity values of >100,000 gpd/foot of available aquifer and have specific capacities of >100 gpm/foot of drawdown.

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SECTION 3: Groundwater Basin Hydrogeology

The Basin is bounded by the Santa Ynez Mountains to the north and the Pacific Ocean to the south. The western and eastern portions of the Basin pinch out against bedrock. Four subunits within the Basin are defined by Hoover (1980) as Storage Unit 1, Storage Unit 2, Storage Unit 3, and the Toro Canyon area. The Toro Canyon area is not hydrologically connected to the Basin and is described separately from the main portion of the Basin. In fact, the Toro Canyon Subbasin is inferred to be hydrologically connected to the Carpinteria Groundwater Basin. A geologic map of the Basin is shown on Figure 2.

The shallower portions of the sedimentary profile within the four main storage units of the Basin are composed of alluvium, older alluvium, and fanglomerate.[3] The alluvial aquifers located in the shallow sub-surface are generally less than 60 to 80 feet and parallel the major creek corridors that cross the area in a general north-to-south direction. The alluvium, older alluvium, and fanglomerate were deposited as moderate to large-scale alluvial fans and mudflows originating along the base of the Santa Ynez Range during periods of heavy rainfall and associated runoff events. Deposits within the active ancient creek corridors contain larger-sized sediments, such as boulders, up to several meters in diameter. Some of these high energy deposits have moderate porosity and permeability and can be water-bearing. However, these sinuous ancient, now buried, creek corridors have a relatively small subsurface footprint within the overall Basin area and are difficult to identify at the surface. Much of the remainder the alluvial/fanglomerate sequence is composed of lower energy over-bank deposits that are dominated by clay-rich, sandy to cobble-sized conglomerates. There are also mud and debris flow deposits throughout much of the Basin that are composed of large cobbles and boulders supported in a clay-rich matrix. These deposits with high concentrations of clay commonly have low transmissivity and specific capacity values, resulting in unfavorable aquifer conditions.

The underlying Casitas Formation is lithologically similar to the fanglomerate, but generally more fine-grained, including relatively thin zones of well sorted sand and gravel that can be water bearing. Underlying the Casitas Formation, the Santa Barbara Formation is a marine deposited sequence of clays, silts and interbedded sand. The Santa Barbara Formation is only encountered in the deeper portion of Storage Unit 3 and in the southern portion of the Toro Canyon area. Many of the larger yielding wells in Storage Unit 3 are inferred to produce groundwater from either the Casitas Formation or the Santa Barbara Formation.

Based on numerous well logs and Rick Hoffman's personal experience from drilling in the Basin, clay-rich over-bank and debris flow deposits dominate the stratigraphic profile within much of the shallower portions of the Basin, especially within Storage Units 1 and 2. This opinion is supported by the presence of only a few moderately yielding wells within most of the Basin. The more successful, higher flow rate wells are typically located in relatively narrow, linear areas that most likely represent the aforementioned ancient creek corridors that bisected the Montecito area. However, even within these hydrologically superior areas, the specific capacity of wells rarely exceeds 1 gpm/foot of drawdown. Outside of these relatively small areas, well yields of less than 10 to 20 gpm and specific capacities of less than 0.5 gpm/foot of drawdown dominate the remainder of the Basin. These characteristics are not favorable for IPR projects.

The 3D geologic model of the Basin was developed to better understand the relationship between the geology, the existing (and known) wells within the District boundaries (especially in and around the areas of interest), and hydrogeologic characteristics of the Basin. The model was constructed using Earth Volumetric Studio, or EVS (C Tech, 2019), a widely recognized, industry standard tool for building 3D models of the subsurface. A single DEM was created using two DEMs from the U.S. Geologic Survey (USGS) National

[3] Fanglomerate is a geologic term that refers to sedimentary rock, similar to a conglomerate, consisting of slightly waterworn, heterogeneous fragments of all sizes, deposited in an alluvial fan and later cemented into a firm rock; it is characterized by persistence parallel to the depositional strike and by rapid thinning downslope.

Elevation Database (USGS, 2018). This DEM was used to represent the ground surface, constraining the upper boundary of the model. The geologic map and cross sections from the Hoover (1980) report were used as the framework to build 3D surfaces representing important faults and geologic formations. Geographic layers were imported to the model to visualize aerial imagery, the District boundary, areas of interest, and well locations. Additionally, all known well screens were imported, along with historic water levels from wells owned by the District. The model demonstrated the abundance of existing wells and the density of well screens, particularly in and around the areas of interest. The model also demonstrated the significant effect on available storage caused by elevated bedrock and water level fluctuations over time. Visualizations of the geologic model are shown in Appendix A.

SECTION 4: Data Collection

4.1 Previous Studies

There have been numerous hydrologic investigations of the Basin by others in the past, some of which date back to the 1950s. Some of the more comprehensive reports for this area include the following:

- Geology and Ground-water Resources of the South-Coast Basins in Santa Barbara County, California (Upson, 1951)
- Hydrologic Investigation of the Montecito Ground Water Basin (Geotechnical Consultants, 1979)
- Safe Yield Evaluation of the Montecito Basin & Toro Canyon Area (Michael Hoover, 1980)
- Hydrologic Assessment, Determination of Groundwater in Storage within the Montecito Water District (Richard Slade, 1991)
- Montecito Groundwater Basin (within California Department of Water Resources Bulletin 118, 2004)
- Montecito Groundwater Basin Recharge Feasibility Study (Dudek, 2015)

Many of these reports, particularly Hoover (1980) and Slade (1991), focus primarily on the volume of available groundwater in storage within the four main subunits of the Basin. Storage is calculated by multiplying the area of each storage unit, the saturated thickness of that storage unit (based on the water table elevation in a particular period), and an estimated specific yield value (a function of porosity). Though the calculated values presented in each report vary, they are generally on the same order of magnitude and the reports agree on the qualitative storage capabilities of the subunits in comparison with the others. The consensus among the studies is that the Toro Canyon area and Storage Unit 2 have markedly lower groundwater storage capabilities compared with Storage Units 1 and 3.

Unlike the older reports, Dudek (2015) focuses primarily on the feasibility of artificial recharge by injection into the basin aquifers. Dudek (2015) utilizes important aspects of the earlier reports in conjunction with more current groundwater level and pumping data to provide general recharge estimates for the same Storage Units (1, 2, 3, and Toro Canyon). The resulting calculations are again in general agreement with the prior studies, indicating that Storage Units 1 and 3 have significantly more storage and recharge capacity than Storage Unit 2 and Toro Canyon. Dudek (2015) provides a strong foundation for evaluating the feasibility of recharge in the Basin, but like the reports that precede it, it provides only a general analysis of each of the storage unit as a whole. In reality, storage units are not homogenous and have a great deal of hydrogeologic variability. This report attempts to address some of that variability by focusing the recharge feasibility analysis on specific areas within each storage unit.

Dudek (2015) provides valuable insight into the groundwater retention time aspect of IPR feasibility. The report discusses a range of retention times (2 months, 4 months, 6 months, and 8 months) based on a calculated groundwater velocity. Dudek (2015) provides a defensible estimate for groundwater velocity in the Basin by utilizing recent pumping test data and synthesizing hydraulic gradient and specific yield estimations from previous reports. The resulting calculations for groundwater retention times are considered appropriate for use in this study.

The Hoover (1980) report was particularly helpful for the geologic interpretation included in this report. Hoover (1980) contains detailed cross sections through several portions of the Basin that are based on numerous water well drilling logs and interpretations of geologic structure (e.g., faults and folds) in the area. As mentioned previously, the cross sections from this report largely informed the design of Geosyntec's 3-D model of the District area, as described below.

4.2 Well Locations

The well information database compiled by Geosyntec shows the location of some, but not all wells in the District area. Three sources of data were used: the California DWR online inventory of well completion reports, the Santa Barbara County EHS paper well records, and data supplied by the District. Information from these three agencies represent the extent of publicly available well data in the area.

The DWR online database consists of redacted well completion reports of varying quality, associated with map locations of varying accuracy. California Water Code Section 13751 requires that “anyone who constructs, alters, or destroys a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well must file with the Department of Water Resources a report of completion within 60 days of the completion of the work.” All available well completion reports within the District area were downloaded from the DWR online database using the DWR Well Completion Report Map Application and incorporated into Geosyntec’s database. The well records are accompanied by a longitude and latitude provided by DWR; however, many records are only associated with the center of the township and range quadrant in which the well resides, and not a precise and accurate location. Any records determined to possibly be within 1,000 feet of the primary areas of interest for this study were more precisely located manually in ArcGIS software using assessor parcel numbers (APN), hand-drawn maps, addresses, or other location information available in the well records.

The EHS well records exist only in paper format, requiring physically collecting files from the County records office. For the sake of efficiency, Geosyntec collected and extracted data from all the records associated with parcels within a 1,000 feet of the primary areas of interest. This additional data collection, though tedious, proved quite valuable, as many of the EHS records were not already included in the DWR database. Some well records included only filed installation permits, but no record of well installation, meaning the existence of the well is not known and details like screen depths and pumping information were not available. Some duplicates were recognized during examination of the DWR and EHS well records; however, a comprehensive duplicates analysis was not performed, due to time and budget constraints. The District supplied a variety of well data, including locations and water levels for District-owned wells.

Some wells were not mapped for the following reasons:

- The well completion report did not contain sufficient location data to map the well.
- The well record exists only in the County database and is not within 1,000 feet of the areas of District control.
- No record was submitted to DWR or the County by the well owner (it is inferred that there are a number of undocumented wells within the Basin).

The uncertainty of well locations can be problematic for the retention time aspect of IPR, as discussed in Section 5.

SECTION 5: IPR Assessment by Area

5.1 Basin Overview

Although this IPR feasibility study is focused mainly on a few select areas of interest, the entire District service area was considered for IPR potential. Unfortunately, the aquifer characteristics in the majority of the Basin are not favorable for an IPR project based upon the review of the criteria presented in Section 2.

Figure 3 shows existing well locations, zones with relatively high yielding wells and high specific capacities as defined in Section 2, and other geologic features. One such feature is the approximate location of the northern extent of the saturated alluvial aquifer (see dark red line on map), which is based on both publicly available and private well data provided by Rick Hoffman. Shallow bedrock and limited alluvial aquifer space would effectively prevent injection activities from being performed north of this approximated limit.

A major challenge for IPR throughout the Basin is the poor aquifer transmissivity and low production rates that exist in the majority of the Basin. Higher production rates, which are associated with the high transmissivity and specific capacity values necessary for IPR, are generally found only within the few specific areas highlighted in pale green color on Figure 3. These highlighted zones represent areas with a small number (fewer than 10) of existing wells with production rates of 75 gpm or higher and specific capacities of 0.75 gpm/foot or higher. This is the minimum degree of production capacity that would be necessary for IPR to be considered for a small-scale injection program, and still most of the Basin has poorer production capacities. For comparison, the highly successful Orange County Groundwater Basin recharge injection program has wells that commonly produce at flow rates in excess of 2,000 gpm, with transmissivities greater than 100,000 gpd/foot of aquifer thickness, and specific capacities of more than 100 gpm/foot of drawdown.

Another challenge for IPR in the Basin is the density of existing wells. As illustrated on Figure 3, the Basin has a large number of existing, known, active wells. Most well locations are known, but the Basin is inferred to have additional wells that are undocumented. As mentioned previously, injection wells must be located far enough away from any other producing well to meet the State's Department of Drinking Water (DDW) Retention Time requirements. Dudek (2015) calculated an eight-month buffer radius of approximately 800 feet of horizontal separation that is necessary between an injection well and nearest production well (municipal, domestic, or agricultural). Furthermore, the buffer distance must not extend to existing wells only but also to the property boundaries in which landowners have the right to drill a new well. Even if a modeling or tracer study were performed and the buffer radius could be reduced to 400 or 500 feet, it would be difficult to find areas with sufficient well spacing, especially within the few areas of relatively high transmissivity and specific capacity.

For these reasons, IPR is not considered feasible anywhere outside of the District's zones of groundwater rights ownership, where the challenges of well spacing and travel distance could potentially be overcome internally by the District. The remainder of this report focuses specifically on the IPR feasibility in each of the aforementioned areas of interest.

5.2 Toro Canyon

The Toro Canyon area is underlain by a sequence of unconsolidated sedimentary rocks including alluvium, fanglomerate, and the Casitas Formation. Within the western and northern portion of the District's area of interest, most wells penetrate a thin (less than 100 feet) section of clay-rich alluvium, followed by bedrock. The District operates one well near the southern edge of this area, the Edgewood Well, which has a reasonably high production rate (150 gpm) and specific capacity (1.4 gpm/foot). However, immediately north and west of the Edgewood Well, yields and specific capacities decrease significantly (see Figure 4).

Many wells inside and surrounding the area of interest exhibit low yields or are dry. Additionally, several wells within the boundary area exist only to monitor water quality issues and are not pumped.

The hydrograph for the Edgewood Well indicates that water levels are relatively stable and have fluctuated within a range of approximately 20 to 30 feet below ground surface over the past several years. Twenty to thirty feet of unsaturated storage space in a small, restricted area (due to unfavorable hydrologic conditions in the majority of the area) does not represent sufficient storage capacity to inject meaningful amounts of water. Furthermore, injected water would cause the already shallow water table to rise, therefore increasing the risk of liquefaction in the area. It is also possible that injection of recycled water would potentially migrate eastward towards the Carpinteria Groundwater Basin.

For these reasons, the Toro Canyon area is not a good candidate for IPR.

5.3 Storage Unit 1

Storage Unit 1 is a wedge-shaped, southward-thickening sedimentary aquifer with a maximum thickness of approximately 400 feet. Most hydrologic maps of Storage Unit 1 show the northern edge of the Basin as the contact between the older alluvium or fanglomerate and the older consolidated bedrock (typically the Sespe or Coldwater Formation). Review of published and private well construction and pumping test data show that most of the wells within Storage Unit 1 produce groundwater at relatively low flow rates, averaging less than 10 to 20 gpm, with specific capacities in range of 0.50 gpm/foot. Groundwater generally flows from north to south through the area of interest, so any injection wells would need to be installed in the northern portion of any potential areas of interest and recovery wells installed in the southern portion, near the Arroyo Parida fault.

There are two potential areas of interest within Storage Unit 1 where the District controls the groundwater rights. These are (1) the area between the District’s Valley Club 2 well and the private Ennisbrook 3 well, just north of the Arroyo Parida fault, and (2) the area east of Valley Club Road and just south of East Valley Road.

The area west of the Valley Club 2 well is in a mapped zone of relatively high production rates and specific capacity that intersect the area of District groundwater rights ownership in Storage Unit 1 as shown on Figure 5. The Valley Club 2 well has a transmissivity of 1,200 gpd/foot and a specific capacity of 1 gpm/foot. This small area, however, has challenges with both the presence of numerous existing residences, high flood risk (one of the recent debris flows occurred in this area), and lack of sufficient offset distance from the northern boundary of the District’s groundwater rights ownership and the Arroyo Parida fault to the south. Therefore, this area is not considered feasible for an IPR program.

The area east of Valley Club Road and just south of East Valley Road (see northwest corner of the District groundwater rights ownership area on Figure 5), is a broad region where the hydrogeologic characteristics of the Basin are possibly favorable for IPR and there are only a few existing, active wells that would complicate meeting the retention time requirements. The potential area for IPR would be constrained to the east by the relatively new Las Fuentes well, located in the eastern portion of the Birnam Wood Development. The specific capacity values for this area are not well known because of the lack of data from nearby wells. As a conservative assumption, and based upon data from the Valley Club 2 and other District wells, a specific capacity of 0.5 gpm/foot is assumed for wells that could be installed along the northern boundary of the District’s preferred area (blue line on figure 5). Given the variability of alluvial sediments in this portion of the Basin, it is evident that a moderate to high degree of hydrologic risk exists in terms of the specific capacity that would be attained in wells in this area.

Additionally, except during drought periods, there is often limited storage capacity in this area for groundwater storage. Figure 6 shows hydrographs of select monitored wells within the area. Water levels are known to be quite shallow during wet periods and occasionally are on the order of approximately 25 to 35 feet below ground surface during normal conditions, with several wells dropping to approximately 70 feet below ground surface during drought conditions. Importantly, it is notable that extended periods (many years) can occur with little available storage to accommodate injection.

To develop additional headspace for injection, especially during wet periods with corresponding shallow water levels, it may be possible to lower the local water table by increasing pumping in both existing and new wells in this portion of the Basin. Excess pumping would induce drawdown, which would in turn create more storage space for injection. Based on the relatively poor aquifer characteristics and low well yields in the area, it is unlikely that the water table could be lowered more than 10 to 15 feet. As shown by the calculations in Section 6, below, this concept could create modest additional IPR capacity, although the logistics of implementation would be complex.

5.4 Storage Unit 2

Storage Unit 2 is a fault-bounded, uplifted block with shallow, non-water bearing bedrock of the Rincon Formation in most portions of this storage unit. The Rincon Formation was mapped at the ground surface by Hoover (1980), adjacent to the Arroyo Parida Fault, in the northern portion of the area of the District's groundwater rights ownership (see Figure 7).

Review of the well logs in this area shows that western and eastern portions of this storage unit have very few wells that produce groundwater in excess of 5 to 10 gpm. There are only a few wells in the central portion of this storage unit that produce several tens of gpm. These wells are generally shallow with a completion depth of less than 150 feet. Historic groundwater levels within this storage unit have been shallow and relatively stable, with little available storage that could be considered for injection.

Storage Unit 2 is not considered feasible for groundwater augmentation due to its shallow depth to bedrock, low well yields and specific capacities, and the general lack of available storage.

5.5 Storage Unit 3

Storage Unit 3 is a wedge shaped, southward thickening aquifer composed of alluvium and fanglomerate, with the Casitas Formation and Santa Barbara formations at depth. Most of the higher yielding wells in this storage unit are inferred to produce groundwater from the Casitas Formation (Hoover, 1979). Some of the groundwater from these aquifers may be confined as indicated by variations in water table elevations and reduced rates of decline in some wells during drought conditions (Dudek, 2015). There are also variations in water quality within this storage unit, most likely reflecting its complex depositional history in relation to depositional patterns, changes in sea level, and tectonic uplift. Well yields and specific capacities within this storage unit may be slightly higher than in the other two storage units because of the presence of more permeable aquifer materials in some portions of the subsurface.

There are several wells within Storage Unit 3 that exhibit relatively high flow rates and specific capacities. Figure 8 shows a detailed view of these mapped zones along with the calculated transmissivity and specific capacity of several District wells. Within the area of interest, the District owns three wells that have transmissivities ranging from 880 to 4,000 gpd/foot and specific capacities ranging from 0.9 to 1.5 gpm/foot. The Amapola well is located a short distance to the west and has a transmissivity of 7,500 gpd/foot and a specific capacity of 3.3 gpm/foot, making it one of the most productive wells in the Basin. However, as with the rest of the Basin, these zones of high production are not laterally continuous. As illustrated on Figure 8, the ground surface in the eastern half of the area is elevated and represents a bedrock high. Wells in this area are expected to have little to no yield, which significantly reduces the amount of available space to implement an IPR project in Storage Unit 3.

Hydrographs of the District's wells in Storage Unit 3 show more headspace for available storage compared with any of the other storage units in the Basin (see Figure 9). Water levels range between 60 and 80 feet below ground surface during normal conditions and upwards of 100 feet below ground surface during drought conditions. The Las Entradas 2 well has significantly higher water levels, but it is located in the far southeast corner of the area of interest, where IPR would be infeasible.

Though the aquifer characteristics in Storage Unit 3 are better than those in Storage Unit 1, the available storage space within the area of interest is also limited. There is space for only one or two injection wells, considering the necessary offset requirements between wells (discussed in more detail in Section 6). Groundwater generally flows from north to south in the area, so injection wells would need to be placed somewhere to the north of the Ennisbrook 5 well. This would, however, effectively terminate the use of Ennisbrook 5 as a potable water supply well during injection, or for many months after an injection period, because of the required groundwater retention times. Other challenges associated with this area are the presence of numerous residences and potential flood risk issues.

Unlike Storage Unit 1, extra pumping in this portion of the Basin to lower water levels and create additional headspace is not recommended. Most wells within the zone of high production already have static water levels close to sea level during normal conditions and are significantly below sea level during drought conditions. Though seawater intrusion has not been identified in any of these wells, intentionally lowering the water levels below sea level would increase the risk of seawater intrusion.

Calculations detailing expected injection volumes and the required number of wells are presented in Section 6.

SECTION 6: Potential Recharge Capacity

This section provides the technical analysis of the localized areas within Storage Units 1 and 3 that have limited potential for IPR injection. Through the calculations provided below, an estimate for achievable injection rates is estimated. Given the local variability of the aquifers in the Basin, it is likely that actual injection rates could be slightly better or much worse than the estimated values. Further site-specific studies—such as performing pumping tests at new, appropriately located and designed temporary wells—would be necessary to more accurately determine the estimated injection rates.

6.1 Storage Unit 1

A specific capacity value of the hydrologically favorable wells within the area of interest in this storage unit is estimated to be 0.5 gpm/foot, based upon information from nearby wells.

The specific capacity of injection is expected to be approximately 50 to 70 percent lower than the specific capacity of pumping. This is a general rule based on numerous IPR studies that have been conducted by GSI and others. The conservative estimate for specific capacity of injection use for the calculation is 0.3 pm/foot, and the product of this factor multiplied by the average available headspace, is an injection rate of 9 gpm. Assuming that the injection well operates at 80 percent efficiency, this results in a total injection volume of approximately 12 AFY per well.

Table 1. Potential Injection Rates in Storage Unit 1

	Units	Estimated Value
Specific Capacity of Pumping	gpm/foot	0.5
Specific Capacity of Injection (50 – 70% of pumping)	gpm/foot	0.3
Depth to Water (average)	foot	30
Rate of Injection	gpm	9
Rate of Injection at 80% Efficiency (per well)	AFY	12
Maximum # of Injection Wells (based on mounding)		3
Total Theoretical Injection	AFY	**36**
If Additional Pumping is Implemented to Induce Drawdown		
Depth to Water	foot	45
Rate of Injection	gpm	14
Rate of Injection at 80% Efficiency (per well)	AFY	17
Total Theoretical Injection	AFY	**52**

Injecting water into a well will raise the water level locally and create a mounding effect. Water levels are increased at the well site and gradually slope down to normal water levels in all directions. Mounding at an injection well can influence water levels in nearby injection wells if the wells are placed too close together, reducing the amount of available headspace in the neighboring well and reducing the injection rate. Storage Unit 1 would have space for a maximum of three wells placed along the northern edge of the District's area of interest. Three wells injecting 12 AFY each would result in a total theoretical injection of approximately 36 AFY.

As stated previously, it may be possible for the District to induce additional storage space through additional pumping. If this were implemented and the local water table was lowered 15 feet (which may be optimistic), the rate of injection would increase to 14 gpm, resulting in the total theoretical injection volumes at three wells to be approximately 52 AFY. There are long periods of time (many consecutive years in a row) during which the water table is at a depth of less than 20 feet below ground surface. This implies that it would not be feasible to conduct an injection during these prolonged periods, due to the shallow depth below ground surface of the local water table. Other planning issues that are important to understand include the challenge of modifying the District's distribution system dynamics by the added pumping, and implications of an increased risk of oversaturation and potential liquefaction risk in the near surface sediments adjacent to each injection well.

6.2 Storage Unit 3

An average specific capacity of pumping for the area is estimated to be 1 gpm/foot. The resulting specific capacity of injection would be approximately 0.5 gpm/foot, and when multiplied by the average available depth to water, results in an anticipated injection rate of 30 gpm. Assuming that the injection well operates at 80 percent efficiency, this results in a total injection volume of 38 AFY per well.

Table 2. Potential Injection Rates in Storage Unit 3

	Units	Estimated Value
Specific Capacity of Pumping	gpm/foot	1
Specific Capacity of Injection (50 – 70% of pumping)	gpm/foot	0.5
Depth to Water (average)	foot	60
Rate of Injection	gpm	30
Rate of Injection at 80% Efficiency (per well)	AFY	38
Maximum # of Injection Wells (based on mounding)		2
Total Theoretical Injection	AFY	**77**

Considering the same spacing requirements (due to mounding) as described for Storage Unit 1, the District's area of interest would have space for 2 injection wells only. Therefore, with two injection wells, the total theoretical injection in Storage Unit 3 is calculated to be approximately 77 AFY.

SECTION 7: Conclusions and Recommendations

Based upon the abundant well and other groundwater information collected and analyzed during this technical study, two areas are identified where injection of fully advanced treated recycled water could be considered. For these areas, the aquifer conditions and the required offset distance to nearest down-gradient wells for new recovery well sites appear sufficient to meet the DDW-required Retention Time for the injected water. The two areas are (a) the northwestern portion of the area of interest in Storage Unit 1 and (b) the northwestern portion of the area of interest within Storage Unit 3. Based on application of the hydrologic characteristics and assumptions outlined earlier in this report, the average injection and recovery capacity of these defined areas is estimated to be approximately 35 and 75 AFY, respectively. These estimates represent the overall groundwater injection/recovery rates attainable primarily during drought years when the water table is low thus allowing for sufficient available storage capacity. Importantly, there would be many years when the District will not be able to inject into either of the storage unit areas due to high water level conditions.

If the District chooses to move forward with either or both of these locations, additional site characterization would be required to more accurately determine potential injection rates and other site-specific hydrologic information (including confirmation of the location of nearby wells). This additional work would require permitting, installation, and testing of temporary wells. Based upon the presence of private homes throughout the areas, site access and permissions for this testing could represent a significant challenge.

Because of the low potential injection rates, proximity to existing wells, and uncertainty of the lateral extent of favorable aquifer materials, the remainder of the areas of the Basin are unfavorable candidates for IPR. Based on this evaluation, IPR is considered infeasible in the Toro Canyon area, Storage Unit 2, and all of the other non-preferred areas in the Basin. In the areas where the District controls groundwater rights in Storage Units 1 and 3, IPR is considered only marginally feasible, with a relatively low expectation of recharging significant volumes of recycled water. Even with small injection volumes, implementing IPR on any scale in the Basin would involve a significant risk and uncertainty, and would be subject to additional challenges related to permitting and construction costs.

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SECTION 8: References

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Figures

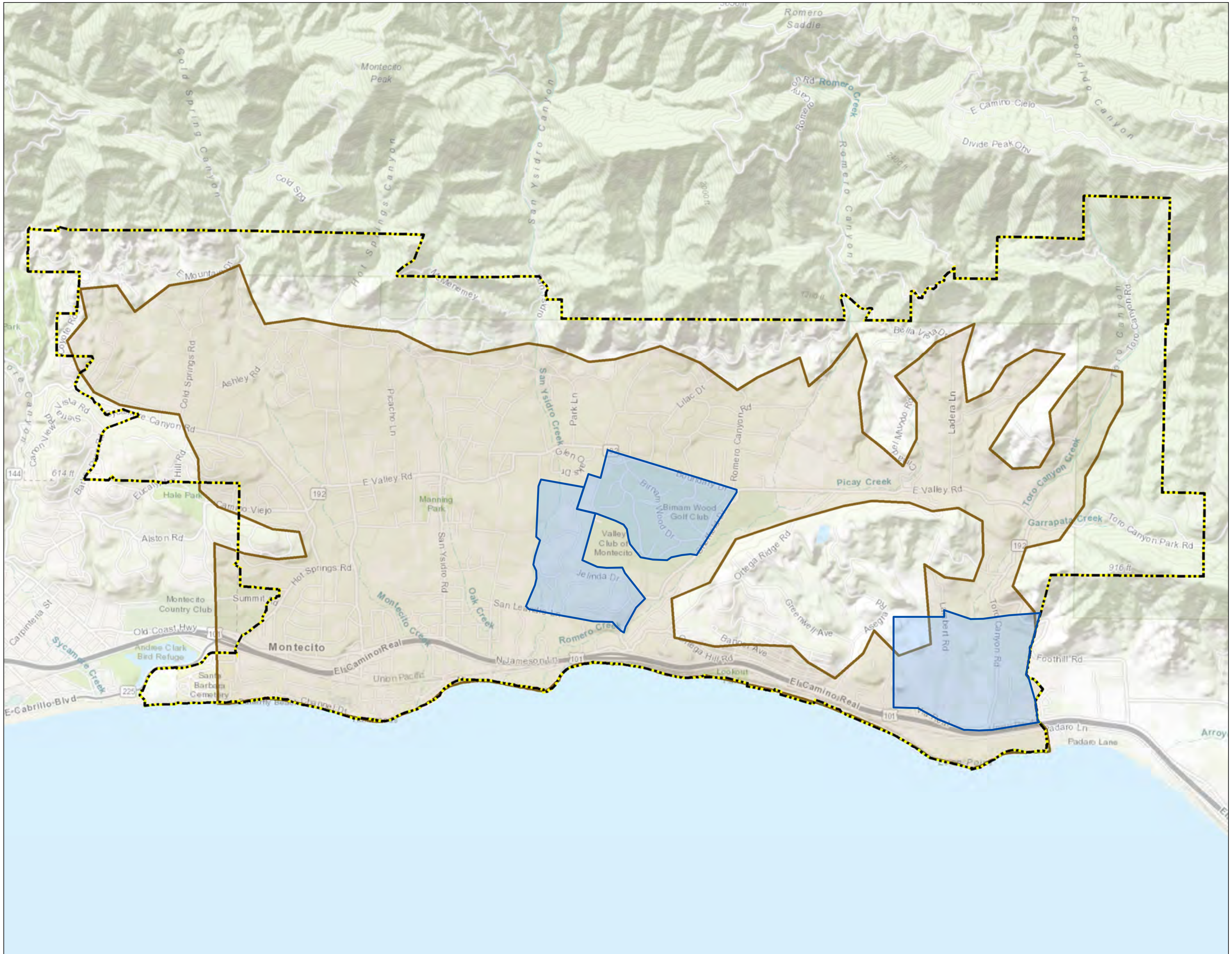

FIGURE 1

Montecito Basin Overview

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

- Montecito Water District Boundary
- B118 Montecito Groundwater Basin Boundary
- Groundwater Augmentation Area of Interest

NOTES:

N

0 1,500 3,000 4,500
Feet

Date: January 6, 2020
Data Sources:

GSI Water Solutions, Inc.

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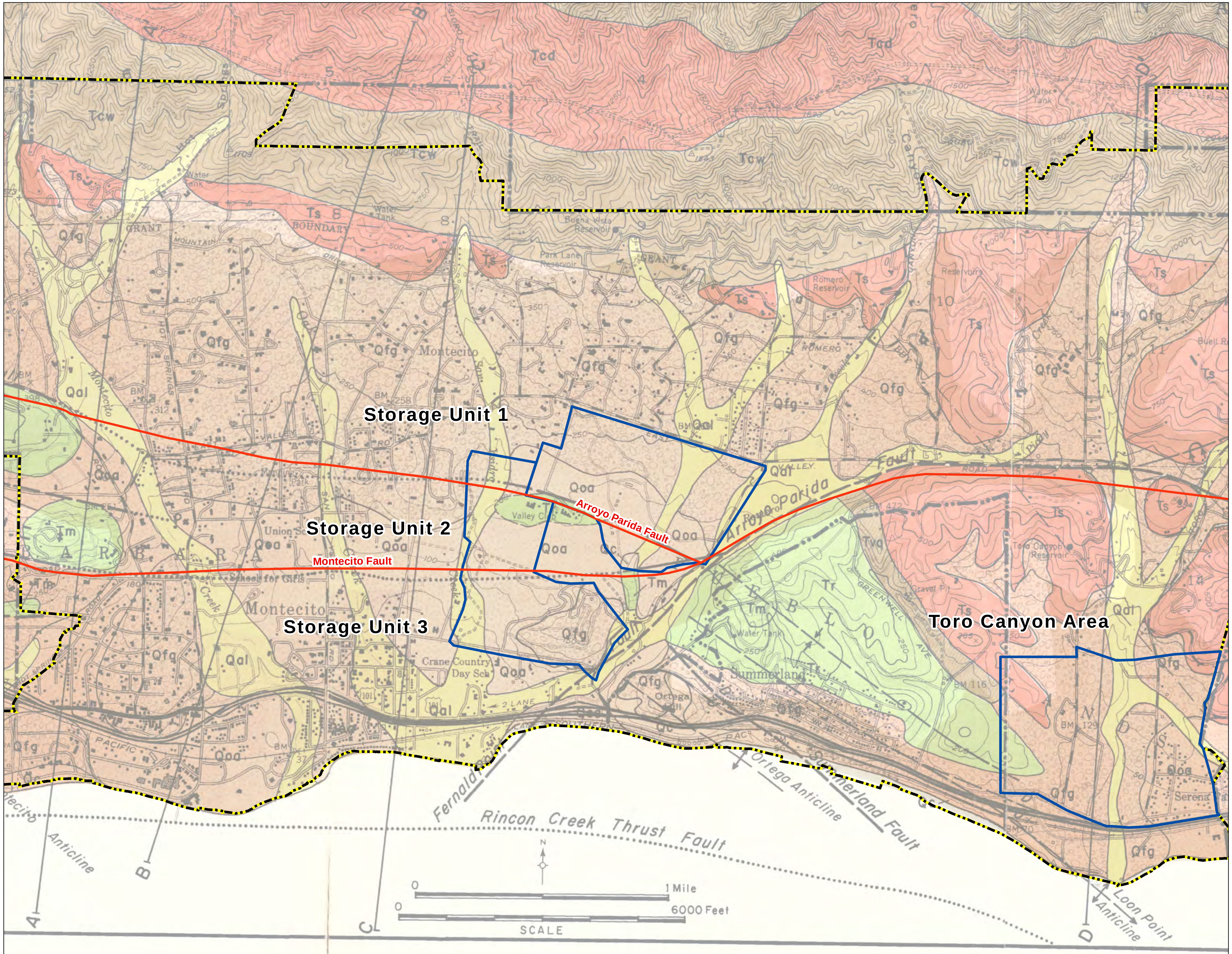

FIGURE 2

Montecito Basin Geologic Map

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

- Fault
- Groundwater Augmentation Area of Interest
- Montecito Water District Boundary

NOTES:

N

0 1,000 2,000 3,000 Feet

Date: January 8, 2020
Data Sources: Hoover, 1980

GSI Water Solutions, Inc.

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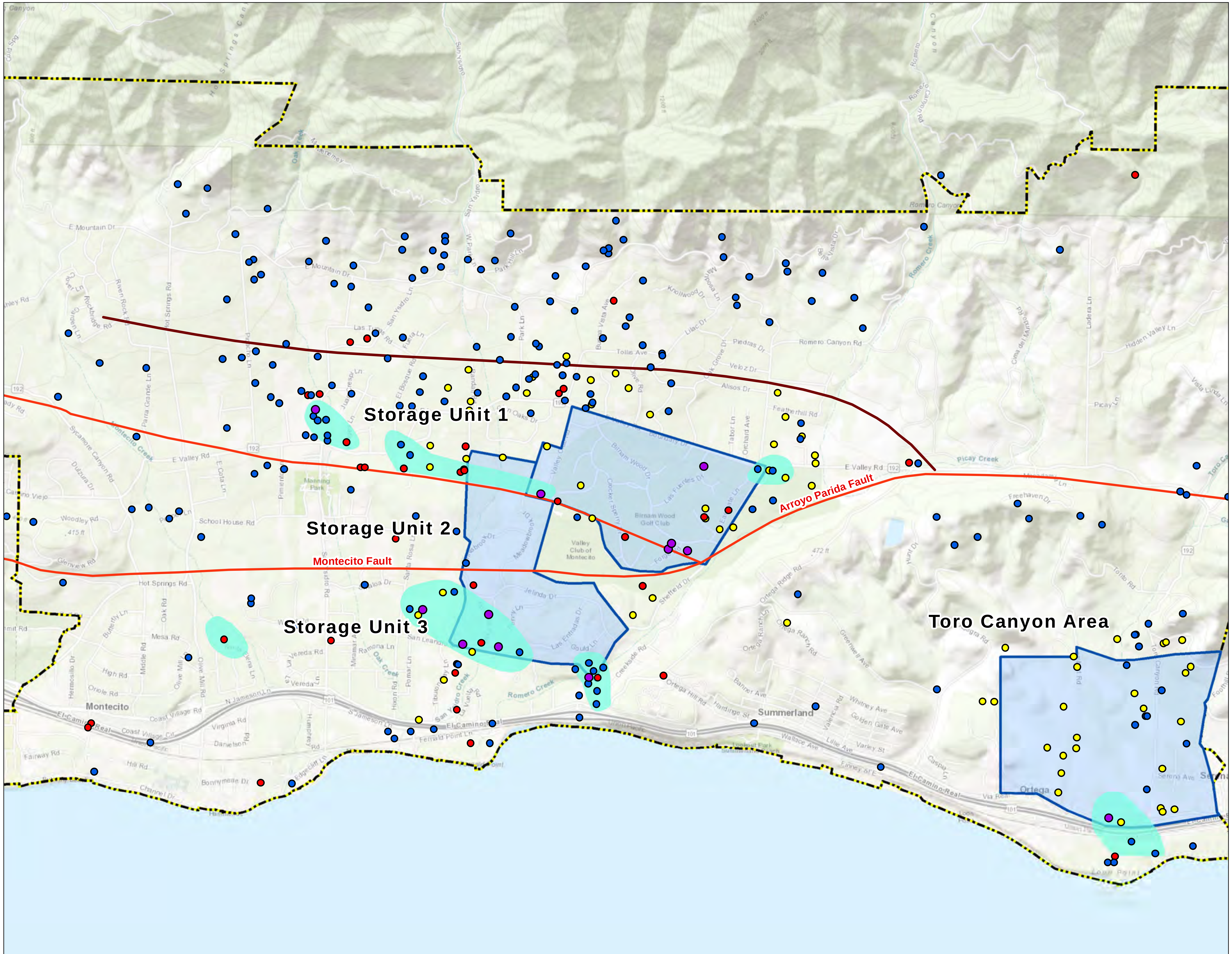
FIGURE 3

Well Locations and Zones with Favorable Aquifer Characteristics

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin



LEGEND

Wells

- MWD Well
- DWR Well Log
- CPH Well Log
- Inactive/Destroyed/Test Hole

Other Features

- Northern Extent of Saturated Aquifer Zone
- Fault
- Area with high flow rate and specific capacity
- Groundwater Augmentation Area of Interest
- Montecito Water District Boundary

NOTES:

N

0 1,000 2,000 3,000
Feet

Date: January 8, 2020
Data Sources: Hoover, 1980

GSI Water Solutions, Inc.

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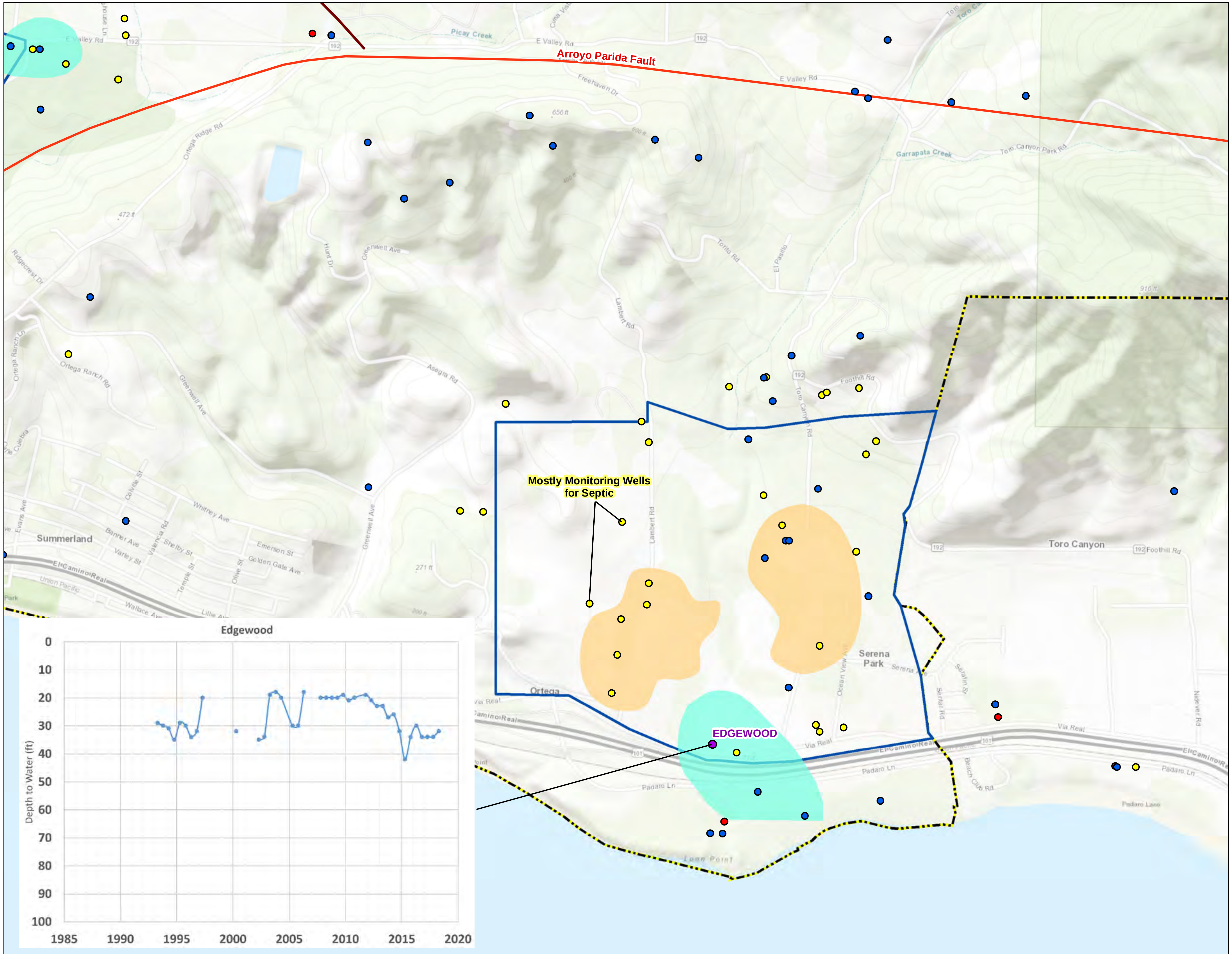

FIGURE 4

Toro Canyon Area

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

Wells

- MWD Well
- DWR Well Log
- CPH Well Log
- Inactive/Destroyed/Test Hole

Other Features

- Northern Extent of Saturated Aquifer
- Fault
- Area with dry or low-yielding wells (well locations confidential)
- Area with high flow rate and specific capacity
- Groundwater Augmentation Area of Interest
- Montecito Water District Boundary

NOTES:

N

0 500 1,000 1,500
Feet

Date: January 8, 2020
Data Sources: Hoover, 1980

GSI Water Solutions, Inc.

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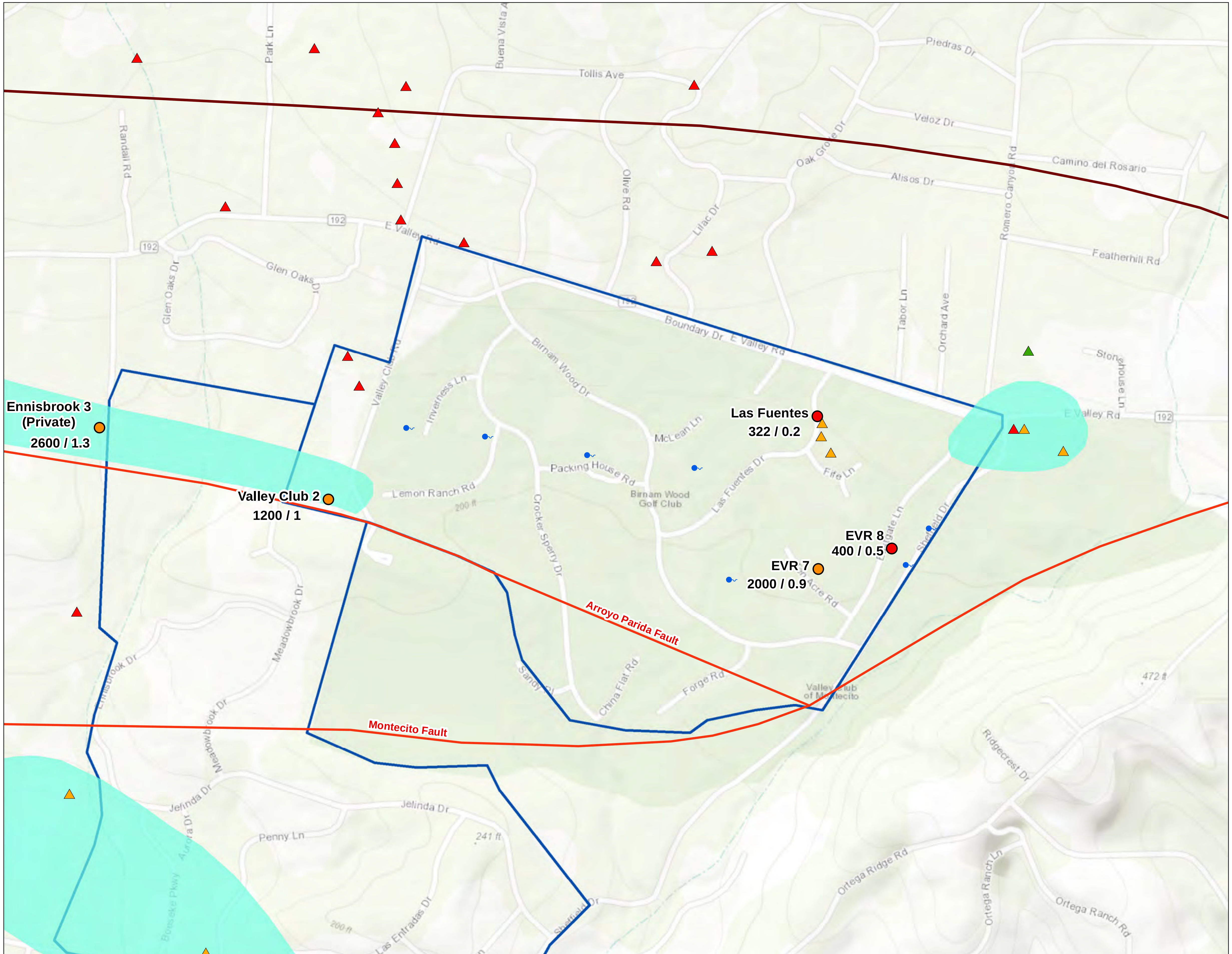

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FIGURE 5

Storage Unit 1 Transmissivity and Specific Capacity Data

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

Calculated T (gpd/ft) / Specific Capacity (gpm/ft)

- 322 - 1000
- 1000 - 3000

Specific Capacity (gpm/ft)

- 0.001 - 0.5
- 0.5 - 1.0
- 1.0 - 5.0
- 5.0 - 10.0
- 10.0 +

Other Features

- Northern Extent of Saturated Aquifer
- Fault
- Springs Mapped by Hoover, 2009
- Area with high flow rate and specific capacity
- Groundwater Augmentation Area of
- Montecito Water District Boundary

NOTES:

N

0 500 1,000
Feet

Date: January 23, 2020

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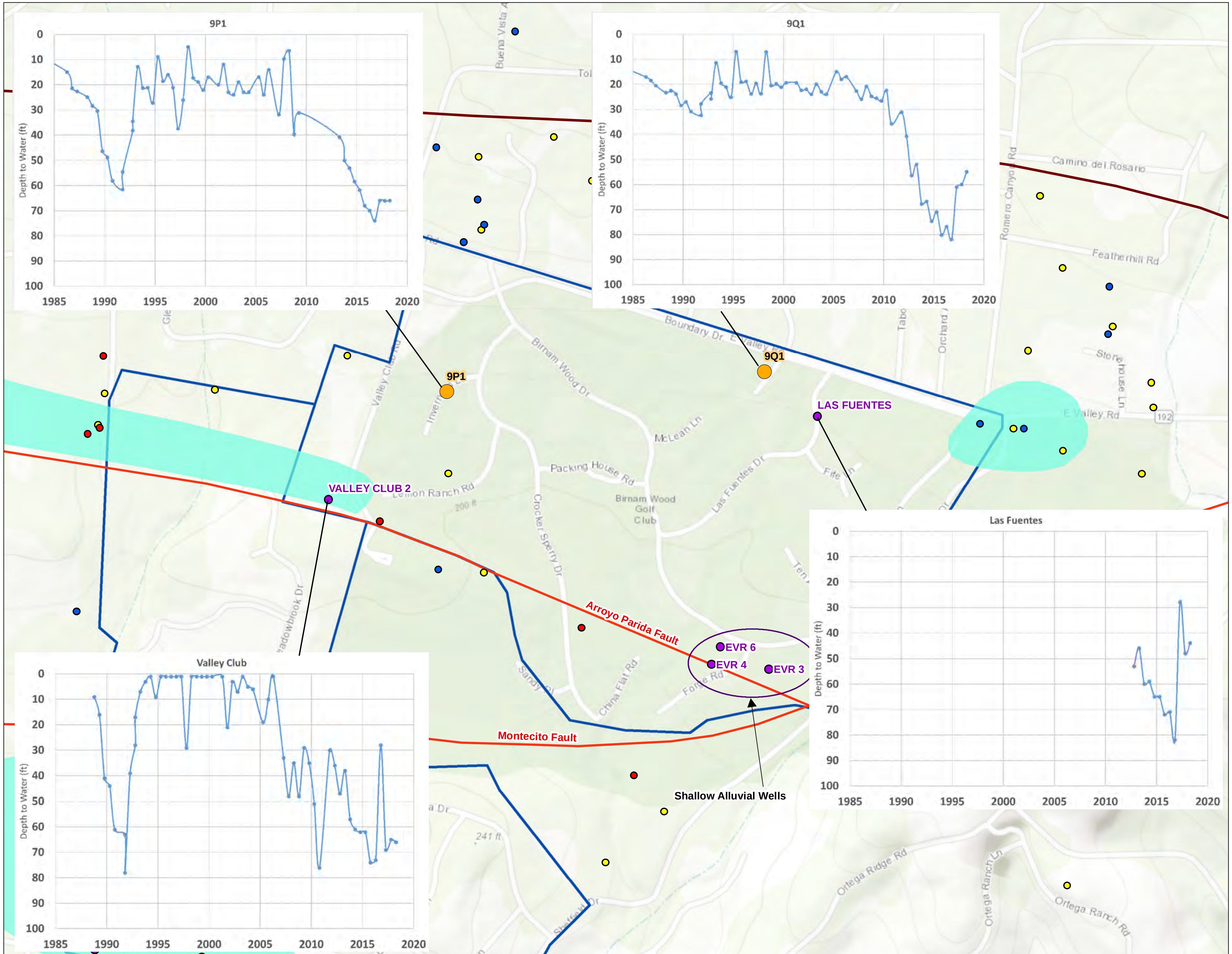

FIGURE 6

Storage Unit 1 Hydrographs

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

Wells

- MWD Well
- DWR Well Log
- CPH Well Log
- Inactive/Destroyed/Test Hole
- Well Monitored by USGS

Other Features

- Northern Extent of Saturated Aquifer
- Fault
- Area with high flow rate and specific capacity
- Groundwater Augmentation Area of
- Montecito Water District Boundary

NOTES:

N

0 500 1,000

Feet

Date: January 8, 2020

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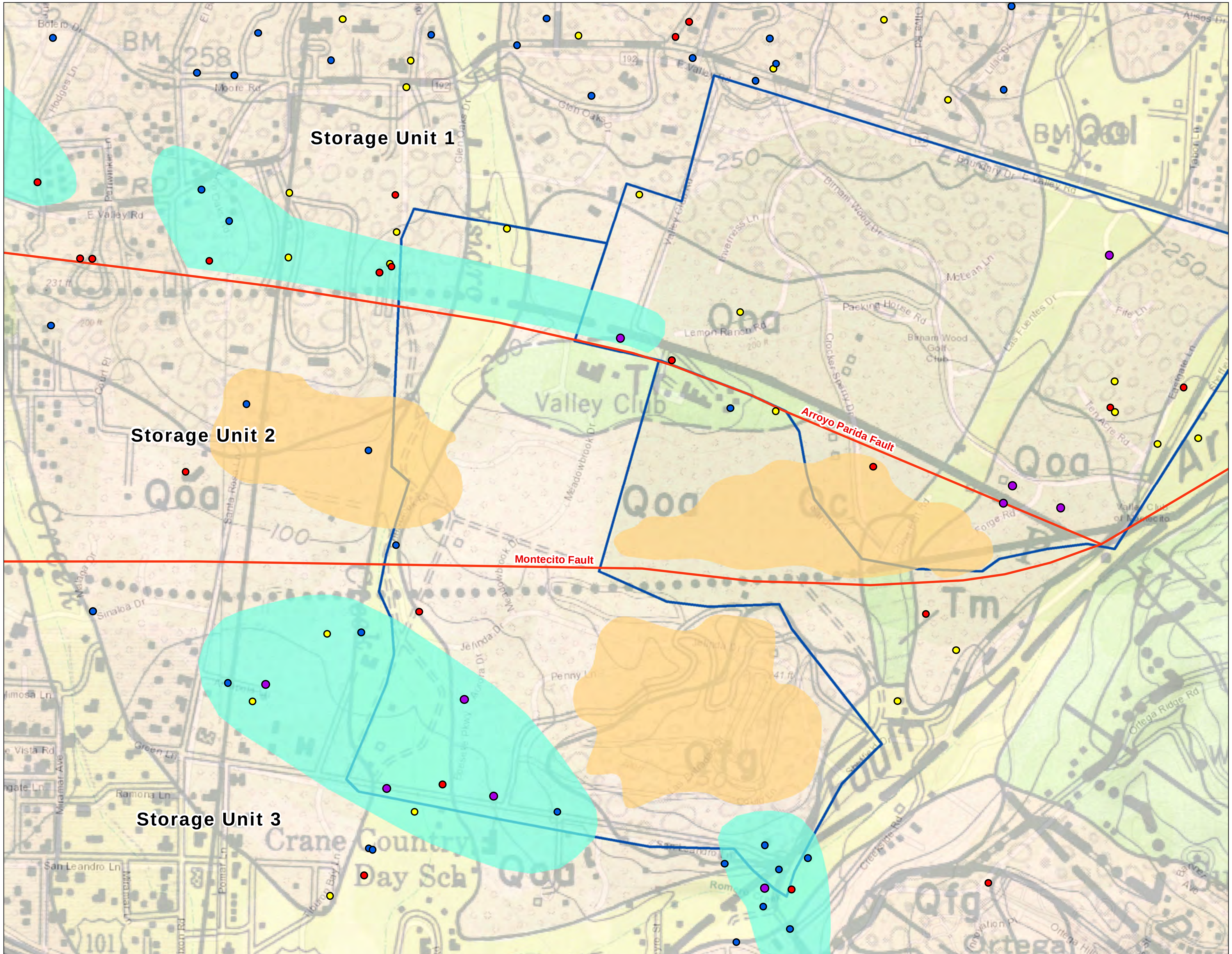

FIGURE 7

Storage Unit 2

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

Wells

- MWD Well
- DWR Well Log
- CPH Well Log
- Inactive/Destroyed/Test Hole

Other Features

- Northern Extent of Saturated Aquifer
- Fault
- Area with dry or low-yielding wells (well locations confidential)
- Area with high flow rate and specific capacity
- Groundwater Augmentation Area of Interest

NOTES:

N

0 500 1,000
Feet

Date: January 8, 2020
Data Sources: Hoover, 1980

GSI Water Solutions, Inc.

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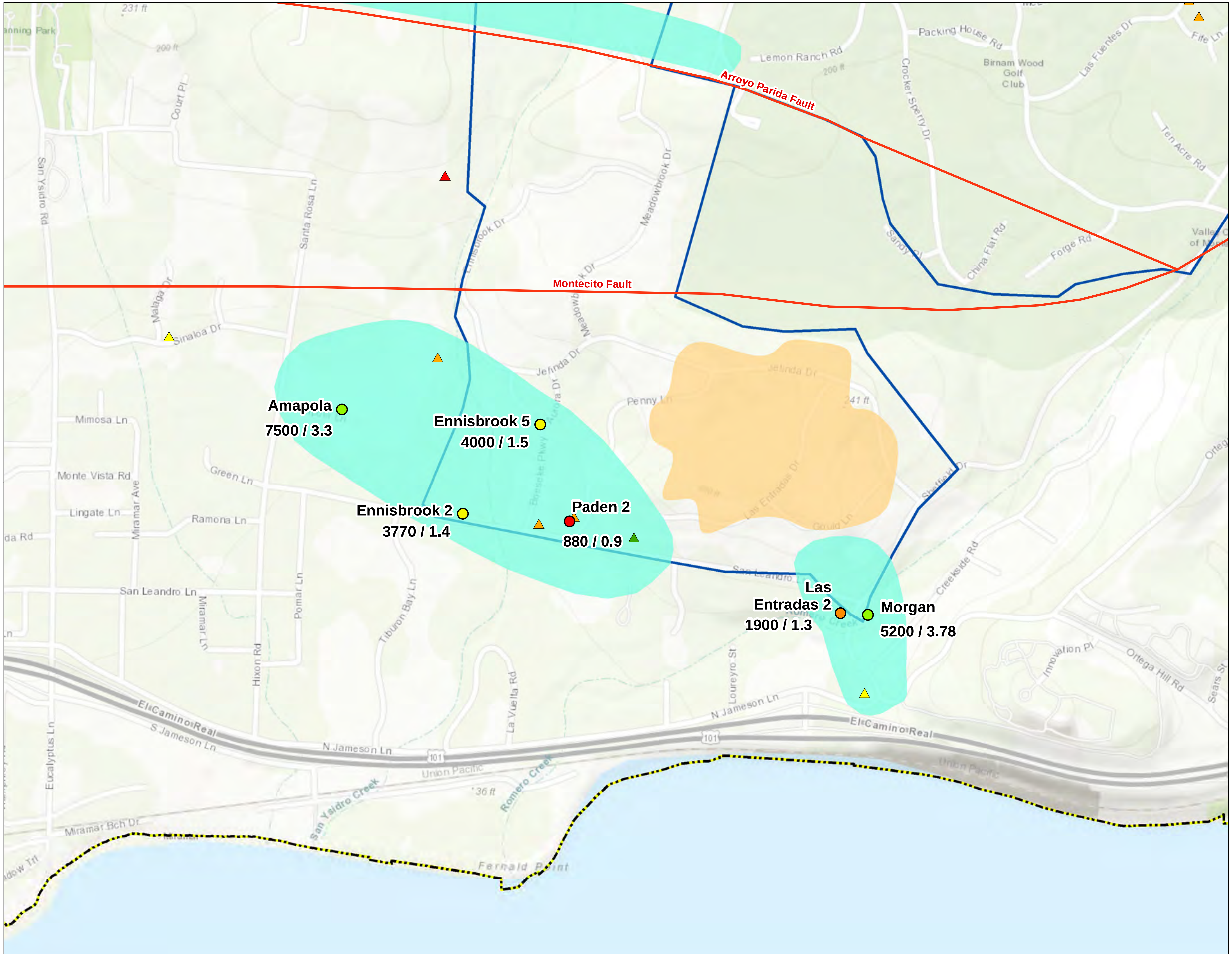

FIGURE 8

Storage Unit 3 Transmissivity and Specific Capacity Data

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

Calculated T (gpd/ft) / Specific Capacity (gpm/ft)

- 322 - 1000
- 1000 - 3000
- 3000 - 5000
- 5000 - 8000

Specific Capacity (gpm/ft)

- 0.001 - 0.5
- 0.5 - 1.0
- 1.0 - 5.0
- 5.0 - 10.0
- 10.0 +

Other Features

- Northern Extent of Saturated Aquifer
- Fault
- Area with Dry Wells (well locations confidential) and Shallow Bedrock
- Area with high flow rate and specific capacity
- Groundwater Augmentation Area of
- Montecito Water District Boundary

NOTES:

N

0 500 1,000
Feet

GSI Water Solutions, Inc.

Date: January 8, 2020

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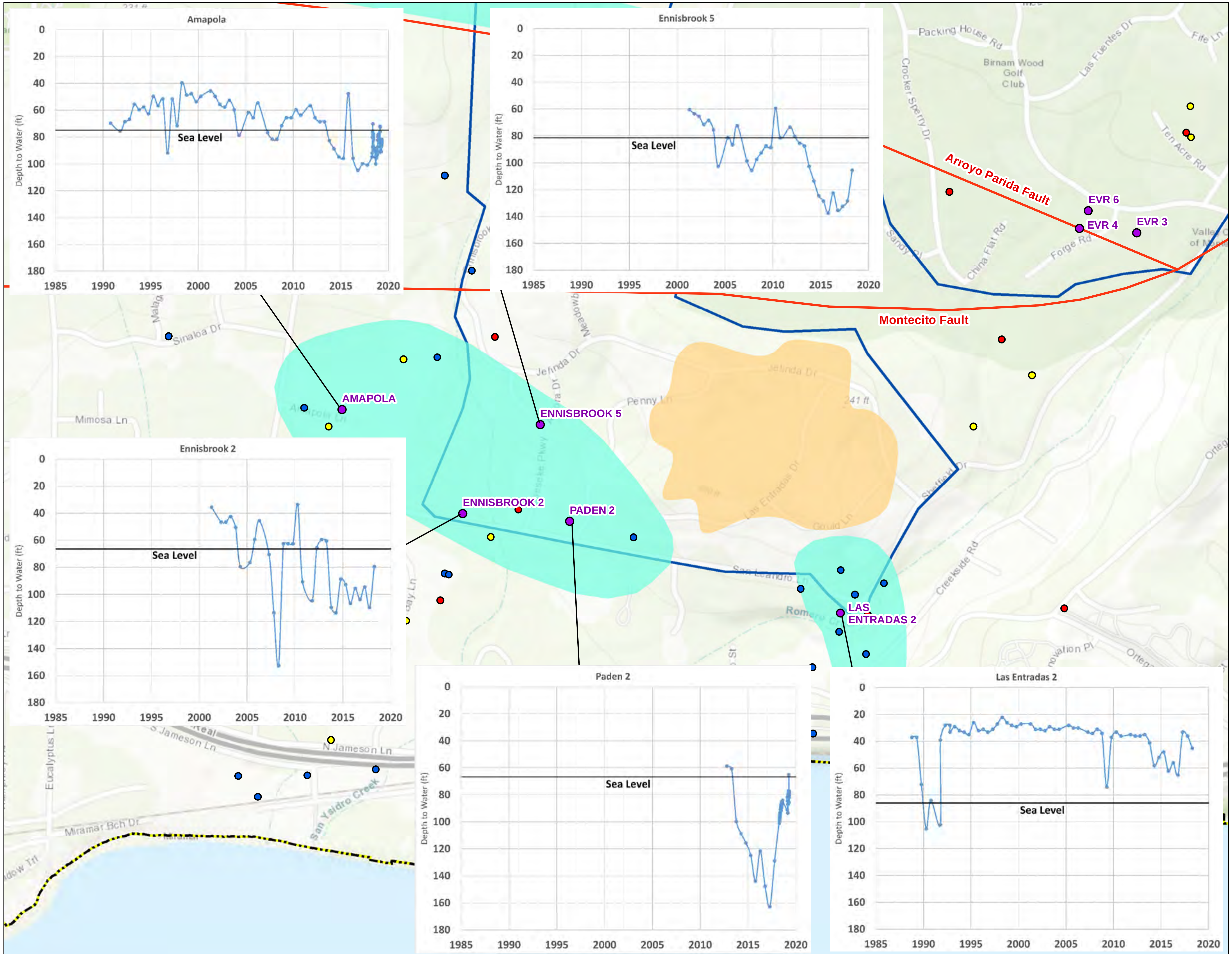

FIGURE 9

Storage Unit 3 Hydrographs

Groundwater Augmentation Feasibility Analysis for the Montecito Groundwater Basin

LEGEND

Wells

- MWD Well
- DWR Well Log
- CPH Well Log
- Inactive/Destroyed/Test Hole

Other Features

- Fault
- Area with Dry Wells (well locations confidential) and Shallow Bedrock
- Area with high flow rate and specific
- Groundwater Augmentation Area of
- Montecito Water District Boundary

NOTES:

N

0 500 1,000

Feet

GSI Water Solutions, Inc.

Date: January 8, 2020

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APPENDIX A

Geologic Model Visualizations

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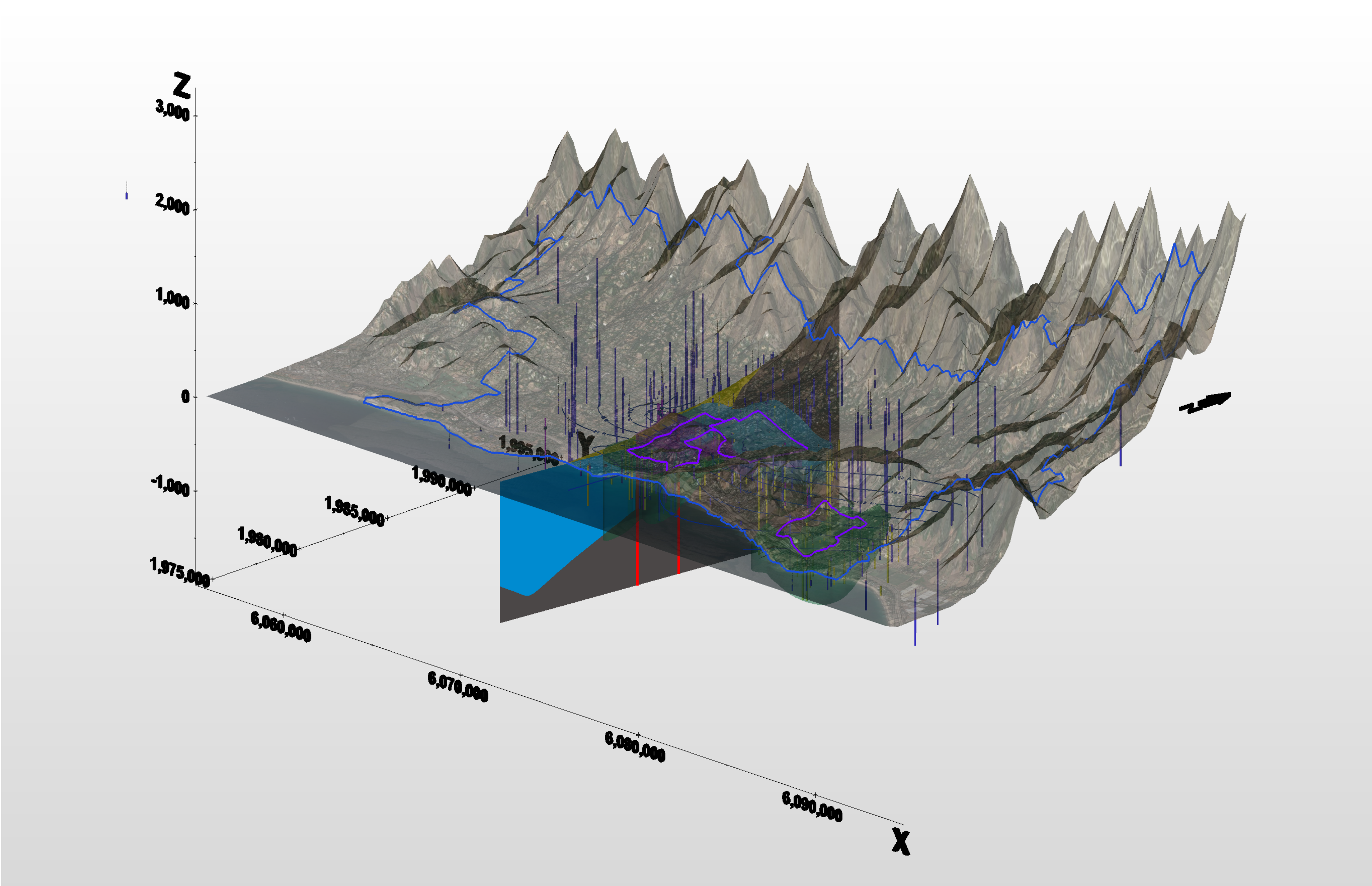

Legend

Well Screens

DWR Locations
MWD Locations
CPH Locations
2018 Measured Water Elevation

Watertable Isocontour

Fault Plane

Fault Intersection

Areas of Interest

Montecito Water District

Aquifer Storage Unit

- Block 1
- Block 2
- Block 3

4X Vertical Exaggeration

Explanation on Use of 3D Viewer

Tools for Navigating

This PDF is enabled for 3D navigation. Use the tools below to navigate:
Rotate: Depress left mouse button and move mouse to rotate model.
Zoom: Use scroll wheel to zoom in or out of model.
-or- Depress right mouse button and move mouse up or down to zoom in or out of model.
Pan: Depress both left and right buttons and move mouse to pan model in any direction.

Note: Many additional tools can be accessed by right-clicking within the model window.

Adding or Removing Layers

With cursor in model window, left click mouse to activate Model Tree;
then with cursor in model window, left click mouse to activate layers.
(It may be necessary to right click in the left most grey bar "Navigation Pane Buttons" and select Model Tree to enable it.)
It may be helpful to uncheck the "transform" or "PDF3D Scene" box to deselect all layers, and then turn on individual layers as needed.
Items can also be selected from the 3D view using the left mouse button to select the corresponding layer in the Model Tree

Available Views

Click the view name in the Model Tree pane on the left of the screen to see the specified view.
New user defined views (including layer combinations) can be saved with the camera icon.
(You may have to right click in the left most grey bar "Navigation Pane Buttons" and select Model Tree to enable it.)

Geologic Model Visualization
Montecito Water District
Montecito, California

Geosyntec consultants

Santa Barbara	December 2019	Figure A1