DRAFT - SUBJECT TO CHANGE

Preliminary Groundwater Zones of Benefit Study
Santa Clara County, California

Prepared for:
Santa Clara Valley Water District

October 2017

Prepared by:

HydroMetrics WRI

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ABBREVIATIONS

Alluvium .... Sediments primarily stream deposits of Quaternary age
Cal Water .... California Water Service Company
CGS .... California Geological Survey
District .... Santa Clara Valley Water District
DWR .... California Department of Water Resources
GIS .... Geographic Information System
GW .... Retailer area where groundwater supply is delivered
Local SW .... Area receives San Jose Water Company surface water supply
RWS .... Retailer area receives water from SFPUC Regional Water Supply System
SBWRP .... South Bay Water Recycling Program
SCRWA .... South County Regional Wastewater Authority
SCVWD .... Santa Clara Valley Water District
SFPUC .... San Francisco Public Utilities Commission
SVAWPC .... Silicon Valley Advanced Water Purification Center
Study .... Zone of Benefit Study
TDS .... Total Dissolved Solids
TW .... Retailer area receives SCVWD treated water deliveries
USGS .... United States Geological Survey

EXECUTIVE SUMMARY

The Santa Clara Valley Water District (District) Act gives the District Board of Directors the authority to establish, amend, and revise groundwater charge zones (Zone, District Act Section 3) and to levy and collect groundwater charges within a zone or zones that benefit from the recharge of underground water supplies or the distribution of imported water (District Act Section 26). The two existing Zones, W-2 and W-5, were established in 1963 and 1977, respectively. Zone W-2 generally covers the Santa Clara Plain in North County while Zone W-5 generally covers the Coyote Valley and Llagas Subbasin in South County (Figure ES- 1) where Santa Clara Plain, Coyote Valley and Llagas Subbasin are groundwater management areas delineated by the District (Figure ES- 2). California Department of Water Resources (DWR) defines the Santa Clara Plain and Coyote Valley areas as the Santa Clara Subbasin.

The purpose of the Groundwater Zone of Benefit Study (Study) is to provide a comprehensive review of the Zones to ensure they reflect areas where groundwater users receive similar benefits from current and planned District groundwater management activities. Although the District is not aware of any specific problems with the existing Zone designations, the District has received requests for exemptions and recognizes that it is important for the District to periodically undertake an updated analysis of the Zones, and revise the boundaries if appropriate. The Study is based on evaluation of the subsurface characteristics that govern the movement of groundwater (called hydrogeologic characteristics) and the ways that District activities benefit groundwater users. These benefits are derived not only from direct groundwater recharge with surface water supplies (called managed aquifer recharge), but also from delivery of treated water, untreated surface water, and recycled water directly to users, which reduces groundwater extraction (called in-lieu recharge). Other direct and indirect benefits of the District's comprehensive groundwater management program include demand management, development of alternative water supplies, long-term water conservation, and protection of water quality.

A groundwater zone of benefit includes any area within the District’s legal jurisdiction where any of the following criteria are met:

- A District activity provides water supply
- District activities improve groundwater supply reliability
- District activities prevent or limit land subsidence
- District activities reverse or control salt water intrusion
- District activities improve or maintain groundwater quality
- District activities improve groundwater levels

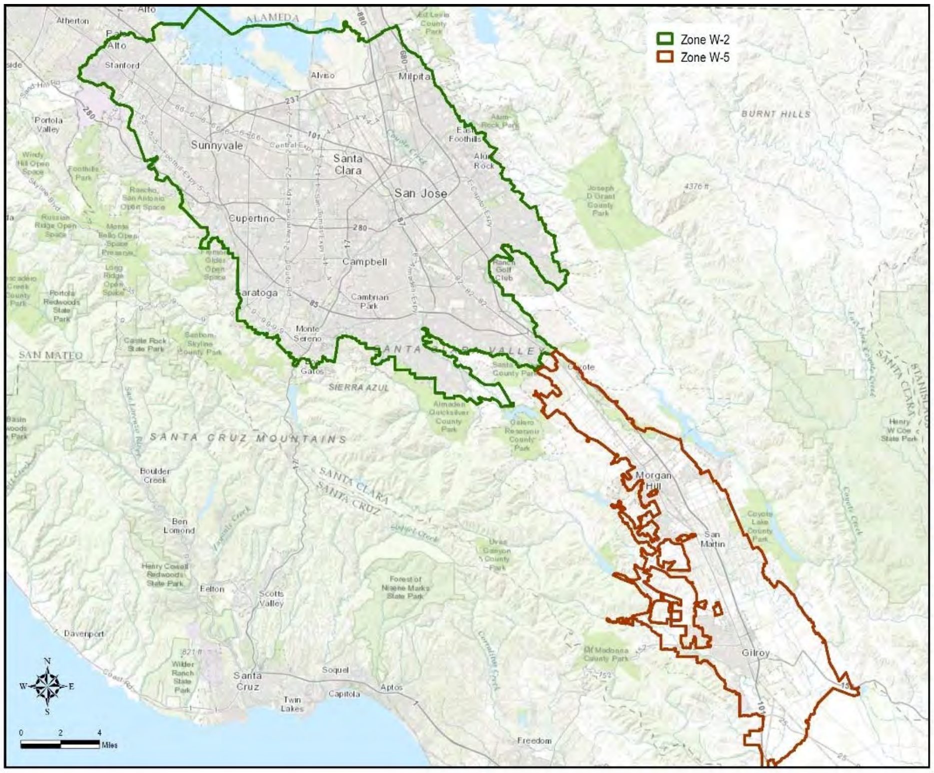

Figure ES- 1: Existing Zones of Benefit

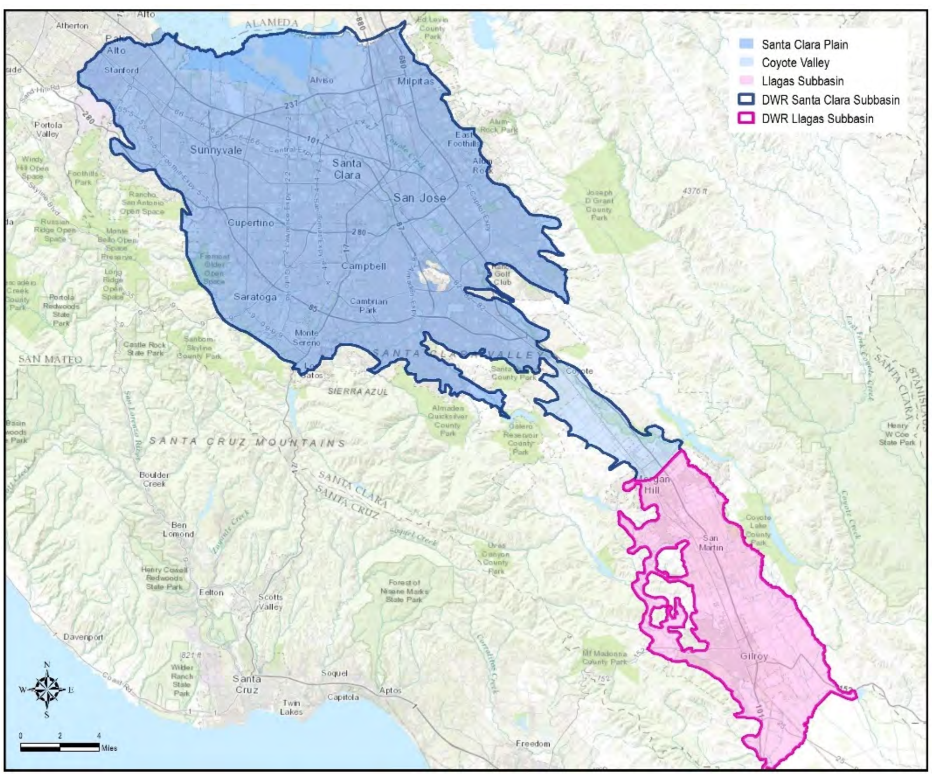

Figure ES- 2: DWR Bulletin 118 Subbasins and District Groundwater Management Areas

The Study is based on the premise that benefits from District activities extend throughout areas connected by groundwater flow (called hydrogeologically connected areas) that occurs in similar geologic deposits. The hydrogeologically connected areas are primarily defined by the geologic contact between alluvium (gravel, sand, silt, and clay sediments deposited by streams) in the valley floors and bedrock of the adjacent mountain ranges (Figure ES- 3 and Figure ES- 4). Groundwater generally flows through the alluvium until encountering bedrock or other hydrogeologic boundaries so continuous areas of alluvium generally hydrogeologically connected. The hydrogeologic connection in bedrock is likely limited in spatial extent. Other hydrogeologic boundaries include groundwater divides between areas where groundwater flows in opposite directions, faults, where alluvium narrows and/or steepens, and contacts between alluvium formations with different levels of consolidation as narrower spaces between the alluvial sediments restrict groundwater flow. Geologic formations of alluvium that are candidates for hydrogeologically connected areas in the Study area include Unconsolidated Alluvium and the Santa Clara Formation (Figure ES- 4).

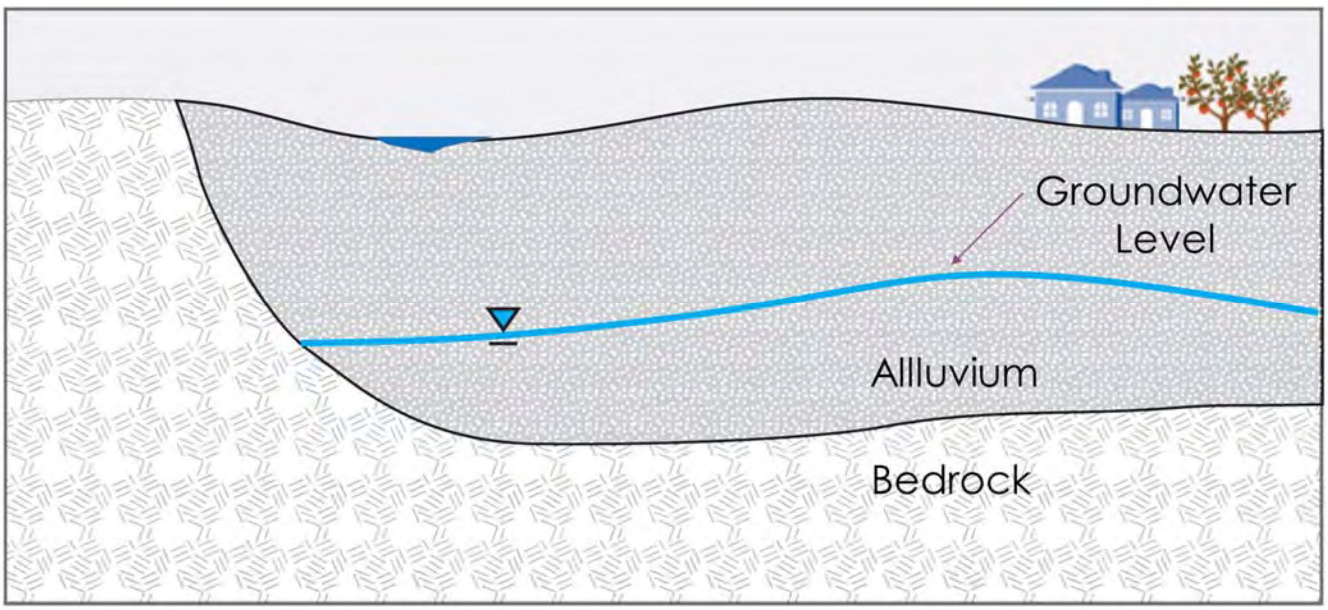

Figure ES- 3: Schematic Cross-Section of Alluvium and Bedrock

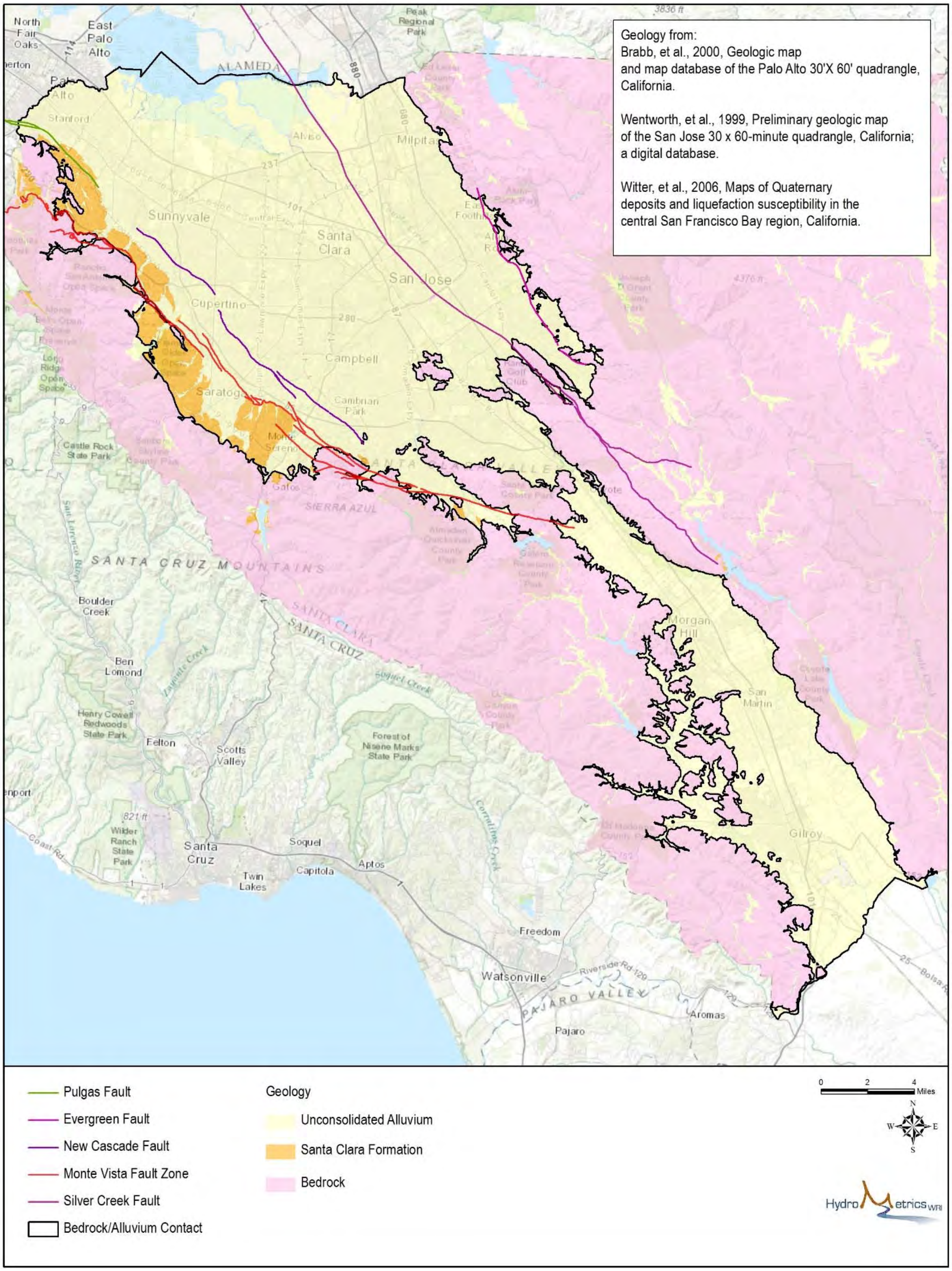

Figure ES- 4: Geology of Santa Clara County

The Study uses historical data and numerical groundwater modeling to evaluate the extent of hydrogeologically connected areas benefiting from District activities (Figure ES- 5). If data and modeling are insufficient to assess whether an area benefits from one or more District activities, the Study uses assumptions about hydrogeologic connection within and between different alluvium and bedrock formations to evaluate where benefits extend from District activities.

The Study reaches the following conclusions that lead to the development of proposed zones of benefit:

1. District recharge activities are located in alluvium that provide hydrogeologic connection throughout the Santa Clara and Llagas Subbasins.
2. District recharge activities have improved the water balance in hydrogeologically connected areas over time.
3. Groundwater level data and numerical groundwater modeling results demonstrate that benefits from District activities extend throughout hydrogeologically connected areas of Unconsolidated Alluvium where the District activities are located.
4. Although the Santa Clara Plain and Coyote Valley are currently both in the Santa Clara Subbasin, the groundwater level data do not conclusively demonstrate that benefits of District treated water deliveries in the Santa Clara Plain extend south into Coyote Valley as Coyote Narrows may restrict groundwater flow between the two management areas.
5. Groundwater level data and modeling results are not available to evaluate whether benefits from District activities in the Unconsolidated Alluvium of the Santa Clara Plain extend into the Santa Clara Formation located on the west side of the Santa Clara Plain.
6. District treated water delivery reduces groundwater demand in the Santa Clara Formation thereby improving the groundwater supply. The Santa Clara Formation consists of hydrogeologically connected alluvium. Therefore, District in-lieu recharge activities in the Santa Clara Formation benefit connected areas of the Santa Clara Formation.
7. Groundwater level data are not available to evaluate whether benefits from District activities in alluvium (Unconsolidated Alluvium or Santa Clara Formation) extend into bedrock. However, bedrock areas receiving District treated water supplies benefit from in-lieu recharge to those areas that reduce groundwater pumping from bedrock fractures. However, bedrock fractures may be limited in areal extent, so the benefit is not considered to extend beyond the bedrock areas receiving District treated water.
8. Groundwater level data and modeling results are not available to demonstrate that managed recharge of imported water in the Llagas Subbasin valley floor benefits the narrow alluvium along Llagas and Uvas Creeks downstream of District reservoirs and upstream of the valley floor. However, the alluvium along these creeks does benefit from District releases of local runoff for managed recharge.

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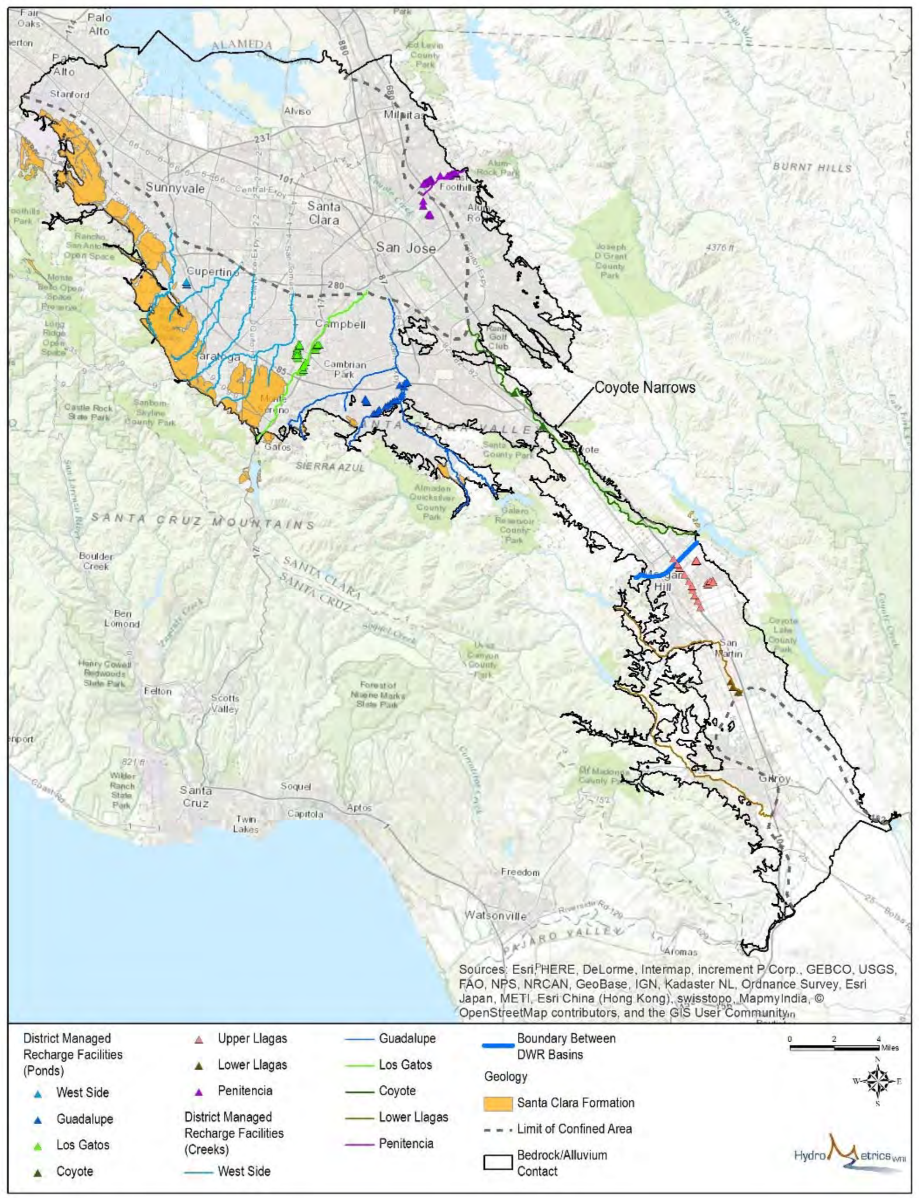
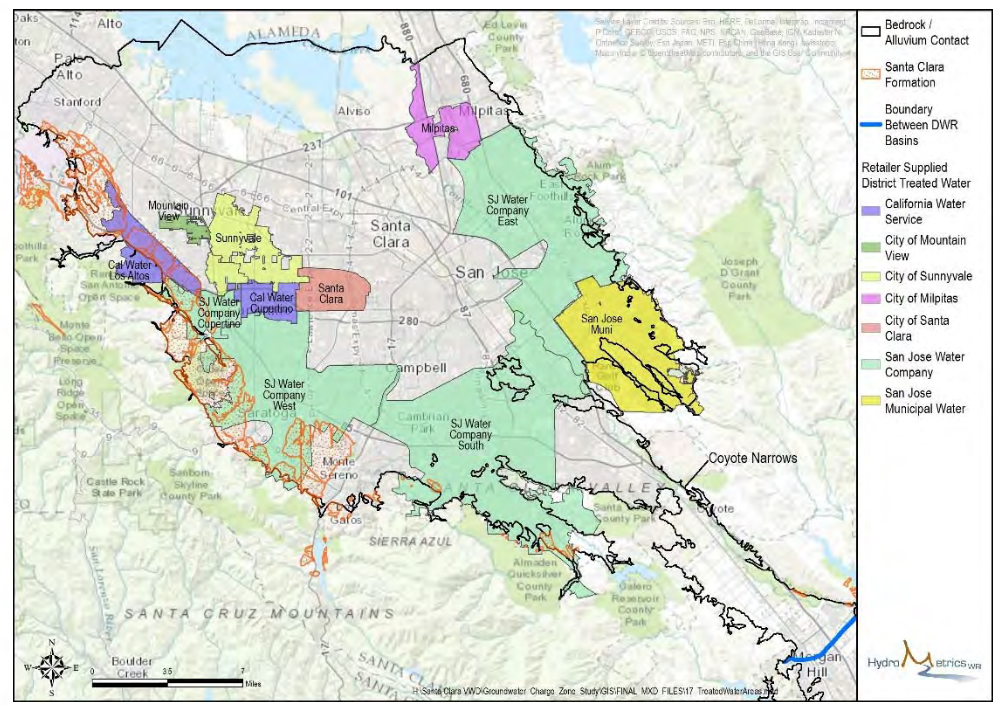
Managed Aquifer Recharge Facilities



Treated Water Delivery Areas (In-lieu Recharge)



Recycled Water Systems and Surface Water Delivery Parcels (In-lieu Recharge)

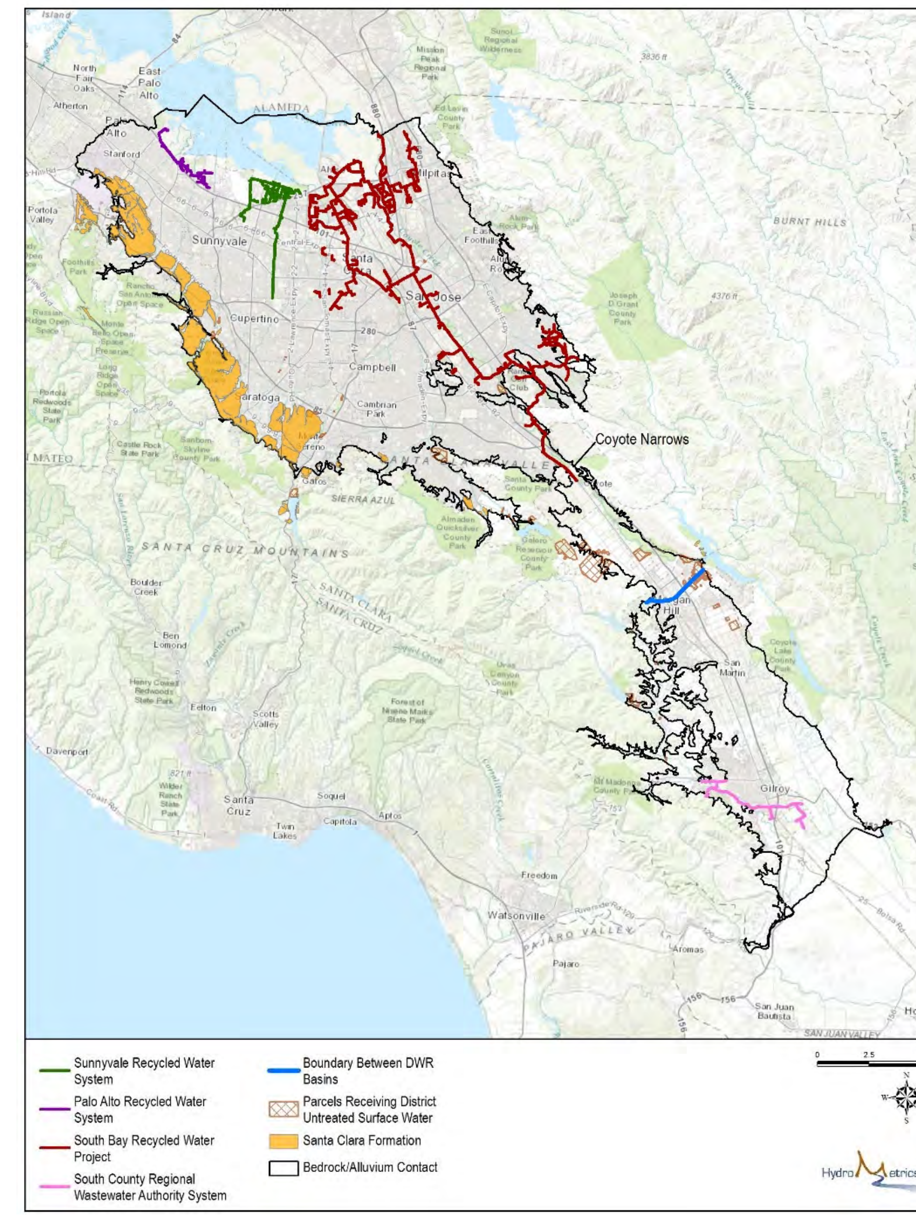


Figure ES- 5: Maps of District Activities

Based on the above conclusions, the Study proposes the following zones as shown in Figure ES- 6:

Zone A: Benefits from Managed Aquifer Recharge (Local and Imported Water), Treated Water Deliveries, and Recycled Water Deliveries in the Unconsolidated Alluvium of the Santa Clara Plain. Zone A includes hydrogeologically connected areas of Unconsolidated Alluvium where benefits from both the District's treated water and managed aquifer recharge activities are demonstrated. This includes Unconsolidated Alluvium overlain by the specific District activities, and Unconsolidated Alluvium where groundwater level data and/or groundwater model results show benefits from both activities.

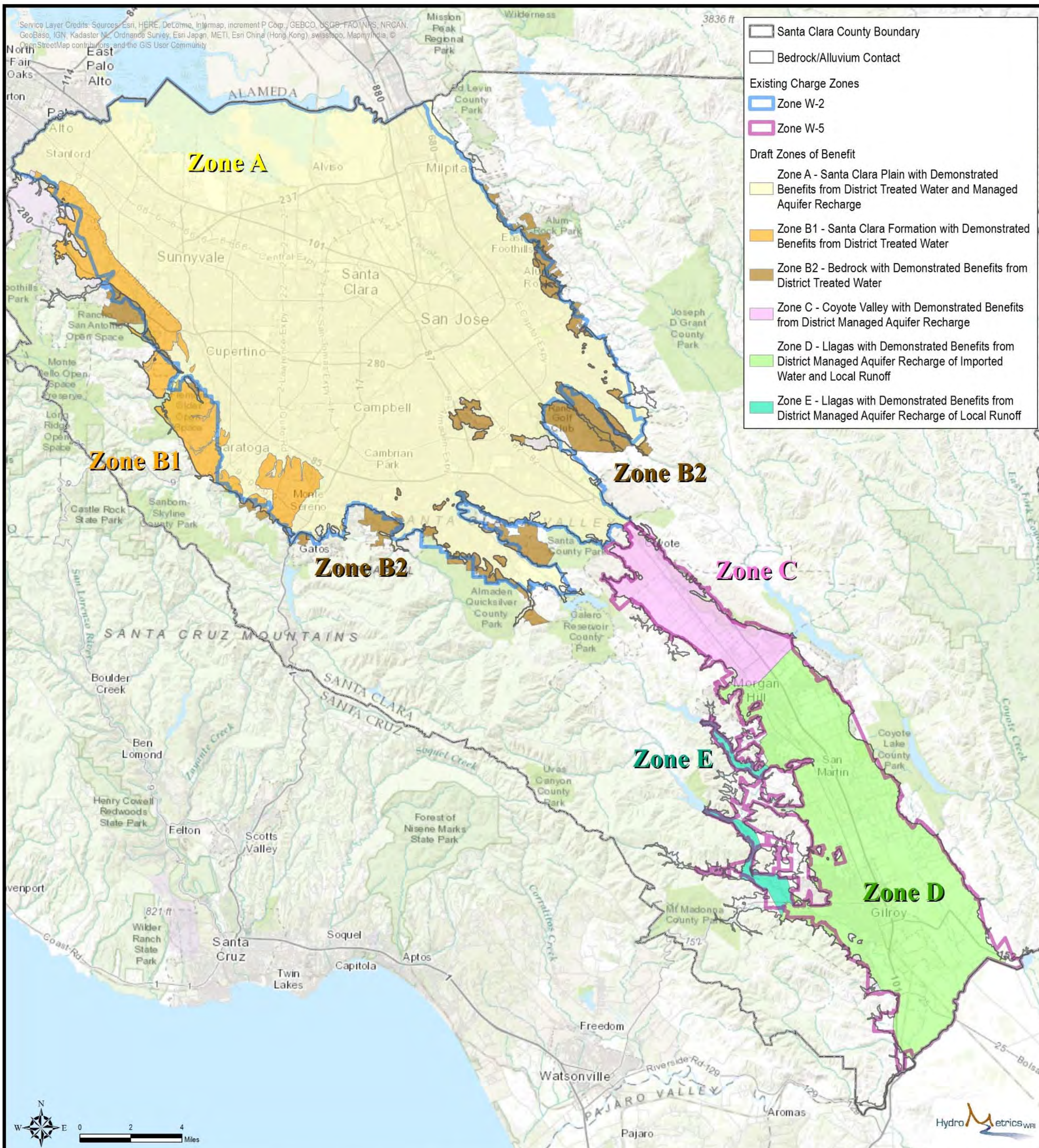
Zone B1: Benefits from Treated Water Deliveries in the Santa Clara Formation. Zone B1 includes areas hydrogeologically connected to where District treated water is delivered, but data or groundwater model results are not available to demonstrate benefits from District's managed aquifer recharge facilities. The area is defined by the Santa Clara Formation outcrop where District deliveries of treated water provide in-lieu recharge throughout the Santa Clara Formation.

Zone B2: Benefits from Treated Water Deliveries in Bedrock. Zone B2 includes areas in bedrock where District treated water is delivered because the deliveries provide in-lieu recharge for pumpers in these areas. The benefit is not considered to extend beyond the bedrock areas receiving District treated water because the hydrogeologic connection in bedrock may be limited in areal extent. Therefore, areas in bedrock outside the delivery areas are excluded from Zone B2.

Zone C: Benefits from Managed Aquifer Recharge (Local and Imported Water) in Coyote Valley. Zone C includes Unconsolidated Alluvium in the Coyote Valley where benefits from managed aquifer recharge are demonstrated by groundwater level data.

Zone D: Benefits from Managed Aquifer Recharge (Local Runoff and Imported Water) and Recycled Water Deliveries in the Llagas Subbasin valley floor. Zone D includes hydrogeologically connected areas of Unconsolidated Alluvium in the Llagas Subbasin where benefits from managed aquifer recharge of imported and local water are demonstrated with data or groundwater model results.

Zone E: Benefits from Managed Aquifer Recharge of Local Runoff in narrow alluvium along Llagas and Uvas Creeks downstream of District reservoirs and upstream of the Llagas Subbasin valley floor. Zone E includes hydrogeologically connected areas of Unconsolidated Alluvium where District managed aquifer recharge of local runoff occurs, but no data or groundwater model results are available to demonstrate benefits from District managed aquifer recharge of imported water. This area includes Unconsolidated Alluvium west of the cities of Morgan Hill and Gilroy that are deposited along Llagas Creek and Uvas Creek below the District's Chesbro and Uvas Reservoirs between bedrock outcrops. The District captures local runoff in the reservoirs and releases the water down the creeks, which recharges these areas of Unconsolidated Alluvium, improving the groundwater supply of these areas.



These mapped zones may be revised further to account for administrative requirements. These zones will also require additional revision to facilitate the development of legal descriptions for the zones. This will involve approximating the boundaries to reduce the number of line segments that require a metes and bounds description.

Zone A includes hydrogeologically connected areas of Unconsolidated Alluvium where benefits from both the District's treated water and managed aquifer recharge activities are demonstrated. This includes Unconsolidated Alluvium overlain by the specific District activities, and Unconsolidated Alluvium where data and/or groundwater model results show benefits from both activities. Zone A excludes areas of mapped Santa Clara Formation where benefits from managed aquifer recharge activities are not demonstrated. The northern boundary is the County boundary and the southern boundary is the boundary between existing Zones W-2 and W-5 at the narrows north of Coyote Valley.

Zone B1 includes areas hydrogeologically connected to where District treated water is delivered, but data or groundwater model results are not available to demonstrate benefits from District's managed aquifer recharge facilities. The hydrogeologic connection is defined by the Santa Clara Formation outcrop, which has overlap with District treated water delivery areas. The deliveries to these areas of the Santa Clara Formation provide in-lieu recharge throughout the Santa Clara Formation, which is considered a hydrogeologically connected area because groundwater flows through porous media of the Santa Clara Formation. District treated water delivery reduces groundwater demand in the Santa Clara Formation and therefore improves groundwater supply of the Santa Clara Formation. The zone includes alluvial outcrop presumed to overlie the Santa Clara Formation. Foothill Expressway is used to approximate the Santa Clara Formation underlying the alluvial outcrop in addition to lining up with the District treated water delivery area for Cal Water Los Altos that provides in-lieu benefits for this area of the zone.

Zone B2 includes areas in bedrock where District treated water is delivered because the deliveries provide in-lieu recharge for pumpers in these areas. District treated water delivery reduces groundwater pumping of bedrock fractures supplying water to wells in those areas, and therefore improves the groundwater supply of those areas. Areas in bedrock outside the delivery areas are excluded from zones because bedrock fractures may be limited in areal extent so the benefit is not considered to extend beyond the bedrock areas receiving District treated water. Zone B2 includes a number of separate areas where bedrock outcrops intersect with District treated water delivery areas.

All zones benefit from long-term water conservation and groundwater protection activities.

Zone C includes Unconsolidated Alluvium in the Coyote Valley where benefits from managed aquifer recharge are demonstrated. The northern boundary is the boundary between existing Zones W-2 and W-5 at the narrows south of Santa Clara Plain. The southern boundary is the boundary between DWR subbasins for Santa Clara Plain and Llagas that approximates the groundwater divide that hydrogeologically separates the two basins.

Zone D includes hydrogeologically connected areas of Unconsolidated Alluvium in the Llagas Subbasin where benefits from managed aquifer recharge of imported and local water are demonstrated. This encompasses Unconsolidated Alluvium where data and/or groundwater model results show benefits from both the recharge of imported water and the recharge of local runoff. The complete retailer areas of the Cities of Morgan Hill and Gilroy are included in the zone, because the city wells draw groundwater from areas that show benefits from imported water and local runoff recharge, and these benefits are extended by the ability of the Cities to distribute water throughout their delivery areas. The northern boundary is the boundary between DWR subbasins for Santa Clara Plain and Llagas that approximates the groundwater divide hydrogeologically separating the two basins. The southern boundary is based on the County line and the extent of Unconsolidated Alluvium.

Zone E includes hydrogeologically connected areas of Unconsolidated Alluvium where SCVWD managed aquifer recharge of local runoff occurs, but no data or groundwater model results are available to demonstrate benefits from District managed aquifer recharge of local runoff. This area includes Unconsolidated Alluvium west of the cities of Morgan Hill and Gilroy that are deposited along Llagas Creek and Uvas Creek below the District's Chesbro and Uvas Reservoirs between bedrock outcrops. The District captures local runoff in the reservoirs and releases the water down the creeks where they recharge these areas of Unconsolidated Alluvium improving the groundwater supply of these areas. Parts of the eastern boundary are located across narrow connections between bedrock outcrops west of where data and groundwater model results are available to demonstrate benefit from imported water. Alluvial channels for tributaries that are not directly downstream of the District's reservoirs are not included in this zone.

Figure ES- 6: Proposed Zones of Benefit

The Study recommends an increase in zones from two to six to associate zones with benefits from specific activities. However, the recommended zones are a result of a technical analysis that does not consider the related administrative issues or requirements for revised zones or increased number of zones. Any changes to the zones must be approved by the District Board of Directors, who will consider all related issues.

The geologic coverage boundaries are based on spatial interpretation and include uncertainty. The proposed zones are based solely on geologic coverages consisting of many connected lines, which would be unnecessarily expensive to describe with metes and bounds. It is justified to simplify boundaries to approximate geologic boundaries and reduce the number of lines for the legal descriptions. Therefore, it is also further recommended to revise the zone boundaries prior to creating legal descriptions with metes and bounds. In addition to simplifying the boundaries, the revision would include adjusting zone boundaries at geologic boundaries to account for the uncertainty of those boundaries. The proposed process for simplifying the boundaries and developing related legal descriptions will be presented to the Board with the staff recommendations..

The Study also includes proposed processes for well exemptions from the zones of benefit and future reviews of the zones of benefit. Well exemptions will be evaluated based on well owner requests and on geology documented by the well log and other sources. Future reviews will be conducted if the District substantially changes the activities that provide benefits or significant new hydrogeologic data become available.

Section 1
BACKGROUND AND SCOPE

1.1 BACKGROUND

The Santa Clara Valley Water District (District) Act gives the District Board of Directors the authority to establish, amend, and revise groundwater charge zones (District Act Section 3), and to levy and collect groundwater charges within a zone or zones that benefit from the recharge of underground water supplies or the distribution of imported water (District Act Section 26). The two primary existing charge zones, Zones W-2 and W-5, were established in 1963 and 1977, respectively. Zone W-2 generally covers the Santa Clara Plain in North County while Zone W-5 generally covers the Coyote Valley and Llagas Subbasin in South County (Figure 1).

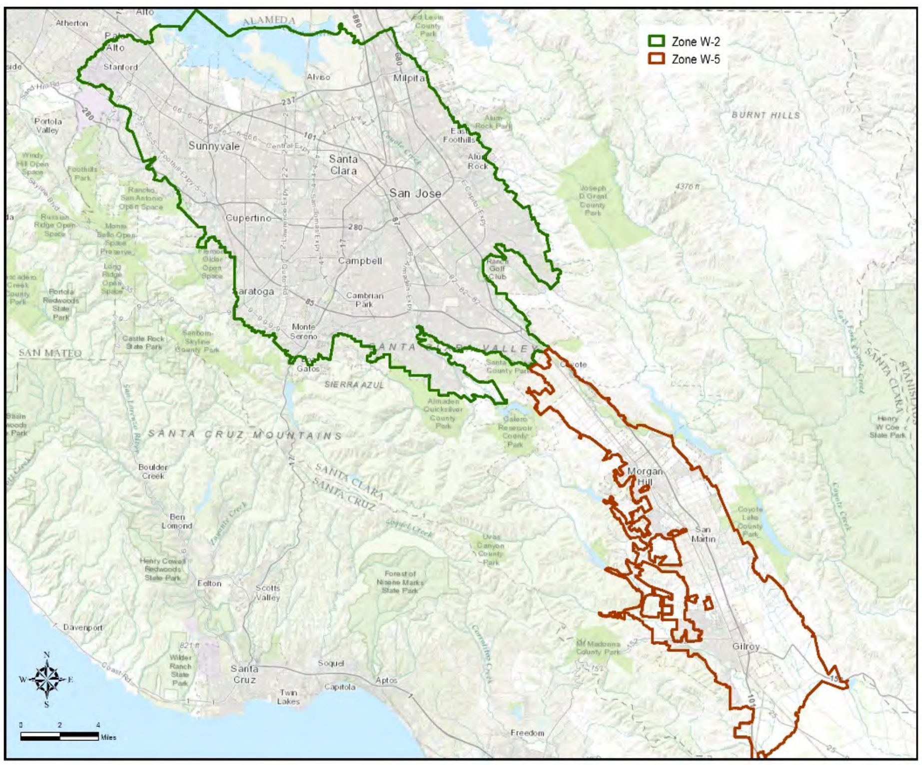


Figure 1: Existing Zones of Benefit

Figure 2 shows the three groundwater management areas of the District: the Santa Clara Plain, Coyote Valley, and Llagas Subbasin, along with the California Department of Water Resources (DWR) subbasin boundaries. Coyote Valley is part of District Zone W-5, but DWR includes Coyote Valley as part of the Santa Clara Subbasin.

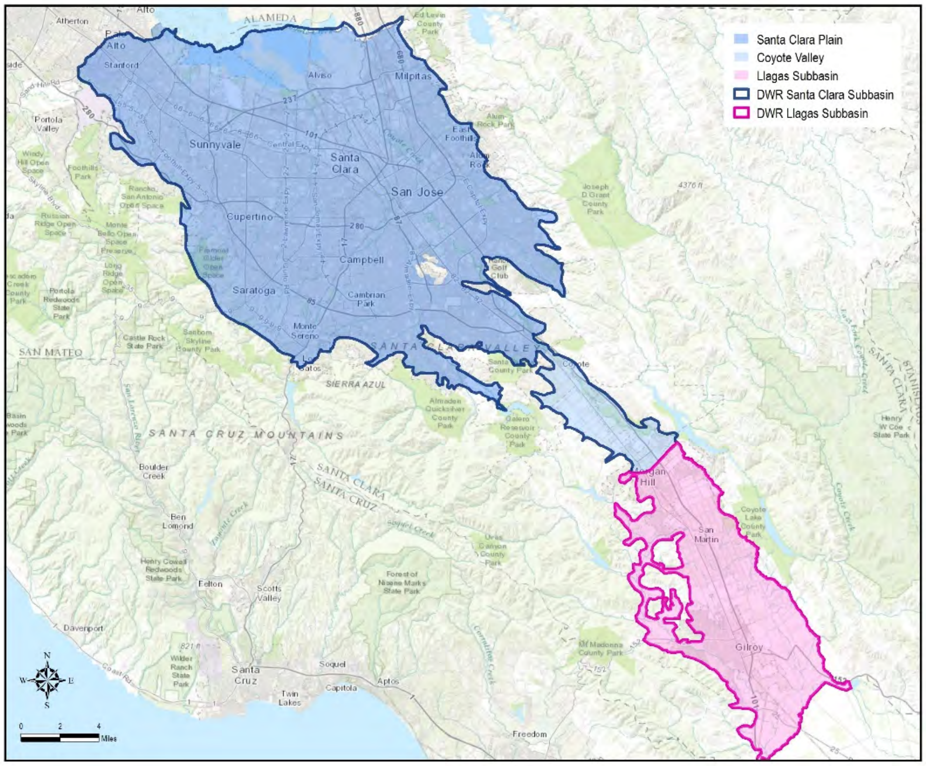


Figure 2: DWR Bulletin 118 Subbasins and District Groundwater Management Areas

The purpose of the Groundwater Zone of Benefit Study (Study) is to complete a comprehensive review of the groundwater charge zones to ensure they reflect areas where groundwater users receive similar benefits from current and planned District activities. Although the District is not aware of any specific problems with the existing groundwater charge zone designations, the District has received requests for exemptions and recognizes that it is important for the District to periodically undertake an updated analysis of various factors upon which the zones are based, and revise the boundaries if necessary. The Study evaluates the ways in which the various District activities benefit groundwater users. These benefits are derived not only from the conjunctive use of surface water supplies for direct groundwater recharge, but also include the direct and indirect benefits of the District's comprehensive groundwater management, including in-lieu recharge, demand management, development of alternative water supplies, long-term conservation, and protection of water quality, amongst others.

1.2 SUMMARY OF METHODOLOGY

HydroMetrics WRI developed the methodology for the Study and documented it in the *Methodology for Evaluating Groundwater Zones of Benefit, Santa Clara County, California* (HydroMetrics WRI, 2016). The District presented draft versions of the methodology to stakeholder groups including at a community open house, a small group briefing, and two meetings with District retailers. A Technical Review Committee (TRC) also provided review of the methodology. Appendix A provides the methodology document and Appendix B provides the stakeholder and TAC comments, and responses to those comments. Implementation of the Study required minor revisions to the methodology based on data availability, including:

- The Study uses pumping in a retailer area to account for in-lieu supplies other than the District activity instead of net demand;
- The Study evaluates periods when the District activity is active and constant instead of just periods when the District activity is increasing; and
- The Study evaluates groundwater levels by retailer area instead of at each well.

A groundwater zone of benefit includes any area within the District's legal jurisdiction where any of the following criteria are met:

- A District activity provides water supply
- District activities improve groundwater supply reliability
- District activities improve groundwater levels
- District activities prevent or limit land subsidence
- District activities reverse or control salt water intrusion
- District activities improve or maintain groundwater quality

The Study uses historical groundwater level, subsidence, salt water intrusion, and groundwater quality data and groundwater flow modeling to assess the extent of areas benefitting from one or more District activities. If data and modeling are insufficient to assess whether an area benefits from District activities, the following assumptions are made:

- Benefits from a District activity extend to all areas that are connected by groundwater flow (hydrogeologically connected) to the activity.
- Areas receiving in lieu supplies from the District benefit from that District activity.

Evaluating groundwater zones of benefit is based on the hydrogeological characteristics that govern the movement of groundwater, District activities, and the benefits to groundwater users provided by the activities. The Study follows the steps below:

1. Map an overview of benefits from District activities such as halting subsidence and reversing salt water intrusion that may require additional evaluation to associate benefits to specific sets of District activities.
2. Map hydrogeologic features and groundwater occurrence and movement to define hydrogeologically connected areas.

3. Plot water balance of pumping, managed recharge and in-lieu recharge over time in hydrogeologically connected areas to assess where the benefit of District activities can be demonstrated.
4. Map current and planned District activities that provide or will provide benefits to groundwater users in the District.
5. Use groundwater data and groundwater flow models to demonstrate the benefit of District activities.
6. Create recommended zones of benefit by grouping areas where users benefit from a specific set of District activities.

In implementing the methodology, the Study considers the following information:

- Geologic maps
- Geologic descriptions
- Groundwater level contour maps
- Fault maps
- Estimates of stratigraphic thickness
- Surface elevation
- Groundwater pumping quantities by area
- District managed aquifer recharge quantities by subbasin
- District treated water delivery quantities by subbasin
- District surface water delivery quantities by subbasin
- District supported recycled water delivery quantities by subbasin
- Conservation rebate locations
- Area precipitation
- Population changes
- Start dates of District activities
- Locations of District managed recharge activities
- Delivery areas of District and District supported in-lieu recharge activities
- Availability of non-District water supplies
- Groundwater level data
- Groundwater quality data
- Well locations
- Groundwater model simulation results

Section 2
OVERVIEW OF DISTRICT ACTIVITIES

2.1 DISTRICT ACT

Section 3 of the District Act empowers the District Board to establish zones of benefit. Section 26 describes the District activities that provide benefits. These District activities include:

- Groundwater recharge,
- Importing water,
- Runoff capture,
- Water storage,
- Water treatment,
- Water distribution,
- Water recycling,
- Groundwater protection, and
- Water conservation.

The primary benefits to groundwater users are derived from District activities that support some form of groundwater replenishment. Groundwater replenishment can be classified as managed aquifer recharge and in-lieu recharge, each of which involves some combination of the above activities, and are described further below.

Groundwater protection activities provide benefits to groundwater quality independently of groundwater recharge activities and maintaining groundwater quality is a key component of maintaining groundwater supply reliability.

2.2 MANAGED AQUIFER RECHARGE ACTIVITIES

Managed aquifer recharge improves groundwater conditions by supplementing natural recharge of the underlying aquifers with both local surface runoff and imported water. Activities that support managed aquifer recharge are shown in Figure 3. Managed aquifer recharge provides benefits of improving groundwater levels thereby potentially improving groundwater supply reliability, preventing or limiting subsidence, and reversing or controlling salt water intrusion. Managed aquifer recharge can also improve groundwater quality.

The Study focuses on evaluating benefits from current activities related to managed aquifer recharge because historical groundwater data are available and show conditions with these activities. Facilities that make up these activities include surface water reservoirs, pipelines, canals, pumping stations, recharge ponds, and recharge creeks. The Study differentiates between systems that can recharge both local runoff and imported water and systems that can recharge only local runoff because imported water is a distinct District activity with different costs. Groundwater users that benefit only from the Lower Llagas System that can recharge only local runoff do not benefit from managed recharge of imported water.

Planned indirect potable reuse involves managed aquifer recharge of purified water. Purified water produced by the Silicon Valley Advanced Water Purification Center (SVAWPC) with advanced oxidation meets or exceeds all California drinking water standards, including all potable reuse regulations for groundwater replenishment

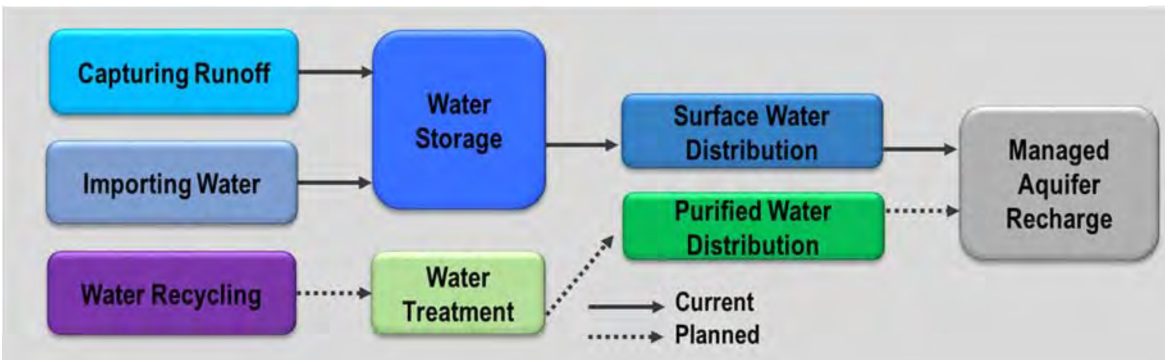


Figure 3: District Activities Supporting Managed Aquifer Recharge For Benefit of Groundwater Users

2.3 IN-LIEU RECHARGE ACTIVITIES

The District's direct delivery of water through various combinations of District activities, as shown in Figure 4, improves groundwater conditions by reducing groundwater extraction; this is referred to as in-lieu recharge. Demand management through water conservation programs also constitutes in-lieu recharge. In-lieu recharge provides benefits of improving groundwater levels thereby potentially improving groundwater supply reliability, preventing or limiting subsidence, and reversing or controlling salt water intrusion.

The Study focuses on evaluating benefits from current activities related to treated water distribution because it is the largest type of in-lieu recharge provided by the District and historical groundwater data are available and they show conditions with these activities. Facilities that support treated water distribution include surface water reservoirs, canals, pump stations, treatment plants, and distribution pipelines.

The Study also evaluates recycled water distribution supported by the District and untreated surface water distribution by the District that provides in-lieu recharge.

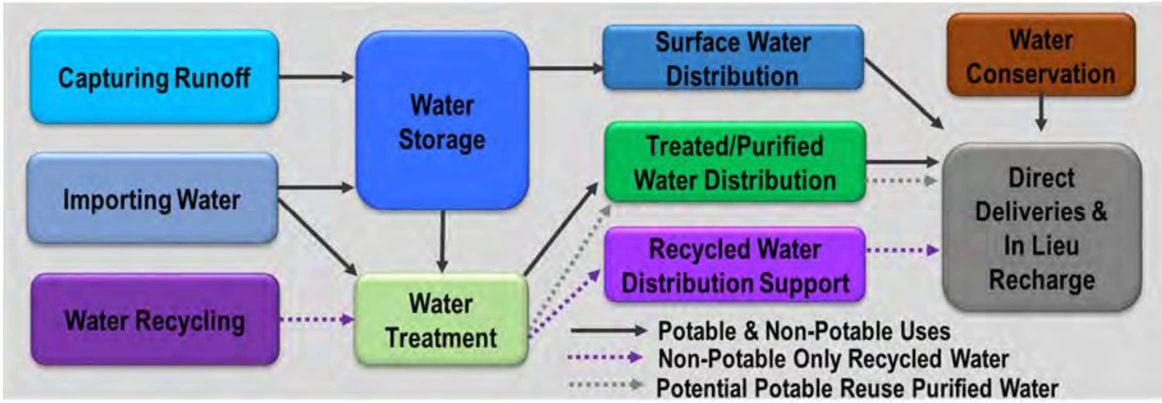


Figure 4: District Activities Supporting In-Lieu Recharge for Benefit of Groundwater Users

2.4 GROUNDWATER PROTECTION ACTIVITIES

Additional benefits are derived from the District's groundwater protection programs, which improve groundwater conditions by maintaining or improving groundwater quality. Protecting groundwater quality is inextricably linked to water supply reliability as groundwater with impaired quality will not be able to meet the uses of water supply. The District's groundwater protection activities include the following programs (SCVWD, 2016b):

- A free domestic well testing program for nitrates, which is offered to private well owners to help owners understand their water quality.
- Salt and nutrient management focused on reducing exposure to high nitrate concentrations, reducing additional nitrate and salt loading, managing nitrates and total dissolved solids (TDS) in groundwater, and monitoring salt and nutrient concentrations.
- Vulnerability assessments evaluating groundwater contamination risks.
- Coordination with land use agencies involving review of local land use plans, policies, and regulations in order to manage increased potential for groundwater contamination.
- Coordination with regulatory agencies to manage sites that pose a risk for releases of groundwater contaminants.
- Public outreach to educate the public on protecting the groundwater resource.

Section 3
OVERVIEW OF BENEFITS FROM DISTRICT ACTIVITIES

Groundwater is a shared resource that can be represented by a water budget, which includes estimates of groundwater inflows (recharge) and outflows (pumping) and conjunctive use of surface water supplies within a given area. Improved groundwater conditions resulting from District groundwater management activities can be demonstrated by an improved water budget, i.e. groundwater conditions would be worse in the absence of District activities. An improved water budget represents the overall benefit of District managed aquifer recharge and in-lieu recharge activities that sustain an area's groundwater supply. As an example, District activities in calendar year 2013 resulted in 96,000 acre-feet of managed aquifer recharge by the District and 148,000 acre-feet of in-lieu recharge (treated water deliveries by the District and recycled water deliveries supported by the District) compared to 39,000 acre-feet of natural recharge (SCVWD, 2014). In addition, the District's conservation activities save approximately 64,000 acre-feet per year, based on 2015 estimates (SCVWD, 2016). District activities that result in an improved water budget provide the following benefits to groundwater users.

3.1 IMPROVED GROUNDWATER SUPPLY RELIABILITY

On average, groundwater accounts for forty percent of the water used in Santa Clara County. Groundwater pumping (approximately 150,000 acre-feet in 2013) far exceeds natural recharge, and the District's managed and in-lieu recharge programs, including sustained and expanded conservation efforts, help replenish and sustain groundwater supplies. Figure 5 shows the rapidly growing population of Santa Clara County after World War II that was supported by a groundwater supply improved by District activities. This groundwater supply also supports high rates of business development and a viable agricultural economy. Community growth, quality of life and economic prosperity depend on a reliable and sustainable water supply that can be attributed to District groundwater management activities.

The Study uses historical groundwater level data and model results to evaluate improved groundwater supply reliability related to District activities.

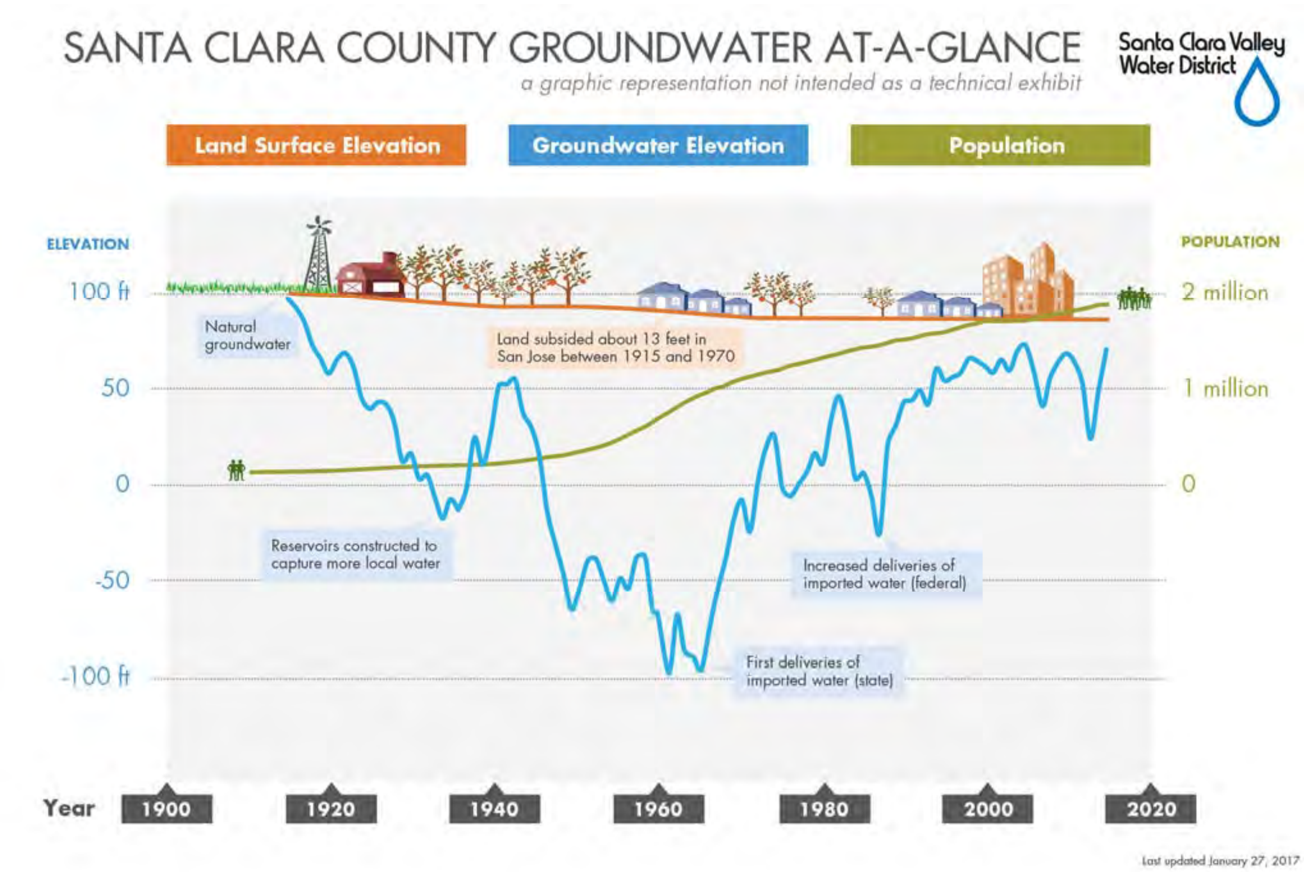


Figure 5: Graphic Representation of Groundwater Levels, Population and Land Subsidence (Courtesy SCVWD)

3.2 Reduced Risk of Land Subsidence

As shown in Figure 5 portions of the Santa Clara Valley subsided approximately 13 feet between 1915 and 1970 when groundwater pumping generally exceeded recharge. During that time, there was at least a 1-foot drop in the land surface over a 100-square mile area including portions of Palo Alto, Mountain View, Sunnyvale, Santa Clara, and San Jose (Figure 6). Since then, permanent inelastic subsidence has been halted due to an improved water budget resulting from District activities (SCVWD, 2016). Subsidence can result in adverse effects such as damaged infrastructure, increased flooding risk, increased sediment erosion or deposition, and, where relevant, impairment of leveled agricultural fields. Therefore, preventing subsidence is a benefit of the improved water budget resulting from District activities.

Figure 5 represents subsidence at one location (downtown San Jose) over time, but subsidence data over time at multiple locations are necessary to evaluate benefits over a broader area.

Maps of subsidence are available only at specific times (Figure 6). Figure 6 also shows subsidence measured at extensometers, which shows subsidence halted before maximum subsidence could occur. Figure 6 shows the area where District activities provide the benefit of preventing subsidence. While it is clear that District activities have contributed to preventing subsidence and therefore support the area being part of a zone of benefit, additional evaluation is required to associate the subsidence benefits to specific sets of District activities and account for other sources of recharge such as rainfall or in-lieu supplies of surface water from San Francisco Public Utilities Commission (SFPUC) Regional Water System (RWS). This additional evaluation may show that the subsidence benefits result from different District activities in different areas which would support defining multiple zones of benefit for the area of subsidence benefits. As shown in Figure 5, raising groundwater elevations prevents subsidence so the Study focuses on groundwater elevation data and model results as a proxy for the benefits of preventing subsidence.

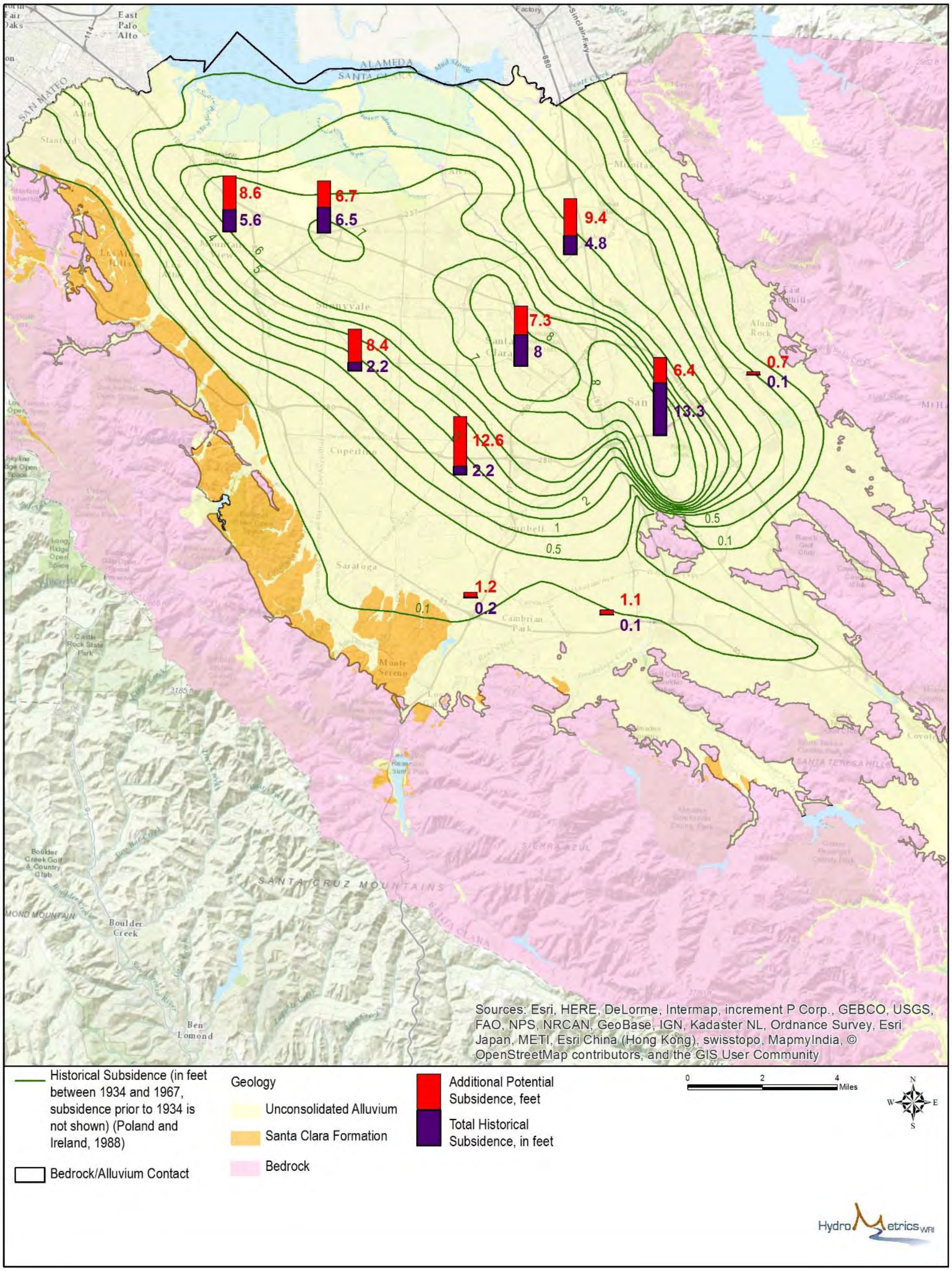


Figure 6: Subsidence Contours with Geology

3.3 SALT WATER INTRUSION PREVENTION

Historically, denser salt water moved inland via creeks connected to the San Francisco Bay then infiltrated groundwater when groundwater pumping exceeded natural recharge and subsidence resulted in greater tidal influence on the creeks connected to the bay (SCVWD, 2016b). Figure 7 shows the inland migration of salt water intrusion in the shallow aquifer zone from 1945 to 1980. Figure 7 additionally illustrates the reversal of salt water intrusion in the shallow zone from 1980 to 2015. Although salt water intrusion has been observed only small part of the deeper aquifer zone that provides groundwater supply (SCVWD, 2016), salt water intrusion would represent a risk to the groundwater quality deeper groundwater supply due to potential for inter-aquifer transfer through improperly destroyed wells or other borings. Reducing this risk to groundwater quality improves the reliability of groundwater supply. Therefore, preventing salt water intrusion is a benefit of the improved water budget from District activities.

Maps of salt water intrusion are available only at the specific times shown on Figure 7. Figure 7 shows areas where District activities provide the benefit of reducing salt water intrusion. Both managed aquifer recharge and treated water deliveries have helped raise groundwater levels in areas subject to saltwater intrusion; however, additional evaluation is required to associate those benefits to specific sets of District activities and account for other sources of recharge such as rainfall or in-lieu supplies of water from SFPUC RWS. Raising groundwater elevations is the mechanism for reducing salt water intrusion so the Study focuses on groundwater elevation data and model results as a proxy for the benefits of preventing salt water intrusion.

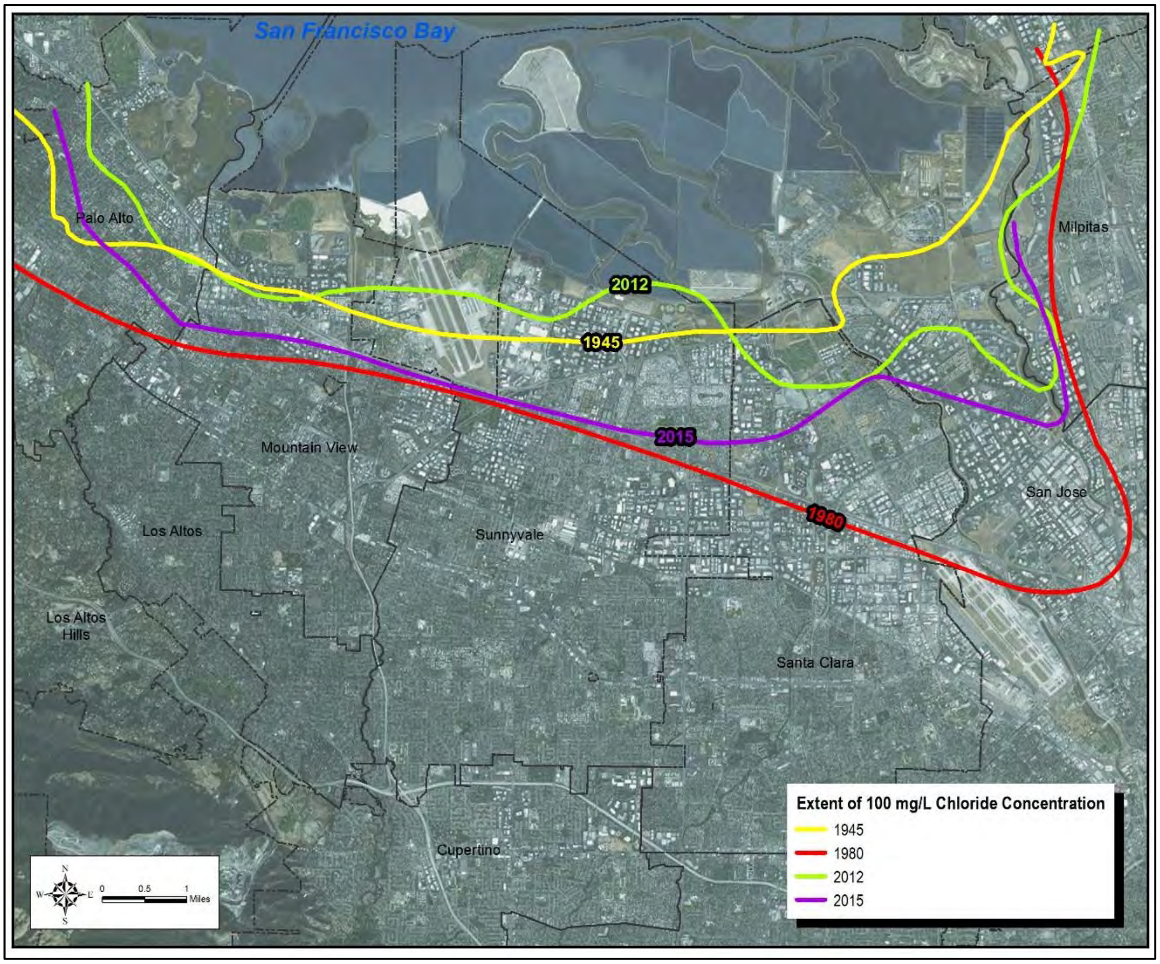


Figure 7. Extent of Shallow Zone Salt Water Intrusion

3.4 Improved Groundwater Quality

Recharge water can be of higher quality than the ambient groundwater so an improved water budget from District activities can also improve groundwater quality. For example, nitrate concentrations are high in ambient groundwater in portions of the Llagas Subbasin, but imported water used for managed aquifer recharge has a dilution benefit by adding water with low nitrate concentrations to the water budget (MACTEC, 2009). SCVWD's study of nitrate in domestic wells in the Llagas Subbasin found that 14% of wells within 2,000 feet of District recharge facilities exceeded the nitrate maximum contaminant limit (MCL), while 40% of wells tested in all other areas exceeded the MCL (SCVWD, 2012). These groundwater quality benefits from specific District recharge activities generally cover a smaller area than benefits represented by groundwater level changes so this smaller area of water quality benefits do not represent the entire area benefiting from the specific activities.

Groundwater protection activities also conserve and improve groundwater quality. Maintaining groundwater quality improves the reliability of the groundwater supply to meet drinking water standards, irrigation quality requirements, and quality needs of other uses. These activities are distributed widely through the District's service area and benefit the entire subbasin. In general, since all groundwater users benefit from these groundwater protection measures; the Study does not focus on groundwater quality for defining zones of benefit.

3.5 WATER REUSE BENEFITS

The District partners and collaborates with recycled water producers, wholesalers, retailers, users, and other interested parties to develop and expand recycled and purified water within the County. Increasing recycled and purified water benefits County groundwater supplies by alleviating stress on existing potable water supply infrastructure during droughts, and provides an alternative local, drought-proof, and reliable water supply to the County.

Some of these partnerships include four agencies that produce recycled water in the County (Palo Alto/Mountain View Recycled Water System, South Bay Water Recycling Program (SBWRP), South County Regional Wastewater Authority (SCRWA), and City of Sunnyvale Recycled Water System) along with other stakeholders. The District is planning to develop a Countywide Water Reuse Master Plan (CWRMP) to identify future potential stakeholder partnerships and determine the institutional agreements needed to advance recycled and purified water. The vision of the CWRMP is a collaborative strategy to integrate and expand recycled and purified water as a local, reliable, environmentally adaptive, drought-proof water supply and guide strategic investment of public funds over the next 20 years.

Section 4
HYDROGEOLOGICALLY CONNECTED AREAS

District activities provide groundwater benefits beyond the immediate location of an activity. Groundwater flow patterns control how benefits extend beyond the activity locations. The Study maps hydrogeologic features that affect groundwater flow to define areas hydrogeologically connected to District activities. Mapped features include contacts between water-bearing sediments and bedrock, and the location of groundwater divides separating subbasins. Other geologic features that may define the limits of hydrogeologic connection include faults, where alluvium narrows and/or steepens, and contacts between geologic formations with different levels of consolidation. The boundaries for the hydrogeologically connected areas are based on some of these features.

4.1 ALLUVIUM CONTACT WITH BEDROCK

The hydrogeologically connected areas are primarily defined by the geologic contact between unconsolidated to semi-consolidated alluvium and consolidated bedrock of the adjacent mountain ranges. Alluvium are primarily sediments that eroded from adjacent mountain ranges by flowing water and deposited in the Valley during the current geologic age (Quaternary age) that began approximately 2.6 million years ago. The bedrock of the adjacent Santa Cruz Mountains and Diablo Range are primarily composed of sedimentary, metamorphic, and volcanic rocks formed in Jurassic, Cetaceous, and Tertiary periods older than 2.6 million years ago (SCVWD, 2016). In addition to bounding the hydrogeologically connected areas of alluvium laterally, bedrock underlies the alluvium (Figure 8).

Alluvium includes fine sediments of silt and clay and coarser sediments of sand and gravel. Groundwater flows through spaces (pores) in these sediments. Groundwater generally flows through the pores of the alluvium until encountering bedrock or other hydrogeologic boundaries so continuous areas of alluvium generally hydrogeologically connected. This groundwater flow through porous media provides greater potential for connecting areas with groundwater users to benefits from District activities than in bedrock. Bedrock is consolidated so groundwater flow typically occurs in bedrock fractures that have not been mapped and may be limited in extent. District activities can benefit the groundwater supply of these fractures but the extent of the benefit would be limited by the unknown extent of fractures. Therefore, the bedrock/alluvium contact within Santa Clara County is the basis for the hydrogeologically connected areas used to define the extent of potential benefit. Quaternary deposits and artificial fill mapped at the surface that are not specifically labeled alluvium are included in the Study's definition of alluvium because they are relatively young (< 2.6 million years) deposits and are relatively permeable compared to the older bedrock that bounds the basin.

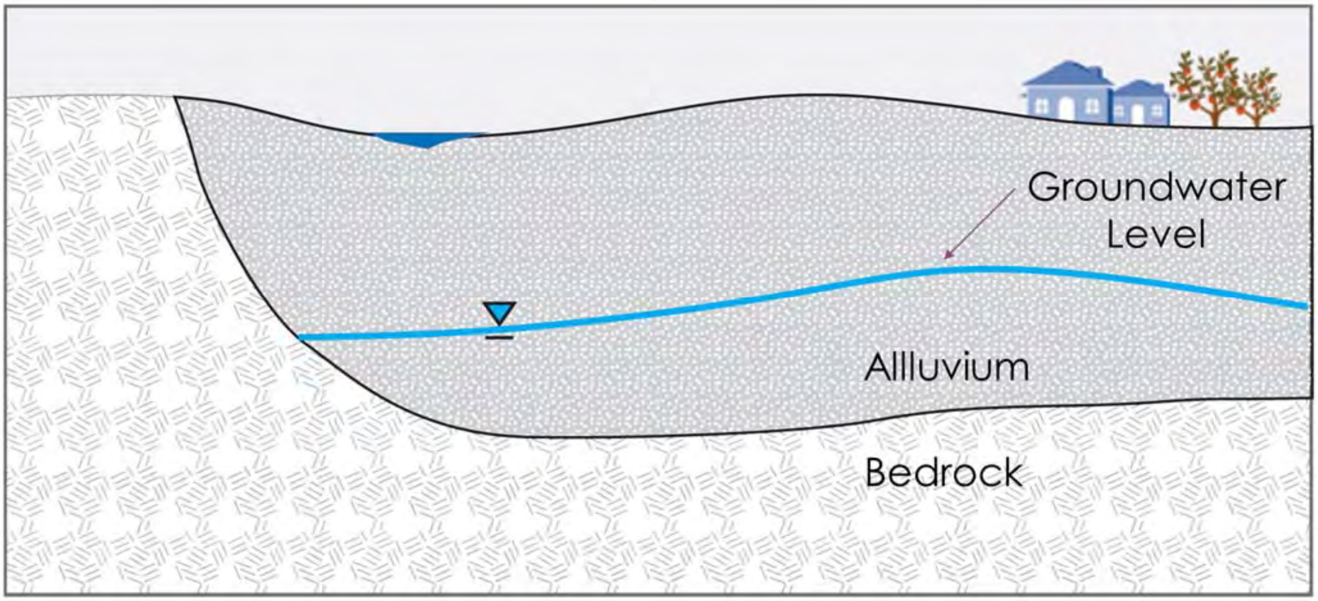


Figure 8: Schematic Cross-Section of Alluvium and Bedrock

4.1.1 GEOLOGIC MAPS

The bedrock/alluvium contact is based on existing maps by the U.S. Geological Survey (USGS) and California Geological Survey (CGS). The Study uses GIS formats of these maps that were downloaded from USGS websites.

Two 30 x 60-minute quadrangles are used for this study: Palo Alto (Brabb et al., 2000) and San Jose (Wentworth et al., 1999). The Palo Alto quadrangle covers the northwestern portion of the County from Palo Alto to Saratoga, with its eastern boundary just west of the North-South Lawrence Expressway. The San Jose quadrangle covers the County from the Palo Alto quadrangle to West 10th St/Highway 152 in Gilroy in the Llagas subbasin. Maps of Quaternary deposits for the San Francisco Bay Region (Witter et al., 2006) are used to cover the rest of the County to the South. Even though it covers the whole County, this regional map has more generalized groupings of geologic formations so the more detailed Palo Alto and San Jose quadrangles are used where available. Figure 9 shows the unified geology from all three maps used in this study.

The listed scale of the Palo Alto quadrangle is 1:62,500 and the listed scale of the San Jose quadrangle and regional map is 1:24,000. The USGS accuracy standard requires that 90 percent of known points must be within 0.02 inches on the map. For 1:24,000 scale, this translates to an accuracy of 40 feet and for 1:62,500, this translates to an accuracy of approximately 105 feet. However, geologic maps involve interpretation between known points and interpretation likely results in some additional inaccuracies.

4.1.2 Alluvium Formations

Alluvium in Santa Clara County primarily consists of unconsolidated sediments, lenses of clay, silt, sand, and gravel deposited in the Holocene (younger than 12,000 years old) and Pleistocene epochs (12,000 to 2.6 million years ago), that this report refers to as Unconsolidated Allivium. Figure 9 distinguishes Unconsolidated Alluvium from the slightly older Santa Clara Formation located on the west side of the Santa Clara Plain. The Santa Clara Formation consists of slightly consolidated or semi-consolidated alluvium deposited during the early Pleistocene and Pliocene epochs (2.6 million to 5.8 million years ago). Groundwater flow through Unconsolidated Alluvium and Santa Clara Formation is through porous media but permeability of Santa Clara Formation is less certain than Unconsolidated Alluvium. Section 4.6 provides additional discussion of hydrogeologic connection in the Santa Clara Formation and between Unconsolidated Alluvium and Santa Clara Formation

4.2 Groundwater Divide

Groundwater divides occur between areas where groundwater flows in opposite directions. The primary groundwater divide in the County is the divide at the southern end of Coyote Valley that is used by the California Department of Water Resources (DWR) to define the boundary between the Santa Clara and Llagas Subbasins (DWR, 2003). North of this divide, groundwater flows to the north. South of this divide, groundwater flows to the south.

The groundwater divide changes slightly over time based on recharge and pumping conditions so groundwater contours maps developed by the District for 1975-2015 were reviewed. Figure 9 shows spring and fall groundwater contours from 2000-2002 and Figure 10 shows spring and fall groundwater contours from 2013-2015 for years when the District developed groundwater contours for the area of the groundwater divide in GIS format. The contours affirm that the DWR basin boundary is a representative approximation of the groundwater divide over time and an appropriate boundary for hydrogeologically connected areas used to define the extent of potential benefit.

The contour maps also show that other groundwater divides may appear seasonally but are not consistent throughout the year. For example, in the spring, the north part of the County has a divide between flow north toward the Bay and south towards pumping depressions but this divide is not maintained throughout the year and does not establish a boundary for hydrogeologically connected areas. A consistent groundwater divide other than the subbasin boundary is also not evident in historical contour maps created by the District for 1975-1999.

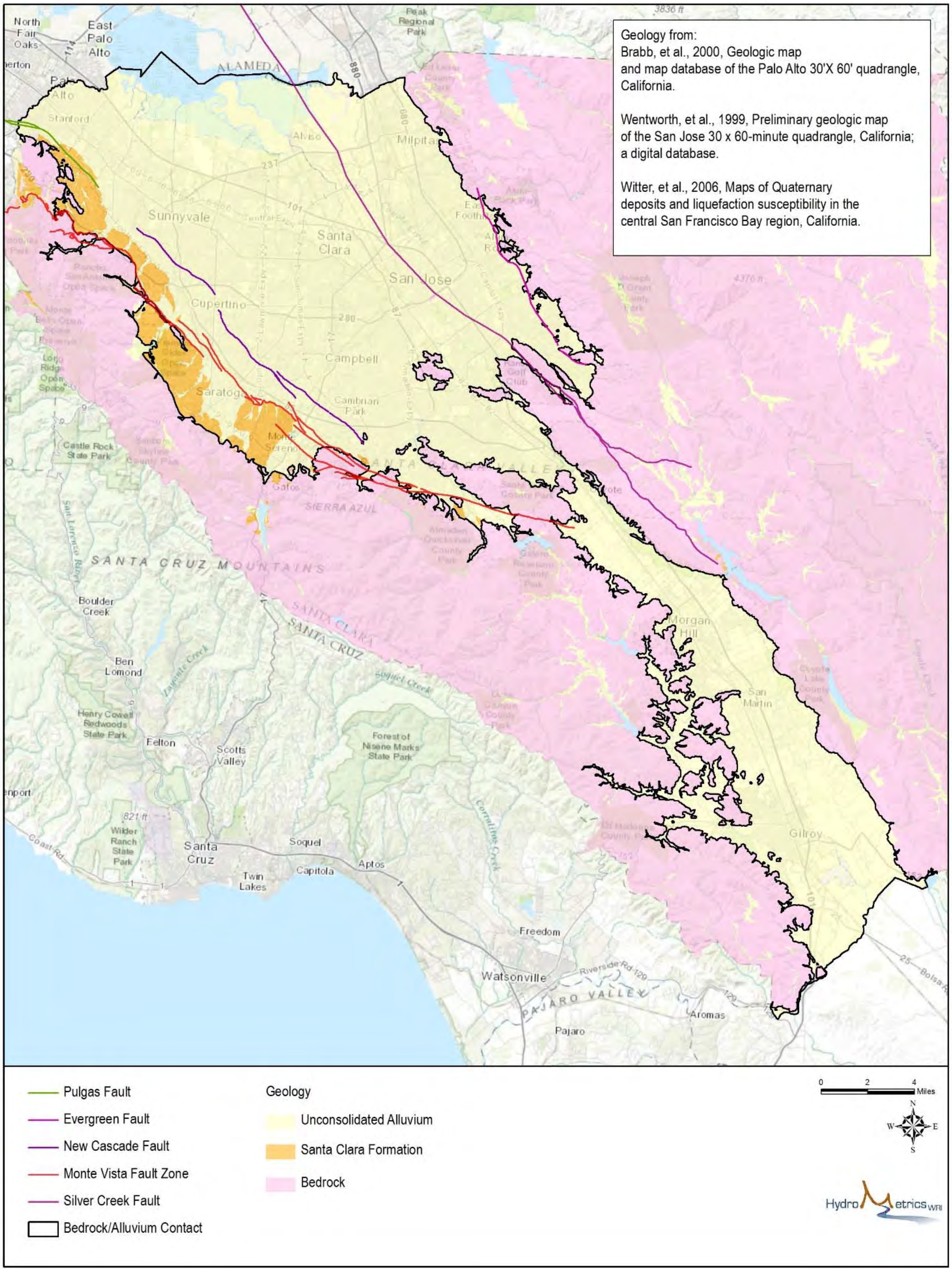


Figure 9: Geology of Santa Clara County

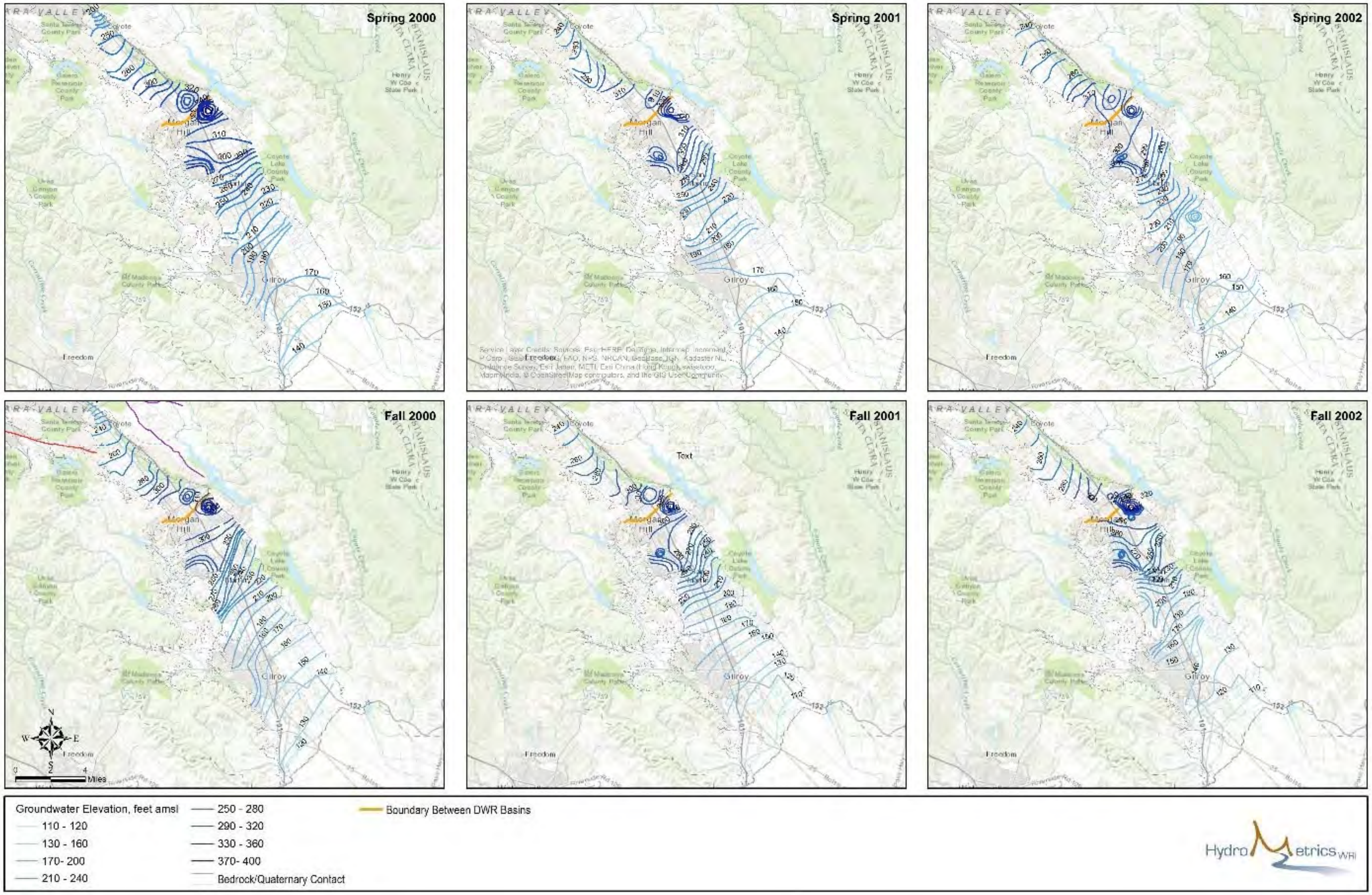


Figure 10: Spring and Fall Groundwater Elevation Contours for Coyote Valley and Llagas Subbasin 2000-2002

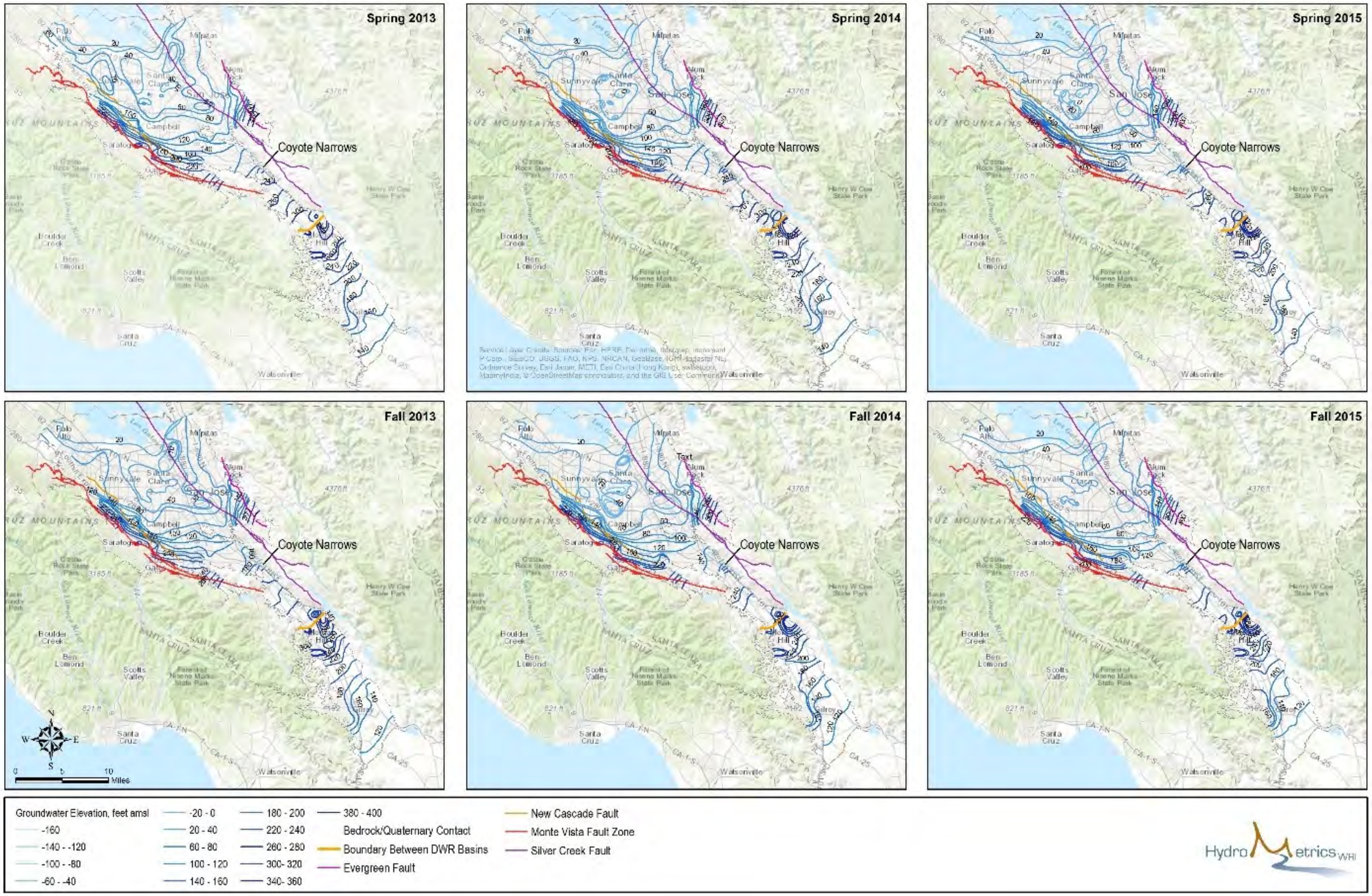


Figure 11: Spring and Fall Groundwater Level Elevation Contours for Santa Clara Subbasin 2013-2015

4.3 FAULTS

Faults can be barriers to groundwater flow. However, faults are not necessarily definitive and significant barriers to flow that limit the extent of benefits from District activities. Previous studies identified the faults that are most likely to be significant barriers to flow. This Study evaluates whether these faults are significant barriers to flow by comparing fault locations with the groundwater level contour maps. The Study assigns faults previously identified as possible barriers to groundwater flow as hydrologic boundaries if the extent of District activity benefits, as estimated by the groundwater level evaluation (Section 6) and modeling evaluation (Section 7), indicate benefits may be limited by the fault.

Fault locations that may be flow barriers were derived from a number of studies. The most recent USGS study of the hydrogeology of the Santa Clara Plain (Wentworth et al., 2015) identifies several faults as at least partial barriers to groundwater flow. Interferometric synthetic-aperture radar (InSAR) imagery indicates a subsidence boundary at the Silver Creek Fault in the eastern part of the subbasin (Galloway et al., 2000). Hanson et al. (2004) includes three segments of this fault and the nearby North Evergreen Fault as horizontal flow barriers in a groundwater model. Based on the model calibration, the greatest barriers to flow in this area are two southern segments of the Silver Creek Fault in layers 3-6 in the model where layers 3-5 represent the confined unit in the subbasin from which most production occurs (CH2M Hill, 1992). However, there is a gap included in the fault near Coyote and Silver Creeks to simulate stream recharge across the fault.

Hanson et al. (2004) also simulates the Monte Vista and New Cascade Faults as horizontal flow barriers in model layers 3-6 to reduce groundwater levels in the central part of the subbasin. The model also includes gaps at District managed recharge facilities Ross Creek and Stevens Creek of the West Side system and Los Gatos Creek to simulate stream recharge across the fault.

Groundwater level contours for 2013-2015 (Figure 11) developed by the District do not indicate a barrier to groundwater flow across these faults based on GIS files produced by the USGS and CGS (2010). However, the contours do not extend west of the Monte Vista Fault into the mapped outcrop of the Santa Clara Formation (Section 4.6).

Given that there is inconsistent information about whether these faults are barriers to groundwater flow, and there is likely some flow across the faults, faults are identified as boundaries only if benefits from a District activity are only demonstrated on one side of the fault.

Wentworth et al. (2010) evaluates evidence for other historically inferred faults in the basin and concludes most of those previously identified faults do not extend into the alluvium of the subbasin. No faults have been identified as barriers to groundwater flow in the alluvium of Coyote Valley and the Llagas Subbasin.

4.4 STRATIGRAPHIC THICKNESS

The Study uses interpreted stratigraphy to map the thickness of the alluvium including Unconsolidated Alluvium and Santa Clara Formation. Large changes in thickness or stratigraphy could be geologic features that affect how groundwater flows between areas. If the thickness decreases over a small distance, groundwater flow can be constricted and limit the hydrogeologic connection across the change in thickness. The Study calculates and maps depth to bedrock in the alluvium of the Santa Clara Plain (Figure 12) based on GIS files for bedrock elevation developed by Wentworth et al. (2010) and ground surface elevation based on the USGS Digital Elevation Model.

While the map of stratigraphic thickness shows an area of thinner Unconsolidated Alluvium in the area north of Coyote Narrows, groundwater level contours do not show that it affects groundwater flow (Figure 11). The area of reduced thickness is not considered a limit on the area of hydrogeologic connection.

Although similar data sets are not available for the Coyote Valley and Llagas management areas, depths implemented in the model do not show substantial changes in thickness over short distances and groundwater contour maps do not indicate a constriction of flow due to thickness changes.

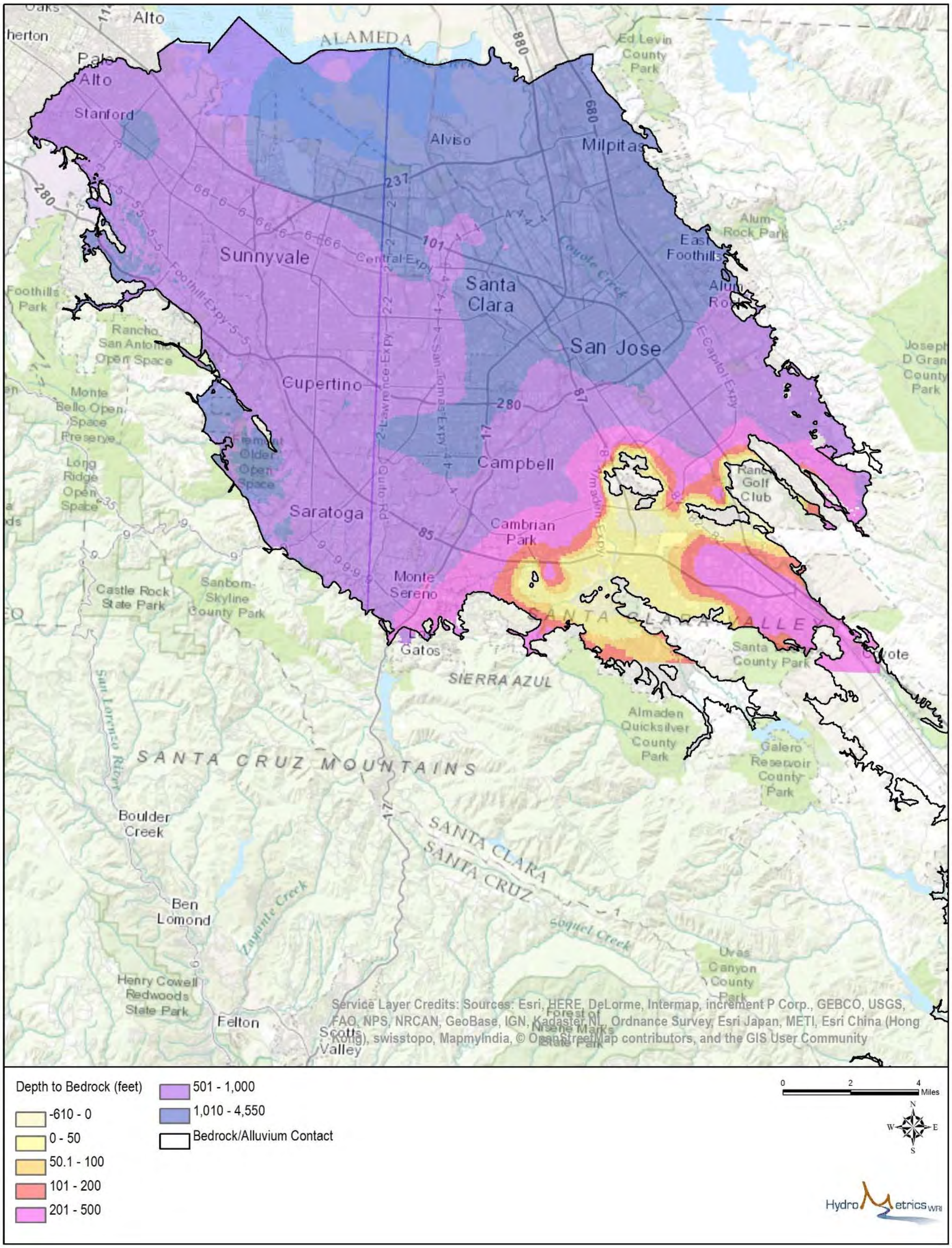


Figure 12: Depth to Bedrock Based on USGS Stratigraphy (Wentworth et al., 2015)

4.5 Constrictions of Unconsolidated Alluvium

A geologic feature that may affect hydrogeologic connectivity occurs when the Unconsolidated Alluvium constricts between bedrock outcrops. Even though groundwater flow may occur through such a constriction, the constriction may have enough effect that the hydrogeologic connection transmitting benefits from District activities is limited.

4.5.1 Coyote Narrows

The existing boundary between Zones W-2 and W-5 is located at the Coyote Narrows between the Santa Clara Plain and Coyote Valley. Groundwater level contour maps (Figure 11) show a steep gradient in this area. This indicates that the constriction is affecting groundwater flow substantially and may limit hydrogeologic connection across the boundary. The existing zone boundary may approximate a boundary for hydrogeologically connected areas if benefits from a District activity are only demonstrated on one side of the Narrows.

4.5.2 Bedrock Outcrops in Llagas Subbasin

There are several bedrock outcrops in the Llagas Subbasin that may affect the hydrogeologic connection of Unconsolidated Alluvium within Llagas Basin (Figure 13). Like at Coyote Narrows, these bedrock outcrops may constrict groundwater flow through Unconsolidated Alluvium thereby limiting hydrogeologic connection. These narrow Unconsolidated Alluvium connections which may be appropriate to use as a boundary if benefits from a District activity are only demonstrated on one side of the outcrop constrictions. Groundwater level maps are not available to show gradients across these constrictions.

4.5.3 Narrow Alluvial Channels

Another constriction of Unconsolidated Alluvium is where narrow and steep streambed alluvium channels flow through bedrock areas into downstream areas of Unconsolidated Alluvium. The constriction may limit the hydrogeologic connection between activities in the downstream areas with the upstream channel. Therefore, the constrictions may be appropriate to use as a boundary. Groundwater level maps are not available to show gradients across these constrictions, but stream elevations in connection with groundwater in the shallow alluvial channels are typically much higher than groundwater levels in the downstream areas. Ground surface elevations and data for alluvial thicknesses can be used to evaluate where this limitation on hydrogeologic connection occurs.

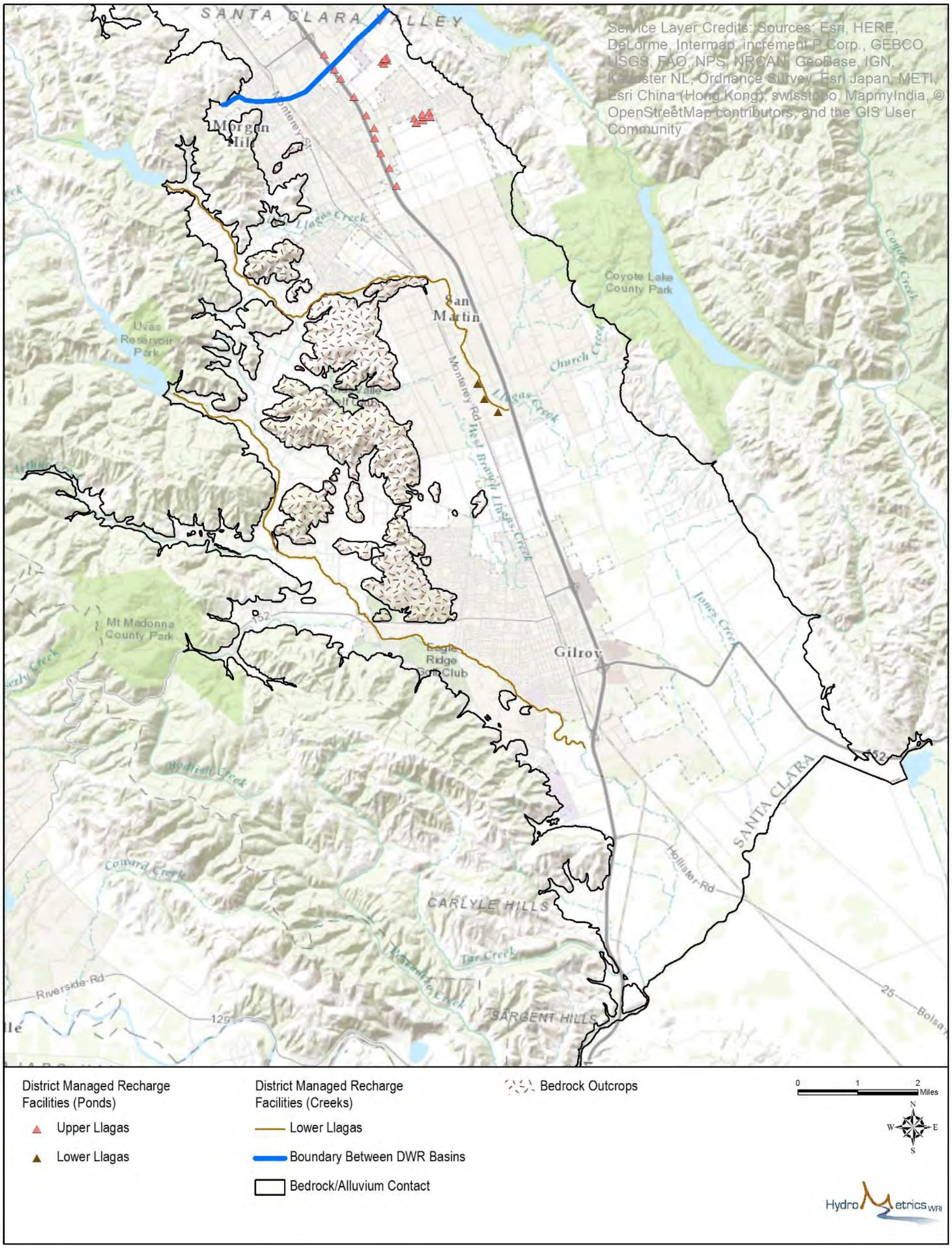


Figure 13: Locations of Bedrock Outcrop Constrictions in Llagas Subbasin

4.6 SANTA CLARA FORMATION

Descriptions of the water bearing alluvium in the Santa Clara Plain distinguish between the Santa Clara Formation of Plio-Pleistocene age and the other Pleistocene-Holocene deposits referred to in this report as Unconsolidated Alluvium. DWR's description of the Santa Clara Subbasin describes the Unconsolidated Alluvium as the more important water bearing unit for the subbasin (DWR. 2003).

Figure 14 shows the largest surface outcrop of the Santa Clara Formation on the west-side of the subbasin where it has been described as "poorly sorted, irregularly bedded material ranging in grain size from silt to boulders" (DWR, 1975). Other studies have described the Santa Clara Formation as partly non-water bearing in this outcropping area (Wentworth et al., 2015), however there are wells that extract groundwater throughout this area as shown on Figure 13. Pumping data are available for wells in the outcropping area of the Santa Clara Formation that are also within current Zone W-2 and production for 2015 totaled 557 acre-feet. In addition, the description of the Santa Clara Formation indicates that groundwater flow is flow through pore spaces in the Formation materials, not through fractures as in bedrock. It is reasonable to consider connected areas of the Santa Clara Formation as hydrogeologically connected.

However, there is a lack of information documenting a hydrogeological connection between the Santa Clara Formation and the Unconsolidated Alluvium. In addition, the previous presumption that the Santa Clara Formation underlies Unconsolidated Alluvium towards the center of the basin (DWR, 1975) has been questioned by Wentworth et al. (2015) who concluded that there is little evidence for its existence much closer to the center of the basin than the surface outcrops shown in Figure 13. Therefore, a hydrogeologic connection between the Santa Clara Formation and Unconsolidated Alluvium is not assumed and must be demonstrated by data and modeling, if available, for benefits from District activities to extend from one geologic formation to the other.

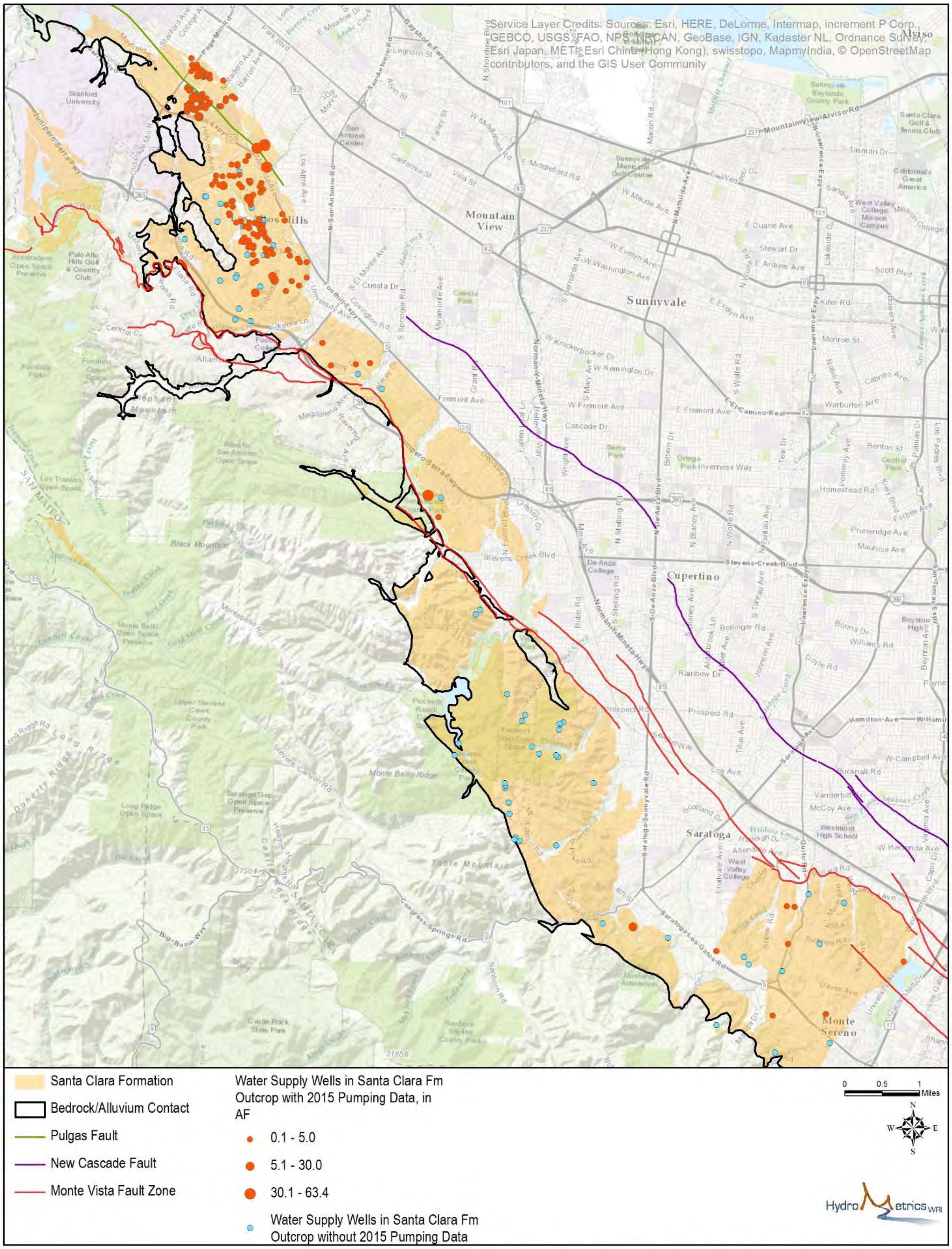


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Figure 14: Santa Clara Formation Outcrop along Westside of Santa Clara Sub-basin

4.7 WATER BUDGET IN HYDROGEOLOGICALLY CONNECTED AREAS

Figure 15 and Figure 16 show the water budget for potentially hydrogeologically connected areas. The potentially hydrogeologically connected areas are based on the Bedrock/Alluvium contact and the groundwater divide that is DWR's boundary between subbasins. Budgets are provided for the Santa Clara Subbasin including Santa Clara Plain and the Coyote Valley (Figure 14) and the Llagas Subbasin (Figure 15). These figures show managed recharge as water the District adds to groundwater separately from groundwater pumping that extracts water from the Basin and quantities of in-lieu recharge from District activities that reduce groundwater pumping. The in-lieu recharge amounts show what pumping quantities would be without District activities and therefore how in-lieu recharge improves the water budgets.

Figure 15 includes the following District activities along with pumping in the Santa Clara Subbasin water budget:

- Managed recharge at the West Side, Los Gatos, Guadalupe, Coyote, and Penitencia systems that can recharge both imported water and local runoff
- Delivery of treated water to retailers that reduces groundwater pumping and provides in-lieu recharge
- Recycled water deliveries by the Palo Alto, Sunnyvale, and South Bay Water Recycling systems supported by the District that reduces groundwater pumping and provides in-lieu recharge
- Delivery of untreated surface water to specific parcels that reduces groundwater pumping and provides in-lieu recharge

Figure 16 includes the following District activities along with pumping in the Llagas Subbasin water budget:

- Managed recharge at the Upper Llagas system that can recharge both imported water and local runoff
- Managed recharge at the Lower Llagas system that recharges only local runoff captured and stored in the District's Uvas and Chesbro Reservoirs
- Recycled water deliveries by the South County Regional Wastewater Authority supported by the District that reduces groundwater pumping and provides in-lieu recharge
- Delivery of untreated surface water to specific parcels that reduces groundwater pumping and provides in-lieu recharge

Figure 15 and Figure 16 do not include natural recharge in order to focus the graphs on District activities and the pumping those activities support. Figure 15 and Figure 16 show that District activities support a very large portion of pumping in each subbasin

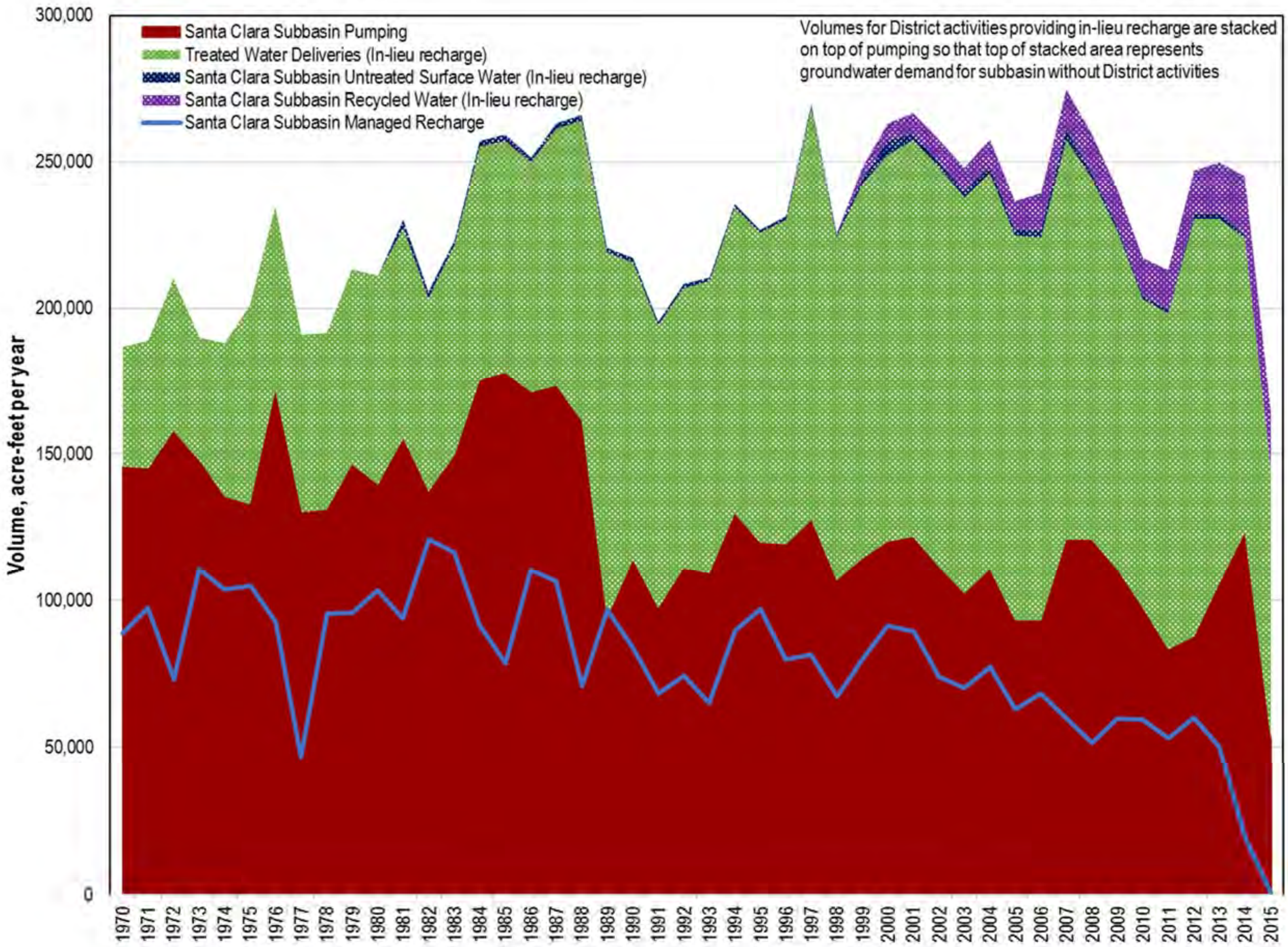


Figure 15 Santa Clara Subbasin Water Budget for District Activities

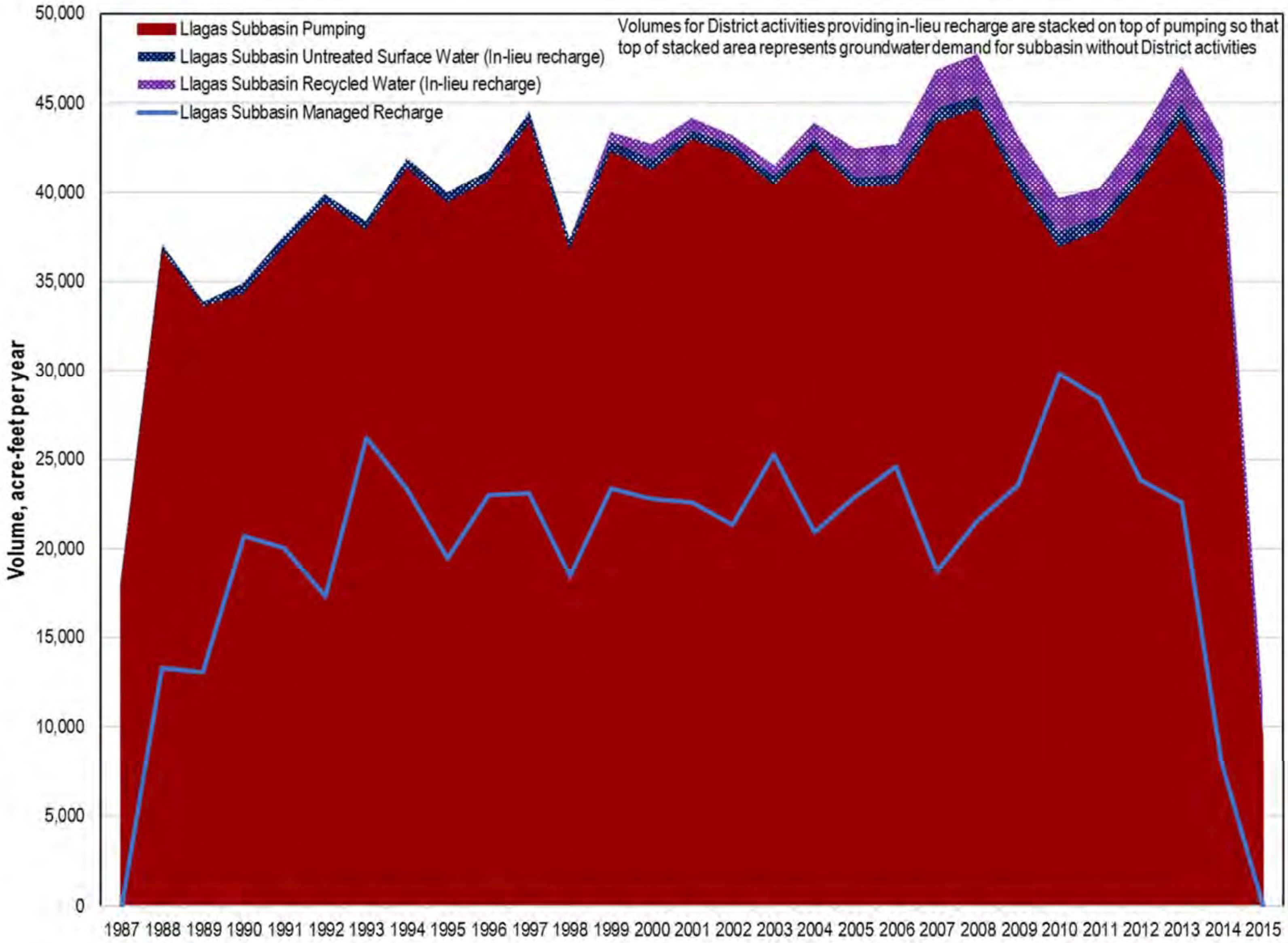


Figure 16 Llagas Subbasin Water Budget for District Activities

Section 5
MAPPING AND QUANTIFYING DISTRICT ACTIVITIES

5.1 Managed Aquifer Recharge

Locations of the District's managed aquifer recharge facilities are based on the files from the District's Geographic Information System (GIS) for recharge ponds and recharge streams supplemented by the National Hydrography Dataset (USGS, 2016).

For identification purposes, the recharge ponds and streams are grouped into systems consistent with District grouping: West Side, Los Gatos, Guadalupe, Coyote, Penitencia, Upper Llagas, and Lower Llagas recharge systems (SCVWD, 2016b). All systems but the Lower Llagas system are able to receive water from the State Water Project or Central Valley Project, and have the ability to recharge imported water as well as local runoff. The Lower Llagas system only recharges local runoff. Figure 17 shows the map of the recharge systems overlain on the basin geology

Figure 17 shows that the managed recharge system creeks generally flow out of the bedrock areas into the alluvium. The West Side system flows over the Santa Clara Formation before flowing into the larger Unconsolidated Alluvium area. The Coyote system flows enters Unconsolidated Alluvium in Coyote Valley and flows north through Coyote Narrows into the Santa Clara Plain. The Lower Llagas system flows through the Unconsolidated Alluvium west of the bedrock outcrops into the Unconsolidated Alluvium in the Llagas Subbasin valley floor. All recharge ponds are located in the Unconsolidated Alluvium in the valley floor.

The District provided monthly recharge quantities for 1967-2014 by recharge facility for the West Side, Los Gatos, Guadalupe, Coyote, and Penitencia systems. The District provided annual recharge quantities from July 1987-2014 by recharge facility for the Upper Llagas and Lower Llagas systems. These data were aggregated into recharge quantities by water year and by system for the groundwater level data evaluation (Section 6).

The District operated these systems before records of recharge quantity data existed. The District compiled the operation start dates of recharge ponds from various sources. The Study evaluates benefits of managed recharge creeks beginning with construction of the upstream reservoirs. Table 1 shows the operation start date for each system is based on the first start date of any facility in the system.

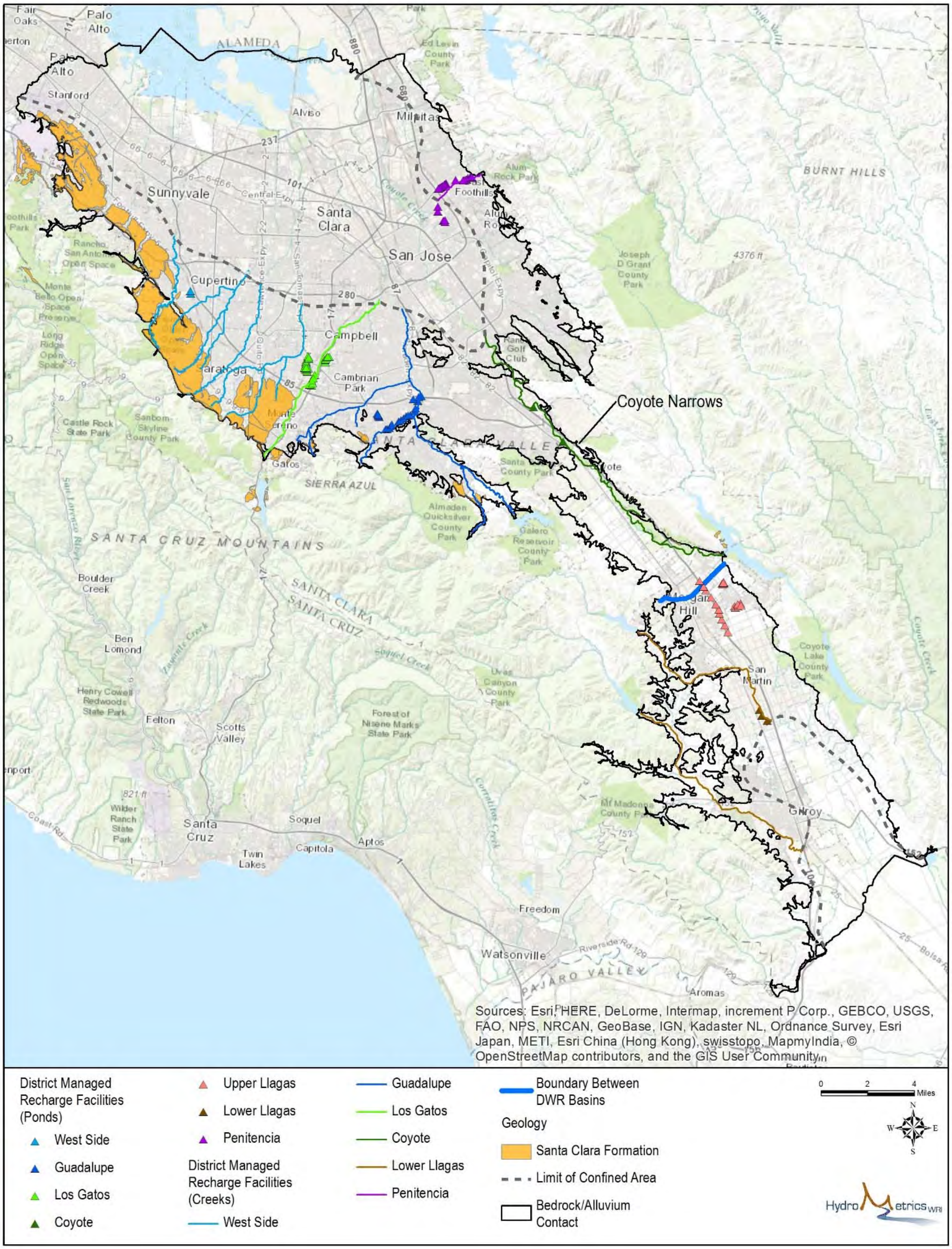


Figure 17: District Managed Aquifer Recharge Systems

Table 1: Managed Recharge Start Dates

System	First Facility	Start Date	Reference
Coyote System	Coyote Percolation Ponds	1934	SCVWD, 1998
Guadalupe System	Alamitos Ponds	1932	SCVWD, 1998
Los Gatos System	Vasona Reservoir	1934	SCVWD, 2016b
Lower Llagas System	Chesbro Reservoir[1]	1955	SCVWD, 2016b
Penitencia System	Capital Ponds	1934	SCVWD, 2016b
Upper Llagas System	Main Ave. Ponds	1955	SCVWD, 1998
West Side System	Stevens Creek Reservoir	1935	SCVWD, 2016b

[1] Although Chesbro Reservoir was built for flood control, recharge benefits can be evaluated from the date of construction.

5.2 Treated Water Deliveries

The Study maps areas receiving District treated water to identify the source waters for different areas within retailer's service areas. Identification of areas receiving District treated water were based on the District's infrastructure reliability project technical memoranda on each retailer (SCVWD and AECOM, 2014a-j[1]), maps provided by the retailers, and Geographic Information System files provided by the retailers. Table 2 summarizes the references identifying these areas receiving District treated water and Figure 18 displays the treated water delivery areas overlain on the basin geology. Discussion of areas receiving other sources of water is provided in Section 6.1.2.1

Table 2: Areas Receiving District Treated Water

Retailer	Zone/Area Identified	GIS Source
Cal Water	Cupertino, Southwest of Foothill Expressway	SCVWD and AECOM, 2014e
Mountain View	Zone 3 (area west of Hwy 85 and approximately south of Cuesta Dr.)	City of Mountain View, 2005
Milpitas	Zones SC1 (West of I-880)and SC2 (South of Calaveras Blvd and west of I-680)	City of Milpitas, 2015
Santa Clara	Zones II and IIA (approximately south of Benton St.)	City of Santa Clara, 2012
Sunnyvale	Zones II and III (approximately El Camino Real and south)	SCVWD and AECOM, 2014b
San Jose Municipal	Evergreen	San Jose Municipal system map
San Jose Water Co.	San Jose, Cupertino, Saratoga, Campbell	San Jose Water Company GIS, 2016

[1] These reports are confidential, but information on delivery areas is not confidential.

Figure 18 shows that treated water delivery areas are located primarily in Unconsolidated Alluvium in the Santa Clara Plain north of Coyote Narrows, but also overlap the Santa Clara Formation and bedrock. Groundwater users in all of these areas receiving District treated water benefit from the in-lieu recharge occurring in these areas. The Los Altos area of Cal Water receiving District treated water overlies the Santa Clara Formation with the Foothill Expressway boundary of this area approximately coincident with the eastern extent of the Santa Clara Formation. The Cupertino and West areas of San Jose Water Company also partially overlie the Santa Clara Formation. Even in bedrock, groundwater users benefit from neighbors receiving treated water as this in-lieu recharge reduces demand for limited supplies in bedrock fractures.

The District provided monthly quantities of treated water deliveries to each retailer for 1967-2015. These data were aggregated into delivery quantities by water year and by retailer for the groundwater level data evaluation (Section 6).

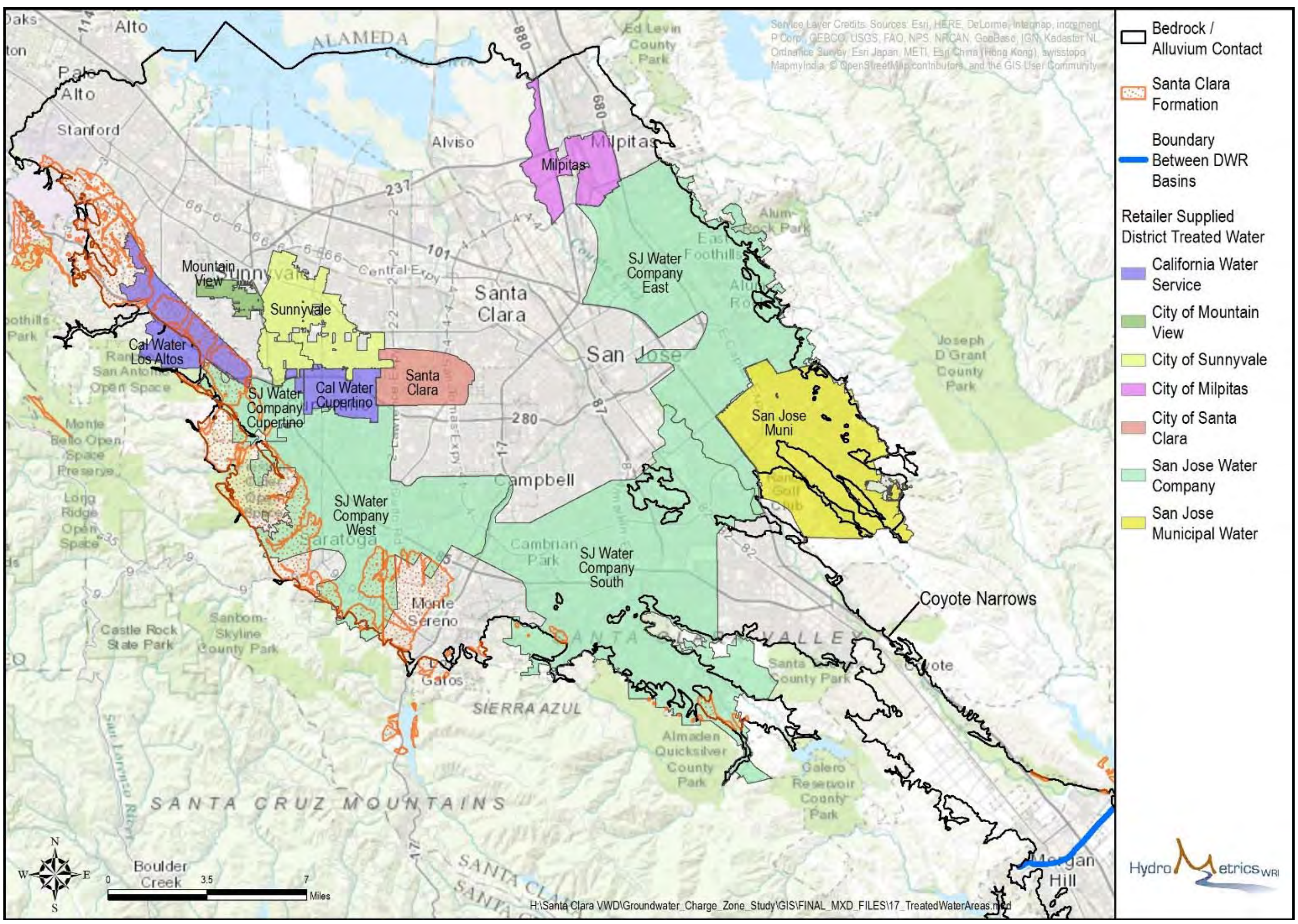


Figure 18: Retailer Areas Receiving District Treated Water Deliveries

5.3 RECYCLED WATER

Mapping of recycled water deliveries is based on GIS files provided by the District of pipeline alignments for the four recycled water systems: Palo Alto, Sunnyvale, South Bay Water Recycling Program and South County Regional Wastewater Authority. Figure 19 shows the pipelines overlying geology.

The Palo Alto and Sunnyvale systems overlie Unconsolidated Alluvium in the Santa Clara Plain. The South Bay Water Recycling Program system mostly overlies Unconsolidated Alluvium in the Santa Clara Plain, but also overlies some bedrock areas to the southeast and extends a short distance across Coyote Narrows into Coyote Valley. The South County Regional Wastewater Authority system overlies Unconsolidated Alluvium deposits in the Llagas Subbasin in Gilroy and east of Gilroy.

The District provided monthly quantities of recycled water deliveries from 1998-2015 for each of the four systems, including deliveries from the District's Silicon Valley Advanced Water Purification Center via the South Bay Water Recycling Program system. Figure 15 and Figure 16 are based on these data aggregated into delivery quantities by water year and by system. However, as shown by Figure 15 and Figure 16, these deliveries are a relatively small part of the overall budget and therefore the effect is not expected to be observed in the groundwater level evaluation.

Existing pipelines (Figure 19) will be need to be extended to deliver purified water for planned indirect potable reuse projects. The District is still in process of evaluating those plans.

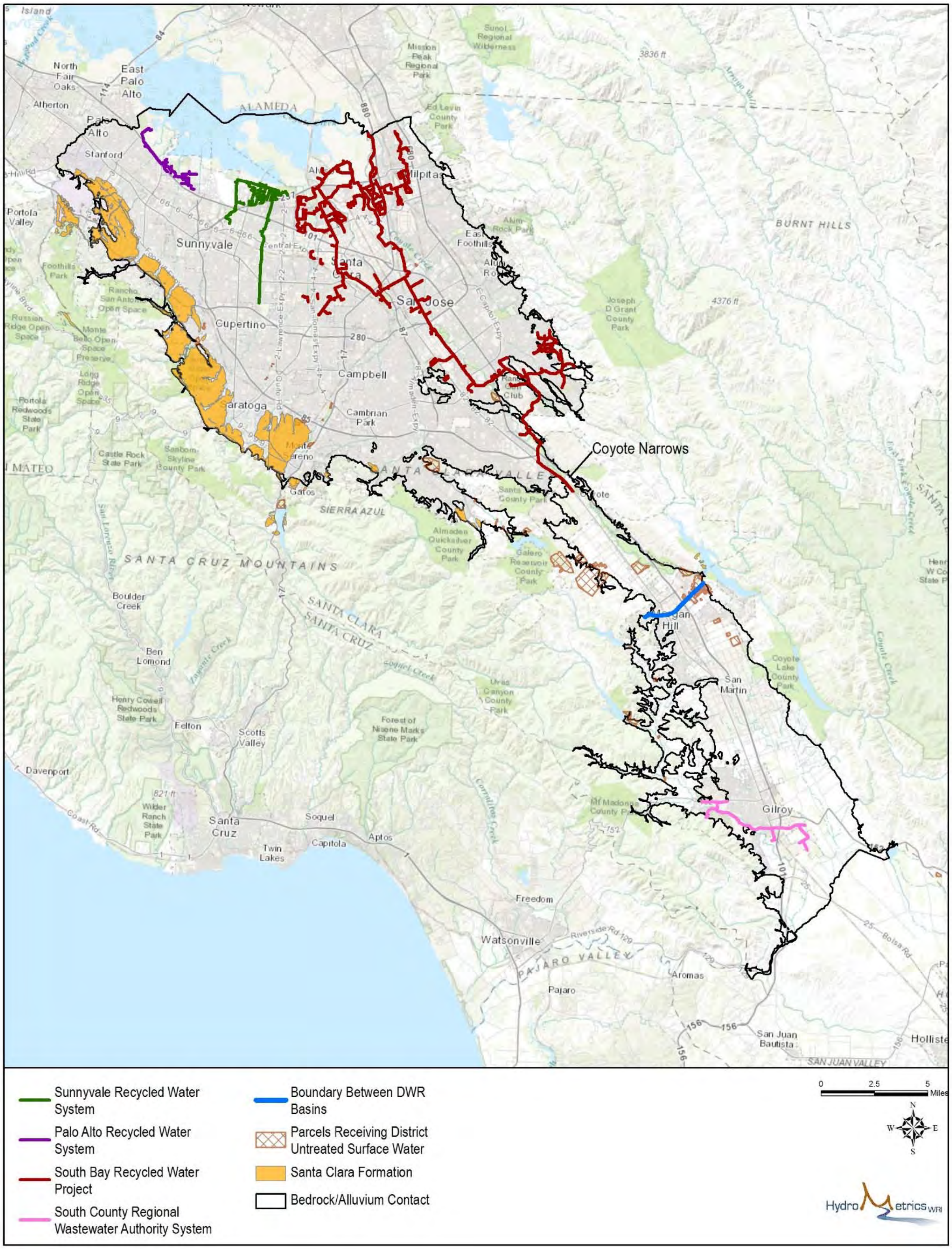


Figure 19: Recycled Water Systems and Parcels Receiving District Untreated Surface Water

5.4 Surface Water Deliveries

Mapping of the District's untreated surface water deliveries is based on District's data of parcels receiving deliveries and County GIS files of parcels. Figure 19 shows locations of parcels that have received surface water deliveries from fiscal years 2010-2015, overlain on the basin geology.

Parcels receiving untreated surface water deliveries overlie Unconsolidated Alluvium in the Santa Clara Plain, Coyote Valley, and Llagas Subbasin both west and east of bedrock outcrops in that subbasin. There are also parcels receiving untreated surface water deliveries in bedrock.

The District provided semi-annual quantities of surface water deliveries. Data are available by existing groundwater charge zone prior to fiscal year 2010 and by parcel since fiscal year 2010. Data for zone W-2 commence in 1981 while data for zone W-5 commence in 1987. Figure 15 and Figure 15 are based on these data aggregated into annual delivery quantities by existing groundwater charge zone. However, Figure 15 and Figure 16 show that these deliveries are a relatively small part of the overall budget and therefore the effect is not expected to be observed in the groundwater level evaluation. Also, surface water delivery areas are parcel based so groundwater users on a parcel are assumed to be the same as the surface water customer for the parcel. Therefore, there are no other groundwater users in the surface water delivery areas that receive in-lieu benefits from surface water delivery areas.

5.5 Conservation Activities

Conservation provides in-lieu recharge benefits to groundwater users by reducing the amount of groundwater pumped. Conservation activities occur throughout the District so groundwater users throughout the District receive in-lieu benefits. Figure 20 shows a map of parcels receiving different conservation rebates to demonstrate the widespread nature of the conservation activities. However, the disperse nature of conservation and its variable application is expected to make it difficult to be observed in the groundwater level evaluation. In addition, the rebates are equally available throughout the District so benefits are available throughout the District. Therefore, conservation activities are not used to define groundwater zones of benefit.

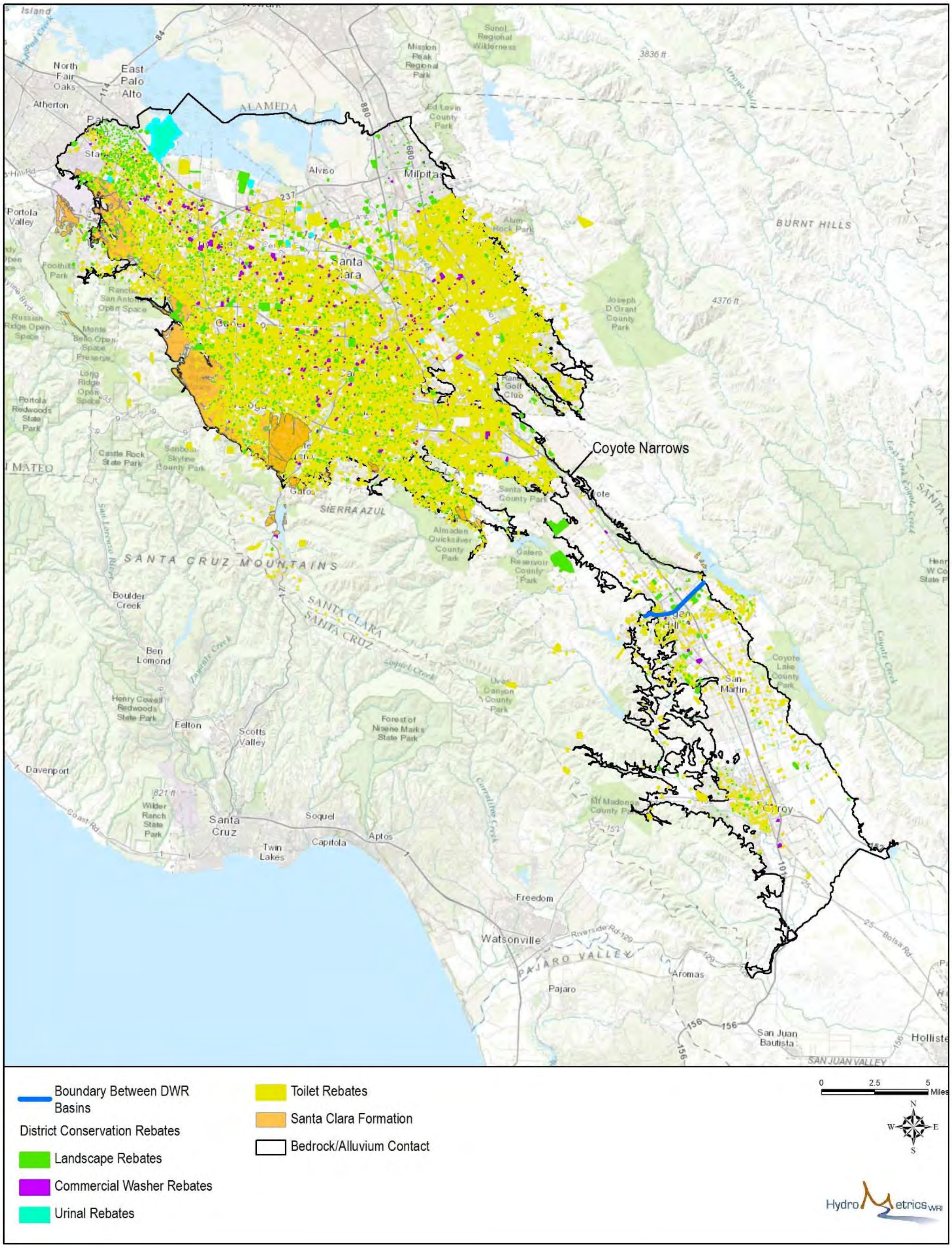


Figure 20. Parcels Receiving Conservation Rebates

Section 6
GROUNDWATER LEVEL DATA EVALUATION

As described in the methodology memo, the Study uses groundwater level data to evaluate areas where groundwater users benefit from District deliveries of treated water and areas where groundwater users benefit from District managed aquifer recharge activities. This evaluation follows two basic steps:

1. Identify periods for evaluating benefits from District recharge activities based on groundwater level trends (evaluation periods). Evaluation periods are chosen based on two criteria:
    a. Climatic conditions and area pumping during these periods would result in an expected decreasing groundwater level trend if no District activity occurred.
    b. These periods show active and stable or increasing District in-lieu or managed recharge during the periods such that a stable or increasing groundwater trend during the period can be attributed to the District activity.
2. During these evaluation periods, evaluate whether observed groundwater level data in the area show a stable or increasing trend indicating a benefit from the District activity.

6.1 Identify Periods for Evaluation

The three factors used to identify evaluation periods are rainfall, area pumping, and quantities of treated water delivery and managed aquifer recharge provided by the District activities. Without a District activity, we expect groundwater level trends to decrease if rainfall is decreasing and/or pumping is increasing. The expectation is groundwater level trends would also decrease if rainfall is decreasing or pumping is increasing while the other factor is stable. In order to attribute an increasing groundwater level trend to either the District's treated water or managed recharge activity during evaluation periods, the quantities provided by the District activity needs to be stable or increasing.

6.1.1 Rainfall

Rainfall at the City of San Jose gauge station ID 6131 of the ALERT hydrologic data collection system (ALERT ID 1453) is representative of changes to climatic conditions within the District's Subbasins. Annual water year rainfall totals from 1932-2013 are used to calculate the cumulative departure from the mean annual rainfall (Figure 21). Periods when the cumulative departure is stable or declining meet the criteria for evaluation periods.

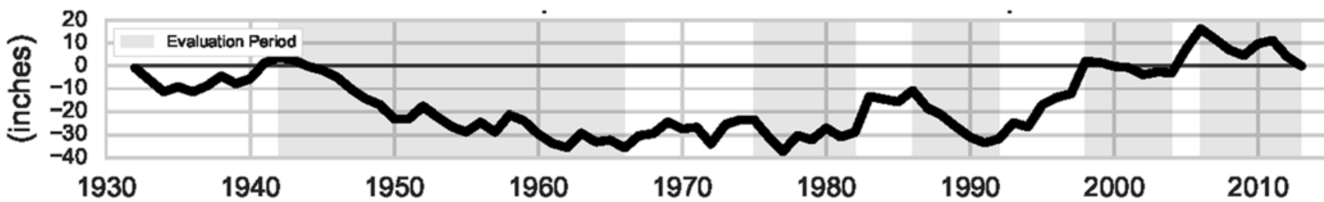


Figure 21: Cumulative Departure of Mean Annual Rainfall

6.1.2 AREA PUMPING

In order to identify evaluation periods, the Study totals pumping for each retailer and non-retailer area distinguished by water source. In other words, a retailer's service area is divided into multiple pumping areas if the retailer delivers different water sources to different areas. These pumping areas are used because the availability of surface water such as District treated water, Regional Water System (RWS) or San Jose Water Company's surface water derived from its own water right affects pumping demand for the area. Appendices C-F and example figures, Figure 25 through Figure 34, include the aggregated groundwater pumping by pumping area over time.

This approach ensures that the groundwater level data evaluation accounts for the effects of in-lieu recharge by non-District deliveries. Therefore, a benefit from any non-District in-lieu recharge such as SFPUC RWS deliveries or San Jose Water Company's surface water will not be misattributed to a District activity.

In addition, the evaluation of benefits from the District managed recharge activity also accounts for the effects of in-lieu recharge by District deliveries of treated water. Even with in-lieu recharge sources for an area, if pumping is increasing while rainfall is stable or decreasing, the expected groundwater level trend is still decreasing. The in-lieu recharge may have reduced the expected decrease in groundwater level trend but a stable or increasing groundwater level trend concurrent with stable or increasing quantities from a District activity would demonstrate a benefit from that District activity. Likewise, in-lieu recharge may result in stable pumping, including zero or near-zero pumping, in an area, but expected groundwater level trend is decreasing if rainfall is decreasing. Thus, the Study seeks to compare anticipated outcomes with no District activity with actual outcomes and recognizes benefits from District activities if the actual outcome reflects an improvement over anticipated outcomes.

6.1.2.1 MAPPING RETAILER AND NON-RETAILER AREAS BY WATER SOURCE

In addition to mapping retailer areas receiving treated water as discussed in Section 5.2, the Study maps retailer areas receiving water from San Francisco Public Utilities Commission's RWS supplies and San Jose Water Company's surface water. The Study also maps areas supplied only by groundwater.

As with mapping areas receiving treated water, the references used to identify areas receiving different sources were the District's infrastructure reliability project technical memoranda on each retailer, maps provided by the retailers, and Geographic Information System files provided by the retailers. Table 3 summarizes the mapped areas. Figure 22, Figure 23, and Figure 24 show the pumping areas in Santa Clara Plain, Coyote Valley, and Llagas Subbasin, respectively.

These areas also are used to summarize pumping because the availability of different sources of water for each area presumably affects groundwater demand in that area. To facilitate these areal pumping summaries, the large area of San Jose Water Company serving primarily District treated water was divided into three areas based on District managed recharge creeks. The west area is the area west of Los Gatos Creek. The south area is the area between Los Gatos and Coyote Creek. The east area is the area east of Coyote Creek.

In addition, non-retailer areas are identified to facilitate areal pumping summaries. North Morgan Hill is the non-retailer area between Morgan Hill and San Jose. Eastern Llagas is the non-retailer area east of Morgan Hill, Gilroy, and the bedrock outcrops in the Llagas Subbasin identified on Figure 13. Uvas-Chesbro is the non-retailer area downstream of the District's Uvas and Chesbro Reservoirs west of Morgan Hill, Gilroy, and the bedrock outcrops in Llagas Subbasin identified on Figure 13

Table 3: Summary of Pumping Areas and Non-District Treated Water Supplies

Retailer	Water Supply Source	Zone/Area Identified	GIS Source
Cal Water	Groundwater	Sunnyvale, Mountain View	City of Mountain View, 2008
Gilroy	Groundwater	All	SCVWD GIS for Retailer Sources
Great Oaks	Groundwater	All	Great Oaks PUC Grid
Milpitas	SFPUC	Zones SF1-4(northeast of I-880 and Calaveras Rd., east of I-680, between I-880, S. Main St, and approximately Great Mall Pkwy)	City of Milpitas, 2015
Mountain View	Groundwater and SFPUC	Zone 1 and 2 (approximately north of Cuesta Dr. and east of Hwy 85)	City of Mountain View, 2005 and 2008
Morgan Hill	Groundwater	All	SCVWD GIS
NASA Ames	SFPUC	All	SCVWD GIS
Palo Alto	SFPUC	All	SCVWD GIS
Santa Clara	Groundwater and SCVWD Treated Water	Zone 1 and Zone 2 and 2A (approximately south of Central Expressway)	City of Santa Clara, 2012
	Groundwater and SFPUC	Zone 1 and 1a (approximately north of US 101)	
Sunnyvale	Groundwater	All (blended)	SCVWD and AECOM, 2014b
	SFPUC	Zone I (approximately north of El Camino Real)	
San Jose Municipal	Groundwater	Edenvale and Coyote	San Jose Municipal system map
	SFPUC	Alviso	
San Jose Water Co.	Groundwater	San Jose (north) Cupertino (with SCVWD Treated Water)	San Jose Water Company GIS, 2016
	Local Surface Water Right	Saratoga, Los Gatos	
Stanford	SFPUC	All	SCVWD GIS

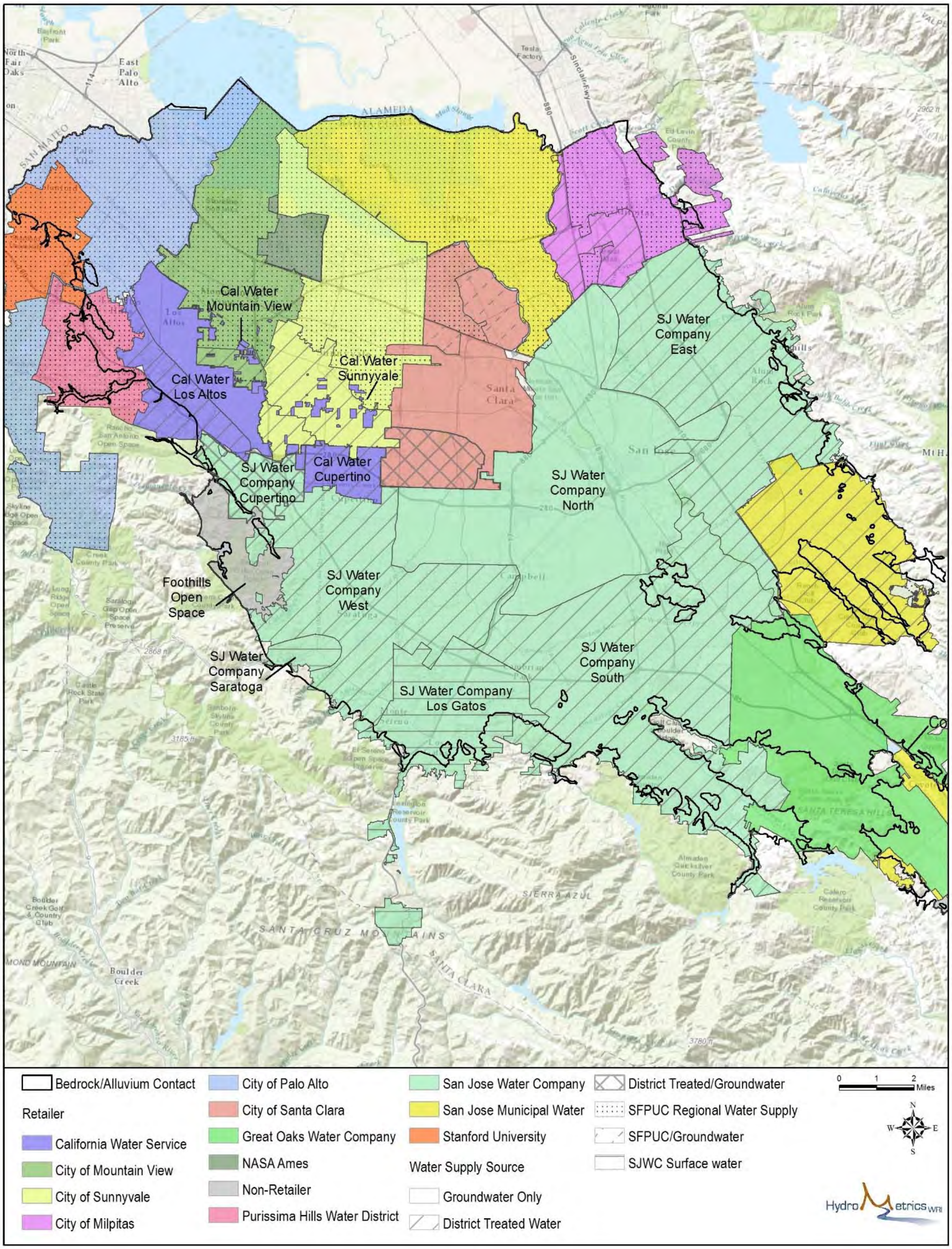


Figure 22: Pumping Areas in Santa Clara Plain

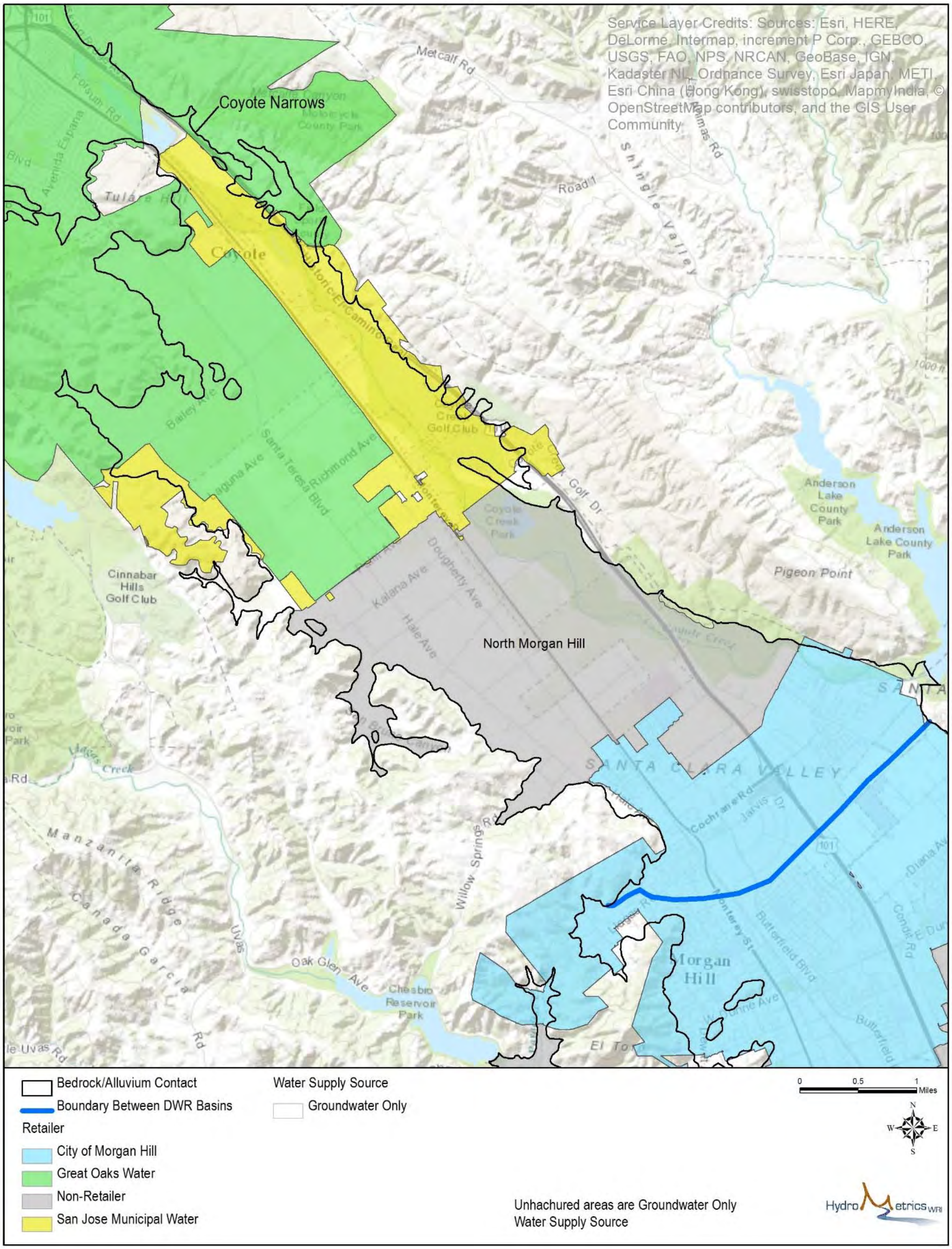


Figure 23: Pumping Areas in Coyote Valley

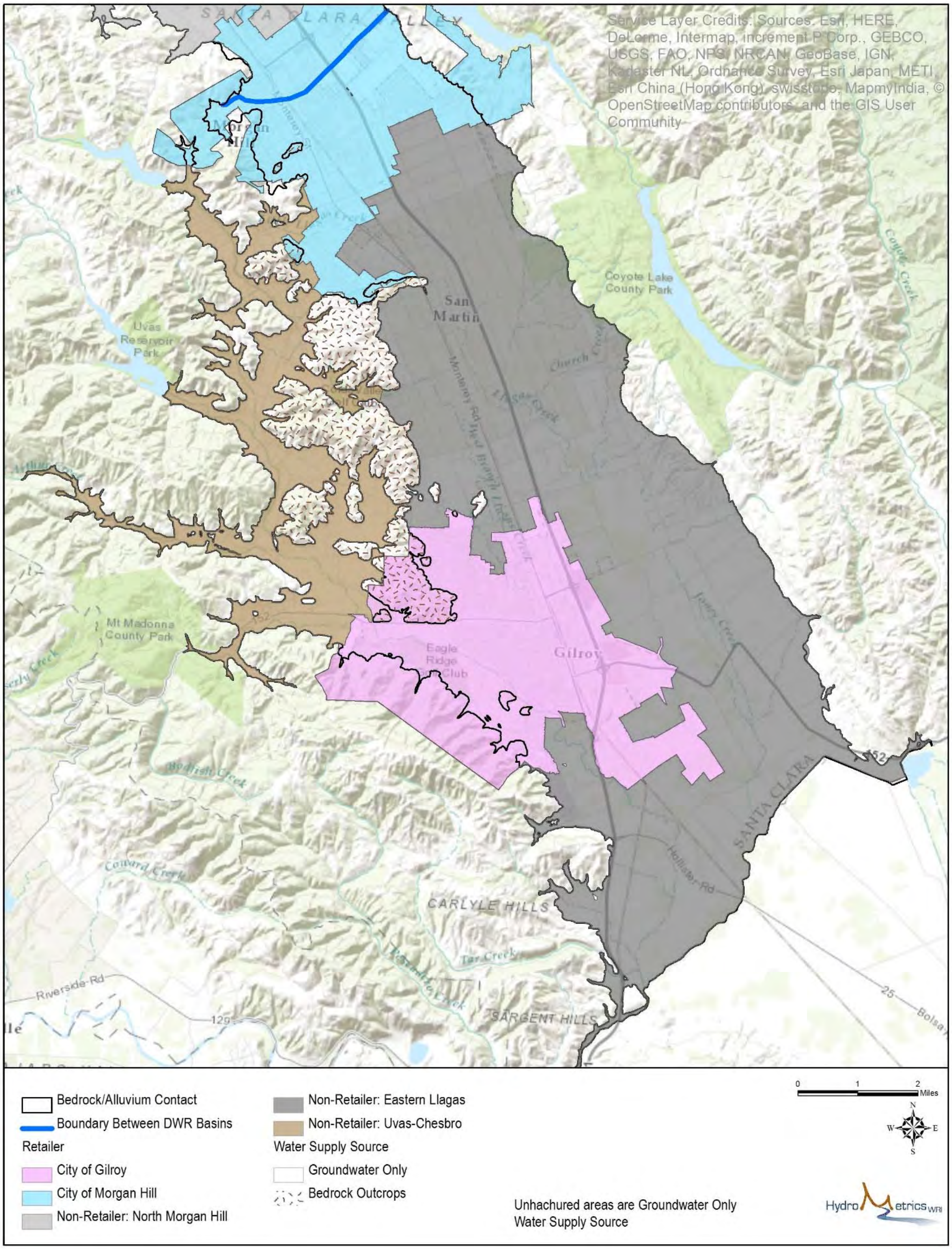


Figure 24: Pumping Areas in Llagas Subbasin

6.1.2.2 DISTRIBUTION OF GROUNDWATER DELIVERIES

One consideration with retailer areas is whether retailers deliver groundwater supplies across potential boundaries for hydrogeologically connected areas such as the Coyote Narrows, DWR basin boundary between the Santa Clara and Llagas Subbasins, between the Santa Clara Formation and Unconsolidated Alluvium areas of the Santa Clara Plain, and through constrictions of bedrock outcrops in the Llagas. This could result in groundwater benefits from District activities in one hydrogeologically connected area extending to a different hydrogeologically connected area. Retailer delivery of groundwater supplies from a hydrogeologically connected area into bedrock is not considered to extend groundwater benefits into bedrock because the delivery of groundwater across the well defined boundary of hydrogeologic connection is not considered a District activity.

Groundwater pumped in Unconsolidated Alluvium of the Santa Clara Plain is delivered to the Cupertino area of San Jose Water Company overlying the Santa Clara Formation. However, the boundary between hydrogeologically connected areas is well defined by the outcrop of the Santa Clara Formation and the delivery of groundwater across that boundary is not considered a District activity. Therefore, this does not result in groundwater benefits from District activities in the Unconsolidated Alluvium of the Santa Clara Plain extending into the Santa Clara Formation.

The San Jose Municipal Water System only pumps and delivers groundwater for the Edenvale area north of Coyote Narrows in Santa Clara Plain and for its Coyote area south of Coyote Narrows in Coyote Valley. However, San Jose Municipal Water System does not pump groundwater and deliver it across Coyote Narrows into the other management area.

Great Oaks Water Company pumps and delivers groundwater on both sides of the Coyote Narrows in the Santa Clara Plain and Coyote Valley. Great Oaks pumps groundwater in Coyote Valley for delivery to the Santa Clara Plain, but the reverse does not occur. The District activity, managed aquifer recharge, that occurs in Coyote Valley, also occurs in the Santa Clara Plain, so this delivery does not alter the area benefiting from managed aquifer recharge.

Morgan Hill straddles the DWR basin boundary representing the groundwater divide between Coyote Valley and Llagas Subbasin. If Morgan Hill's pumping distribution changed enough to substantially move the location of the average groundwater divide, the areas considered hydrogeologically connected would be subject to revision.

Morgan Hill and Gilroy are primarily overlying the Unconsolidated Alluvium east of the bedrock outcrops (valley floor) in the Llagas Subbasin, but the western service area boundaries approach or extend into the Unconsolidated Alluvium west of the bedrock outcrop. The boundary between separate hydrogeologic areas defined by bedrock outcrops are not well defined in these areas and delivery of groundwater in the Morgan Hill and Gilroy areas help define the areas with demonstrated benefits.

6.1.2.3 Pumping Quantities

The District provided annual pumping data by well for calendar years 1981-2015 in existing Zone W-2 and 1987-2015 in existing Zone W-5. The Study identifies the pumping area for each well location and the pumping subplots in Appendices C- F and example figures, Figure 25 through Figure 34, show total annual pumping aggregated for each area.

Pumping data by well are not available prior to 1981, but recorded pumping is included in the Santa Clara Plain groundwater model for 1970-1980. The pumping subplots in Appendices C and D show modeled pumping aggregated for each of the pumping areas in the Santa Clara Plain.

Some of the pumping subplots in Appendices C-F and example figures, Figure 25 through Figure 34, also plot population for the city of the area or Census Designated Population (CDP) to evaluate likely changes in pumping demand before pumping data or estimates are available. Population increases indicate likely increase in pumping demand. However, when non-District sources of supply such as SFPUC Regional Water System or San Jose Water Company surface water become available to an area, population no longer represents a proxy for pumping demand. Therefore, the pumping subplots display milestone dates for the availability of these supplies (Walker and Williamson, 1983).

6.1.3 District Activity

The District activity subplots in Appendices C-F and example figures, Figure 25 through Figure 34, show quantities of managed recharge and treated water deliveries in the potentially hydrogeologically connected areas of the Santa Clara and Llagas Subbasins. The closest system activity to the pumping area being evaluated is plotted at the bottom with the quantities of other systems stacked based on distance. The plots for managed recharge show the start date of managed recharge systems as shown in Table 1. Prior to recharge quantity data being available, the operation of managed recharge is assumed to result in stable or increasing quantities. Evaluation periods that meet conditions for rainfall, pumping, and the District activity are identified with grey shading.

For the Santa Clara Subbasin including the Santa Clara Plain and Coyote Valley, the Study evaluates treated water deliveries (Appendix C) and managed recharge (Appendix D) separately. The Study does not evaluate managed recharge of imported water separately from managed recharge of local runoff because all managed recharge systems in Santa Clara Subbasin are connected to imported water supplies. Therefore, groundwater users that benefit from managed recharge systems in the Santa Clara Subbasin benefit from imported water supplies as well as capture of local runoff.

For the Llagas Subbasin, the Study evaluates managed recharge (Appendix E). The subplots on Appendix E plot managed recharge from the Upper Llagas and Lower Llagas systems separately based on distance from each pumping area, but the Study evaluates the systems together. The Upper Llagas system recharges both local runoff and imported water so it is not possible to evaluate the effects of recharging the two sources separately. Unlike the Upper Llagas system, the Lower Llagas system recharges only local runoff, periods when recharge in only one of the two systems is increasing were too short to evaluate the benefit from only that system. Therefore, the groundwater level evaluation is unable to distinguish between benefits from local runoff and benefits from imported water for groundwater users that benefit from managed recharge systems in the Llagas Subbasin.

Periods that have stable or increasing District managed recharge or treated water in the potentially hydrogeologically connected areas that line up with necessary rainfall and pumping conditions to evaluate are identified by the shading on the plots.

In the Santa Clara Subbasin, several periods were evaluated for both treated water and managed recharge because quantities for both activities were stable or increasing during a period with necessary rainfall and pumping conditions. Groundwater level improvements in areas during these overlapping periods demonstrate benefits from the District activities for those activities. However, groundwater level improvements can only be attributed to a specific activity if one activity increased during the overlapping period while the other activity was stable and groundwater level trends increased. As a result, the benefit demonstrated by increasing groundwater level trend can be attributed to the increasing activity. Otherwise, benefits cannot be attributed to a specific activity.

6.2 AREA GROUNDWATER LEVEL TRENDS DURING EVALUATION PERIODS

In Appendices C-F, plots of groundwater level data by area stacked with the plots of rainfall, pumping by area, District activity quantities are shown with the shaded evaluation periods identified. If the plotted groundwater level trends during the shaded periods are stable or increasing, a benefit from a District activity during that period is demonstrated.

6.2.1 MONITORING WELL GROUNDWATER LEVEL TRENDS BY AREA

For each pumping area, Appendices C-E present plots of static groundwater levels from monitoring wells over time. The monitoring wells are identified as wells that do not have groundwater pumping data so may include wells constructed as water supply wells. To evaluate whether treated water deliveries or managed recharge demonstrates benefits in the area, the Study evaluates groundwater level trends in the pumping area for each evaluation period. The Study evaluates trends based on groundwater levels from all the monitoring wells in the area because benefits to the area, not any specific well, is the criteria for establishing zones of benefit. Example figures from Appendices C-E are shown in Figure 25 for managed recharge in the Santa Clara Subbasin, Figure 26 for treated water in the Santa Clara Subbasin, and Figure 27 for managed recharge in the Llagas Subbasin. The shaded periods are the evaluation periods when groundwater level trends in the bottom plot are evaluated. If the plotted groundwater level trends during the shaded periods are stable or increasing, a benefit from a District activity during that period is demonstrated.

Table 4 summarizes the evaluation of managed recharge in the Santa Clara Subbasin corresponding to plots in Appendix C. Table 5 summarizes the evaluation of treated water deliveries corresponding to plots in Appendix D. Table 6 summarizes the evaluation of managed recharge in the Llagas Subbasin corresponding to plots in Appendix E. Most of the pumping areas evaluated have data that demonstrate benefits from each evaluated activity.

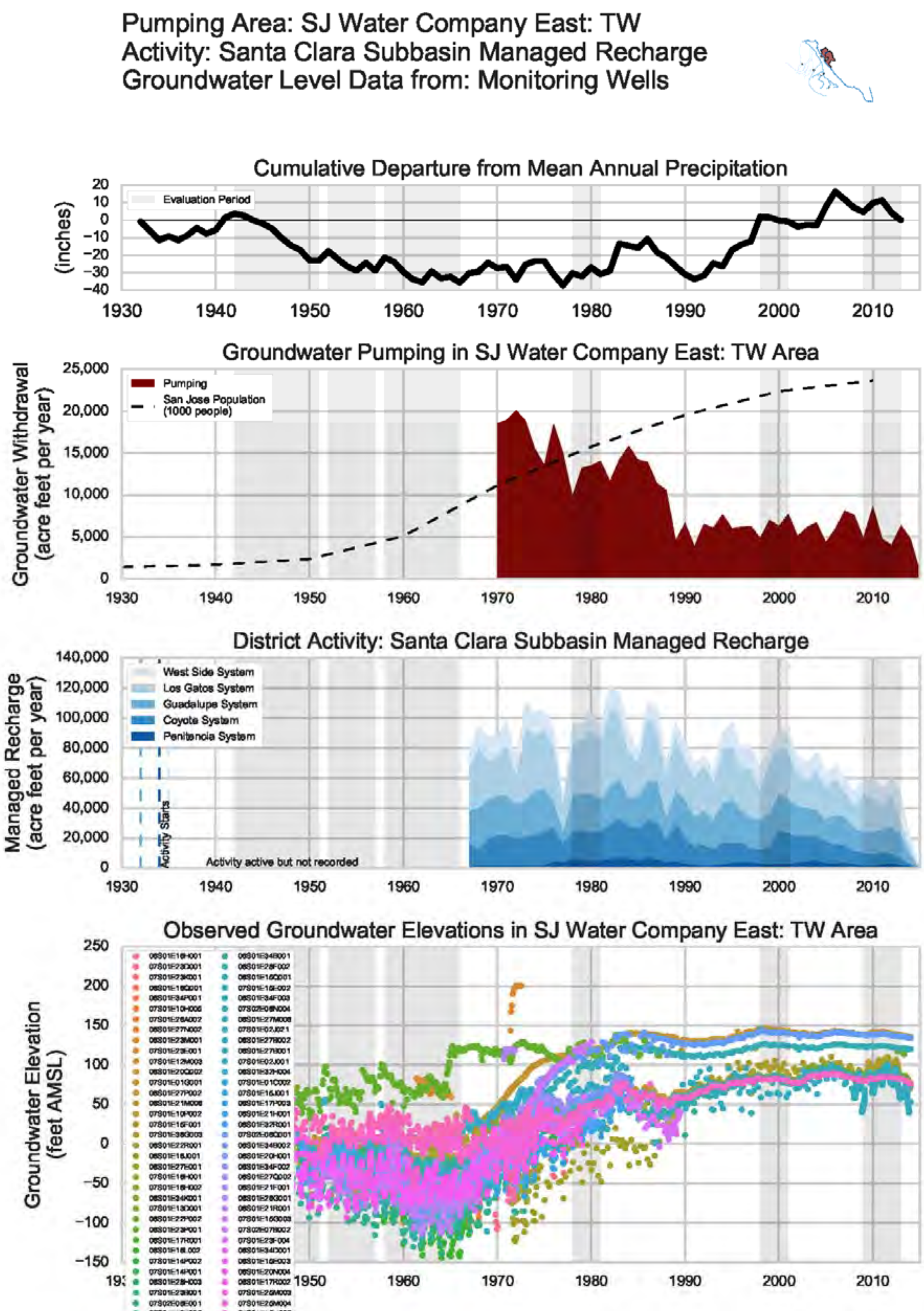


Figure 25. Example of Monitoring Well Groundwater Level Trend Evaluation of Managed Recharge in the Santa Clara Subbasin

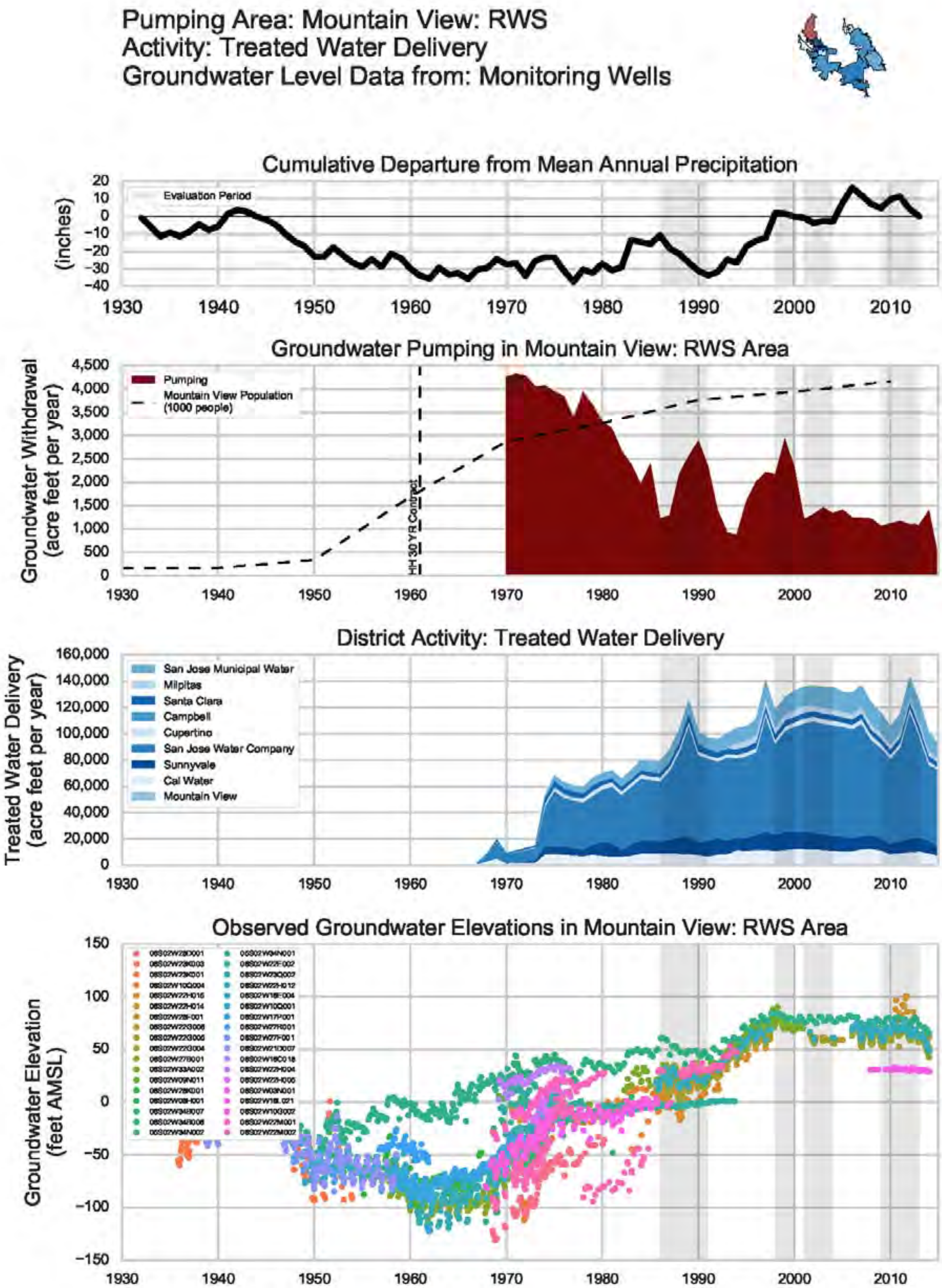


Figure 26. Example of Monitoring Well Groundwater Level Trend Evaluation of Treated Water in the Santa Clara Subbasin

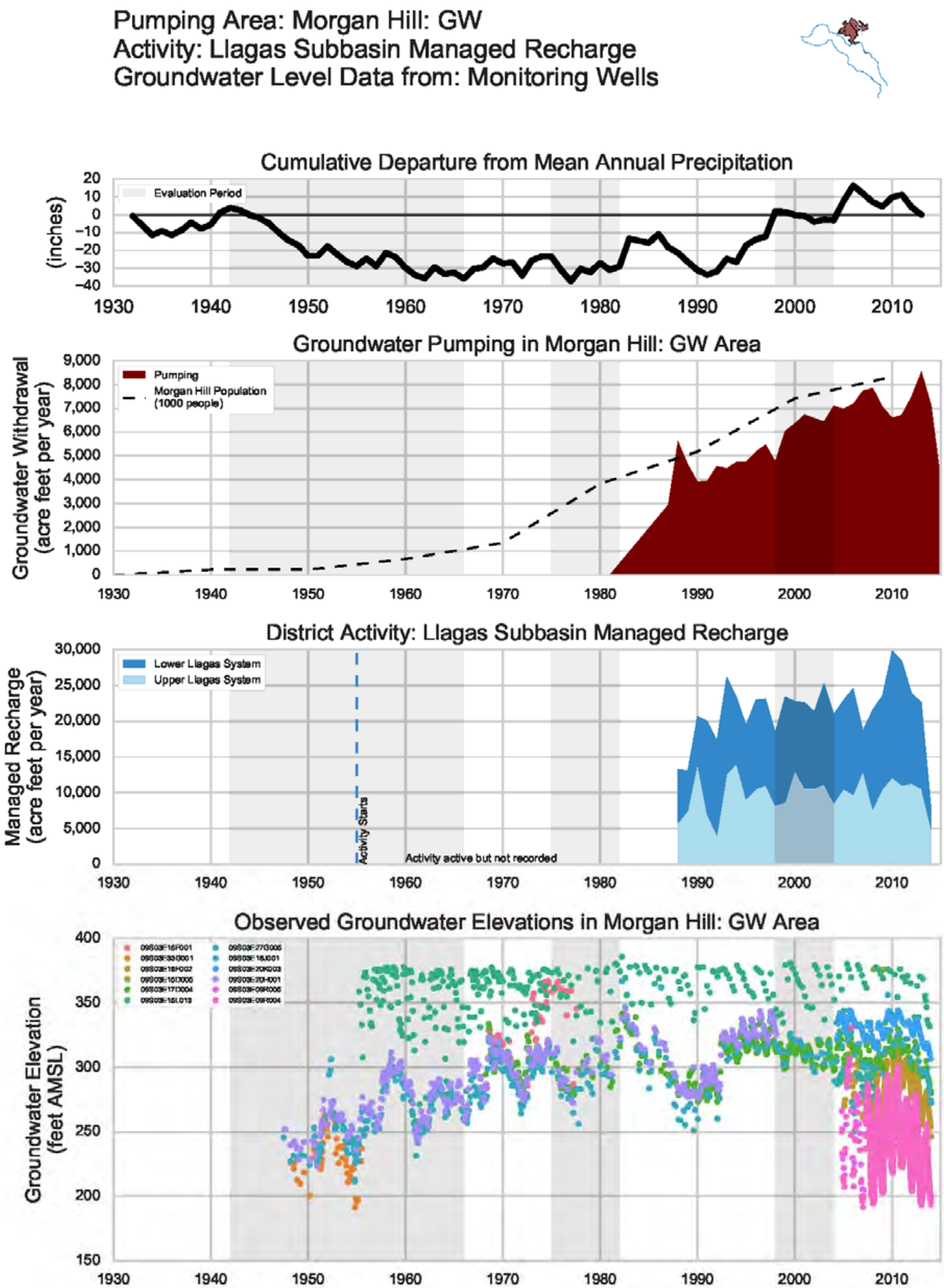
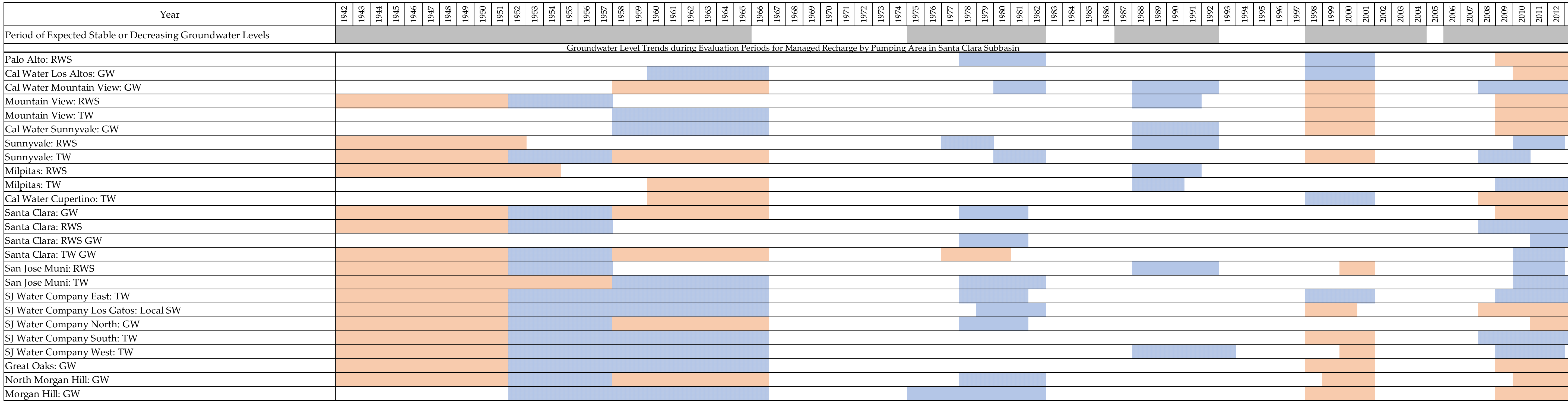


Figure 27. Example of Monitoring Well Groundwater Level Trend Evaluation for Managed Recharge in the Llagas Subbasin

Table 4: Summary of Monitoring Well Groundwater Level Trends during Evaluation Periods for Managed Recharge by Pumping Area in Santa Clara Subbasin



Decreasing
Stable/Increasing but Overlapping Activities
Stable/Increasing Not Overlapping - Benefit Demonstrated
Increasing Attributable to Overlapping Activity -Benefit Demonstrated
Insufficient Data

TW= Retailer supplied by District treated water
RWS= Retailer supplied by SFPUC Regional Water System
Local SW= Retailer supplied by retailer surface water right
GW=Retailer supplied by groundwater
Cal Water: Los Altos TW and San Jose Muni: GW do not have data available during evaluation periods
Stanford: GW, Purissima Hills: GW, SJ Water Company Saratoga: Local SW, Open Space: GW do not have available data

Table 5: Summary of Monitoring Well Groundwater Level Trends during Evaluation Periods for Treated Water by Pumping Area in Santa Clara Subbasin

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Period of Expected Stable or Decreasing Groundwater Levels																																							
Groundwater Level Trends during Evaluation Periods for Treated Water Delivery by Pumping Area in Santa Clara Subbasin																																							
Palo Alto: RWS																																							
Cal Water Los Altos: GW																																							
Cal Water Mountain View: GW																																							
Mountain View: RWS																																							
Cal Water Sunnyvale: GW																																							
Sunnyvale: RWS																																							
Milpitas: RWS																																							
Santa Clara: GW																																							
Santa Clara: RWS GW																																							
San Jose Muni: RWS																																							
SJ Water Company Los Gatos: Local SW																																							
SJ Water Company North: GW																																							
Great Oaks: GW																																							
Morgan Hill: GW																																							
North Morgan Hill:																																							

Decreasing
Stable/Increasing but Overlapping Activities
Stable/Increasing Not Overlapping - Benefit Demonstrated
Increasing Attributable to Overlapping Activity -Benefit Demonstrated
Insufficient Data

TW= Retailer supplied by District treated water
RWS= Retailer supplied by SFPUC Regional Water System
Local SW= Retailer supplied by retailer surface water right
GW=Retailer supplied by groundwater
Italicized periods overlap with evaluation periods for managed recharge
Santa Clara: RWS does not have data available during evaluation periods
Stanford: GW, Purissima Hills: GW, SJ Water Company Saratoga: Local SW, Open Space: GW do not have available data

Table 6: Summary of Monitoring Well Groundwater Level Trends during Evaluation Periods for Managed Recharge by Pumping Area in Llagas Subbasin

Year	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Period of Expected Stable or Decreasing Groundwater Levels																																																																							
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Decreasing
Stable/Increasing but Overlapping Activities
Stable/Increasing Not Overlapping - Benefit Demonstrated
Increasing Attributable to Overlapping Activity -Benefit Demonstrated
Insufficient Data

GW=Retailer supplied by groundwater

Italicized periods overlap with evaluation periods for treated water in the Santa Clara Subbasin

Uvas-Chesbro does not have available data

6.2.2 Pumping Well Groundwater Level Trends for Selected Areas

The Study evaluates monitoring wells that do not have associated pumping data because pumping at the individual well can mask any groundwater trends in the area. However, there are a few areas where monitoring wells with data during evaluated periods do not fully cover the area. These areas are Palo Alto, Stanford, Milpitas, the Los Gatos area of San Jose Water Company receiving the company's surface water, the Edenvale area of City of San Jose Municipal receiving only groundwater and the part of the Eastern Llagas area south of Gilroy. In these areas, Appendix F includes plots of groundwater levels from wells with associated pumping data during evaluation periods. Example figures from Appendix F are shown in Figure 28 for managed recharge in the Santa Clara Subbasin.

6.2.3 Areas where Benefits are not Demonstrated by Groundwater Level Trends

For the evaluation of benefits from treated water deliveries in the north Morgan Hill non-retailer area between San Jose and Morgan Hill in Coyote Valley, three monitoring wells with data during three evaluation periods show decreasing trends. This may indicate that benefits do not extend from the District deliveries of treated water north of Coyote Narrows into Coyote Valley.

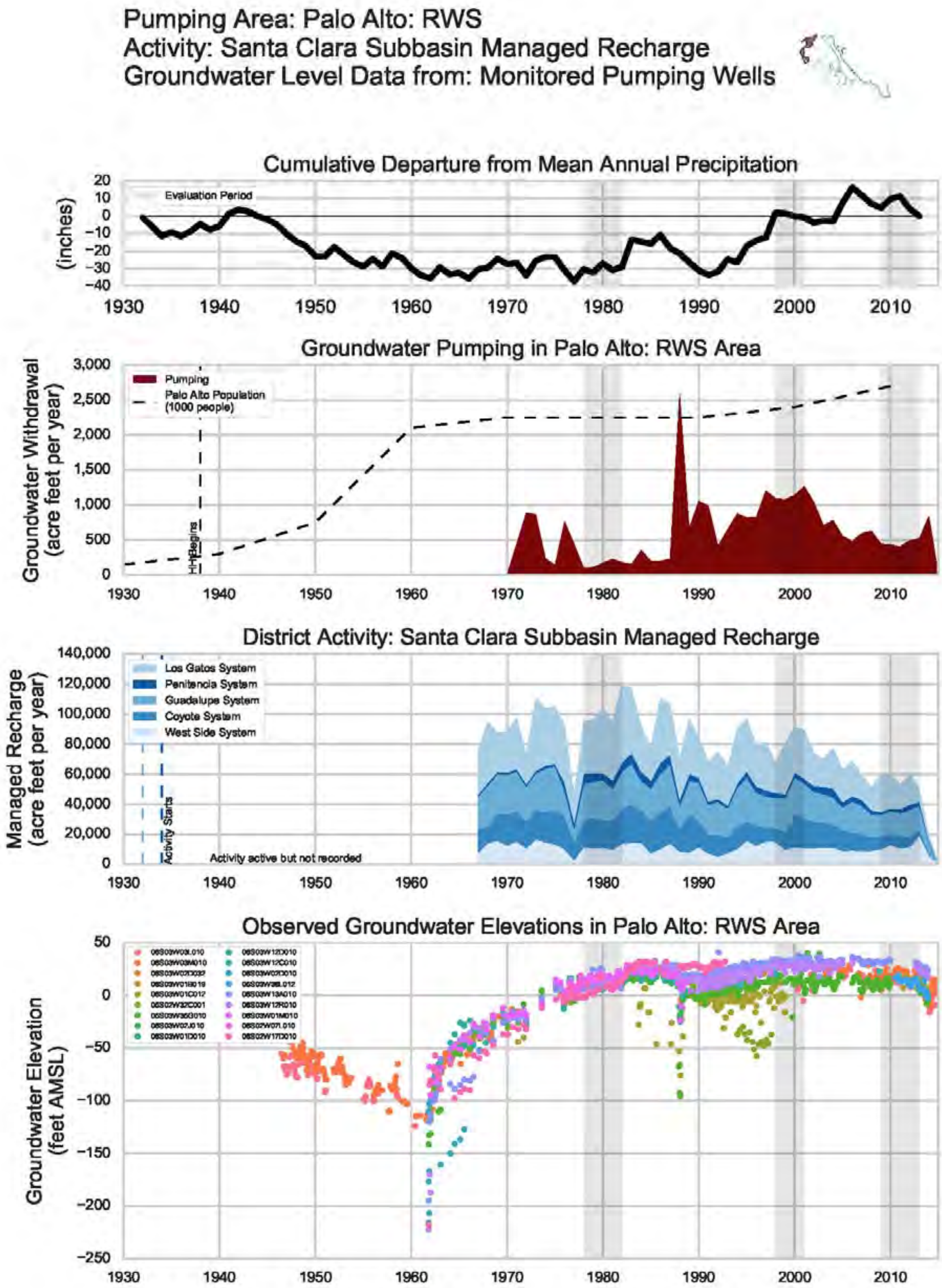

Figure 28. Example of Pumping Well Groundwater Level Trend Evaluation of Managed Recharge in the Santa Clara Subbasin

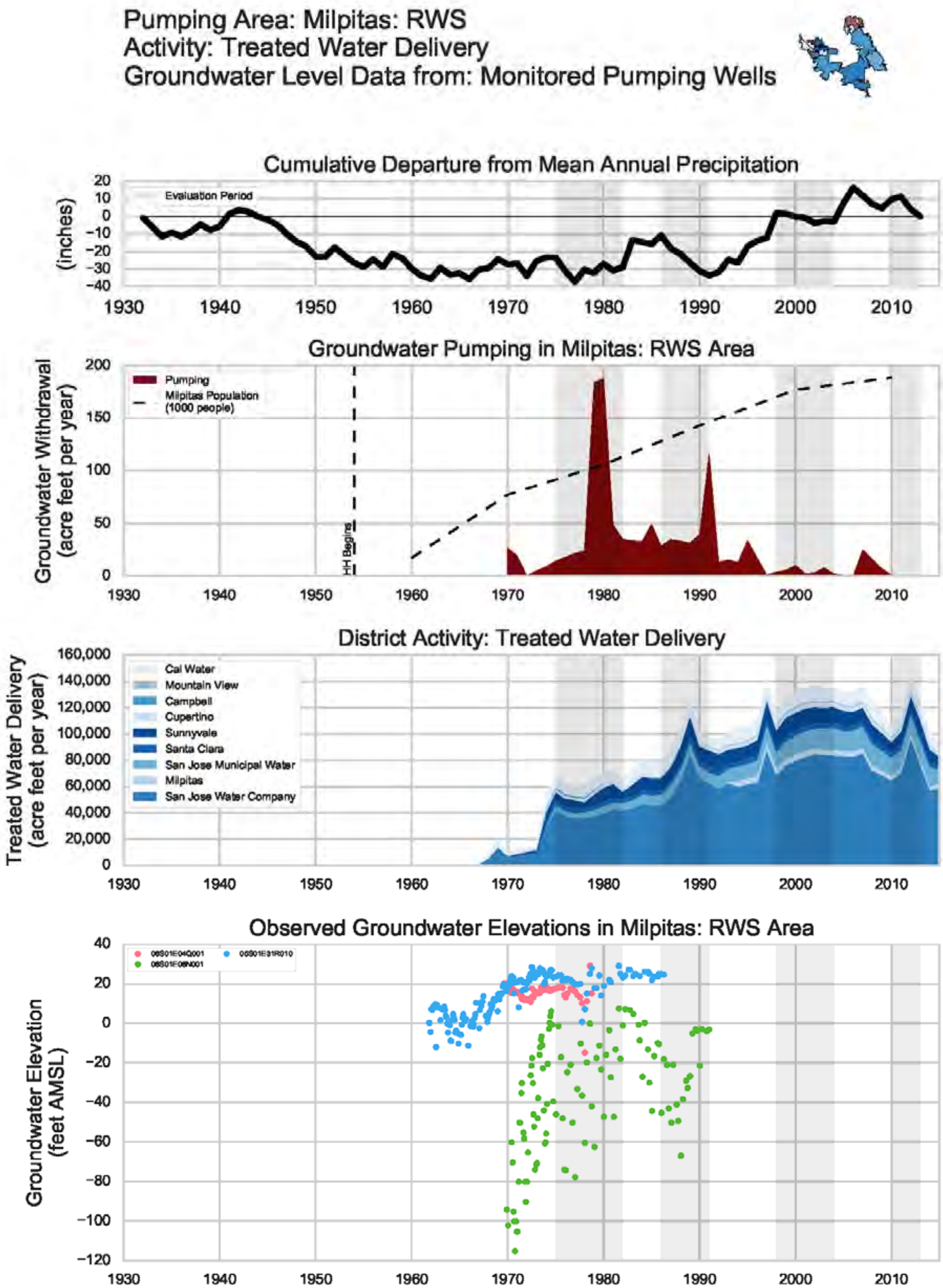

Figure 29. Example of Pumping Well Groundwater Level Trend Evaluation of Treated Water in the Santa Clara Subbasin

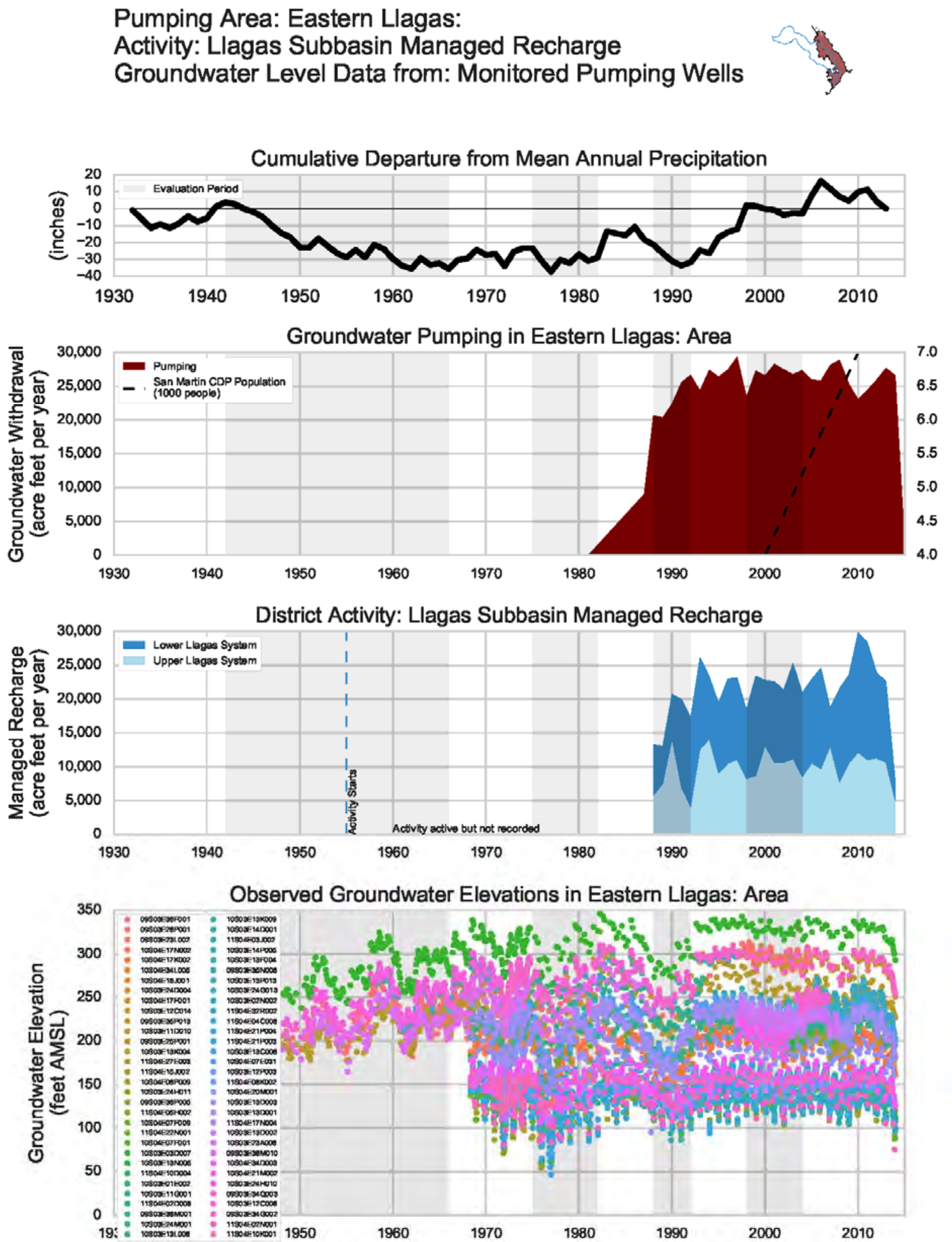

Figure 30. Example of Pumping Well Groundwater Level Trend Evaluation of Managed Recharge in the Llagas Subbasin

Table 7: Summary of Pumping Well Groundwater Level Trends for Selected Pumping Areas

Year	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
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Decreasing
Stable/Increasing but Overlapping Activities
Stable/Increasing Not Overlapping - Benefit Demonstrated
Increasing Attributable to Overlapping Activity -Benefit Demonstrated
Insufficient Data

6.2.4 Areas where Benefits from Are Only Demonstrated by Groundwater Level Trends during Overlapping Periods

There are several areas where groundwater level trends indicate a benefit from either managed recharge, treated water deliveries or both. These areas have stable or increasing groundwater level trends during evaluation periods that overlap in the evaluation of both managed recharge and treated water deliveries. For at least one of the activities, there is no stable or increasing groundwater level trend for a period that is not overlapping so benefit cannot be attributed specifically to the activity unless specific conditions are met. For example, the City of Santa Clara area that only receives groundwater has an increasing groundwater level trend from 1978-1981, which is a period evaluated for both managed recharge and treated water deliveries. A stable groundwater level trend is observed for 1952-1957 so benefit is demonstrated from managed aquifer recharge for periods other than the overlapping period (Figure 31). However, no evaluation periods besides the overlapping period have enough data to evaluate treated water delivery benefits (Figure 32). Therefore, the benefit cannot be attributed specifically to treated water deliveries based on the groundwater level trends for this area. Table 8 shows the areas where groundwater level trends show benefit from District activities during overlapping periods but benefits cannot be distinguished as resulting specifically from one or both of the activities.

A benefit can be specifically attributed to an activity where benefits are demonstrated only during overlapping periods if the activity is increasing while the other activity is stable and groundwater level trends are increasing. This occurs in the areas of Cal Water Mountain View where groundwater is delivered and Sunnyvale and San Jose Municipal Alviso area where Regional Water System water is delivered. For the 1987-1992 and 2010-2012 periods, treated water deliveries increased (Figure 33) while managed aquifer recharge quantities were stable (Figure 34). Meanwhile, groundwater level trends increase in at least one of the two periods for the three areas. Therefore, the benefit can be attributed specifically to treated water deliveries is demonstrated for these three areas. Table 8 also shows the areas where groundwater level trends show benefit from District activities during overlapping periods and benefits specific to the activities are demonstrated.

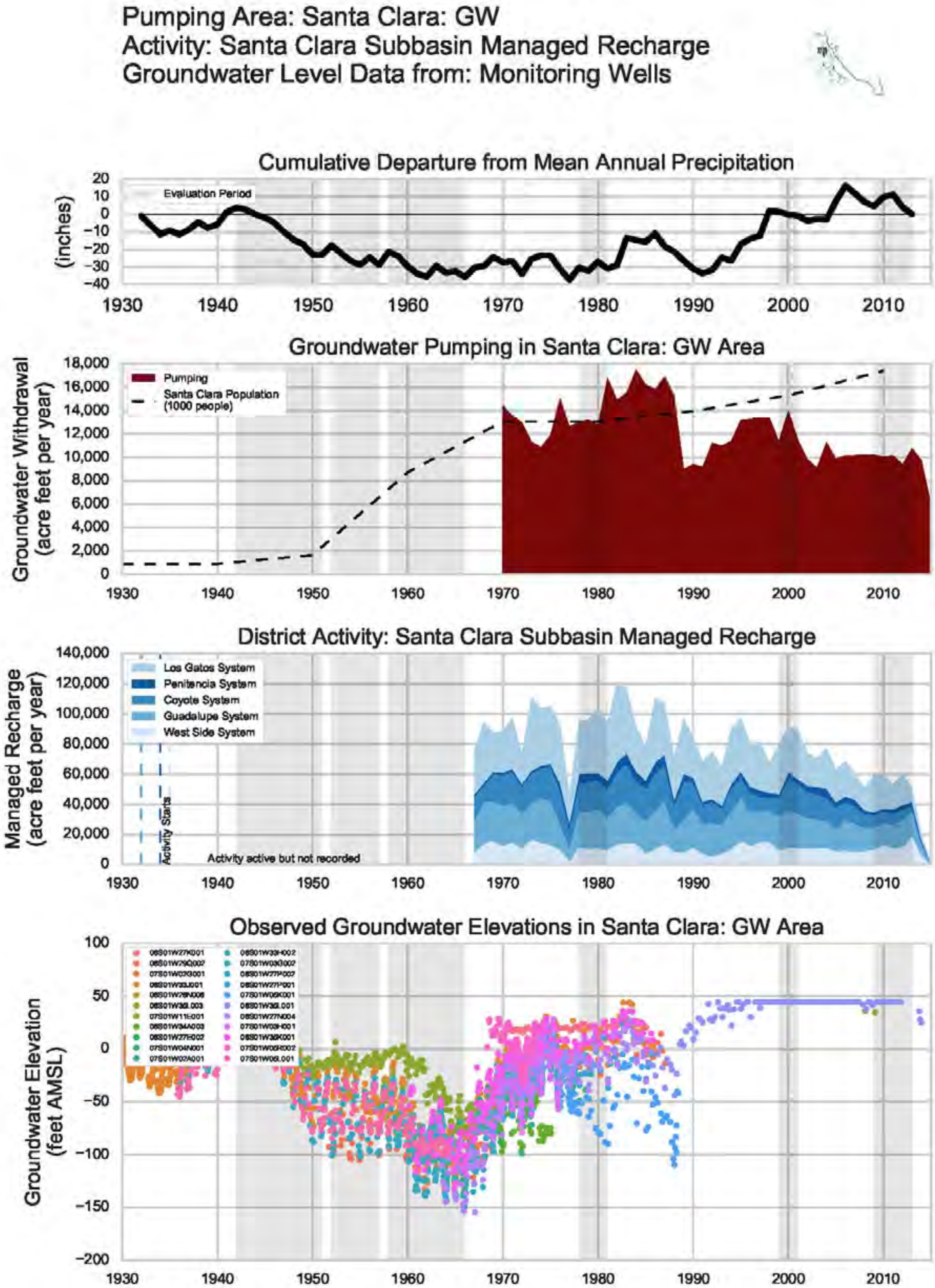

Figure 31. Example of Monitoring Well Groundwater Level Trends Demonstrating Benefits from Managed Recharge Overlapping with a Period Demonstrating Benefits from Treated Water

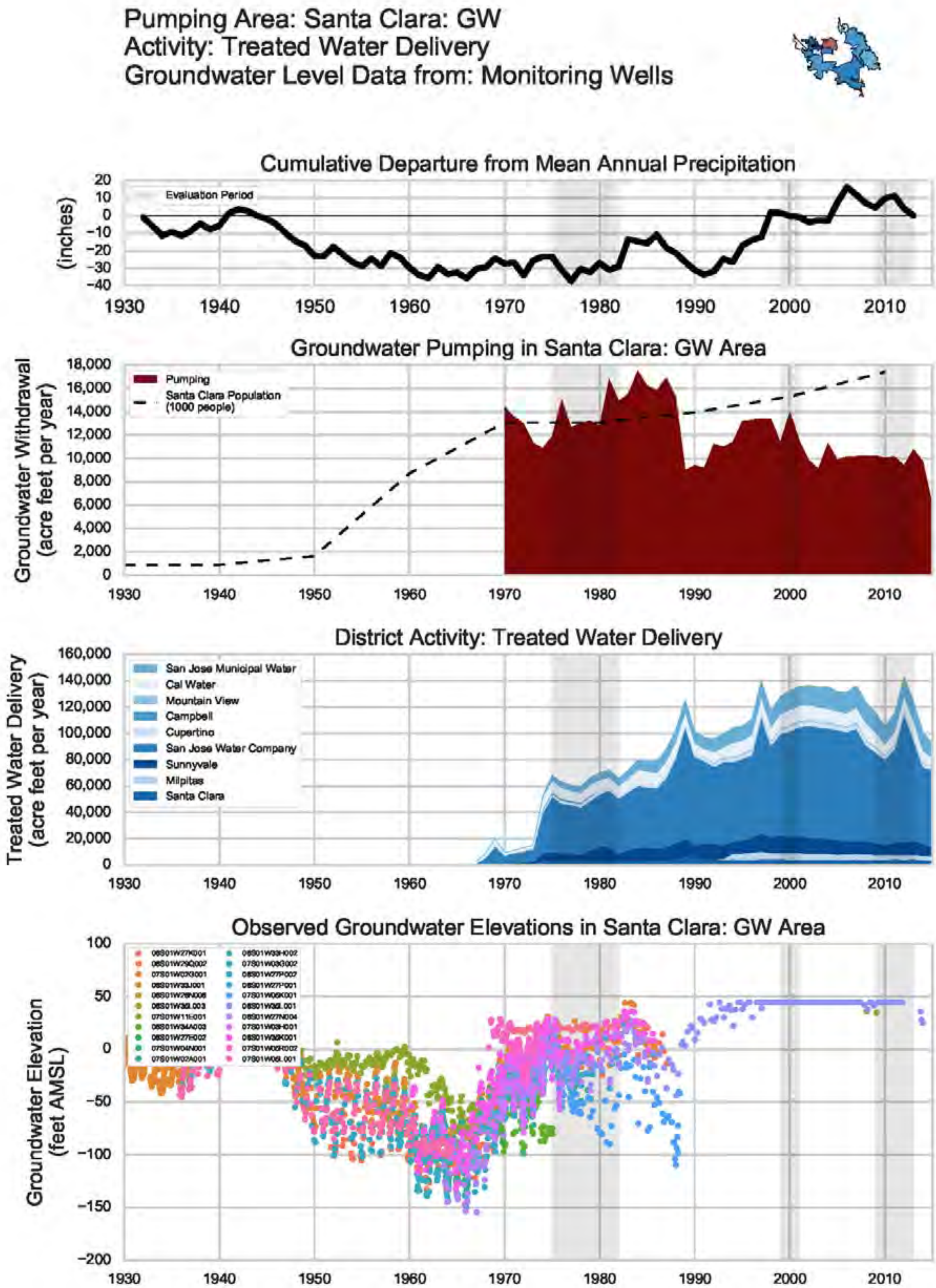

Figure 32. Example of Monitoring Well Groundwater Level Trends Demonstrating Benefits from Treated Water Only in an Overlapping Period

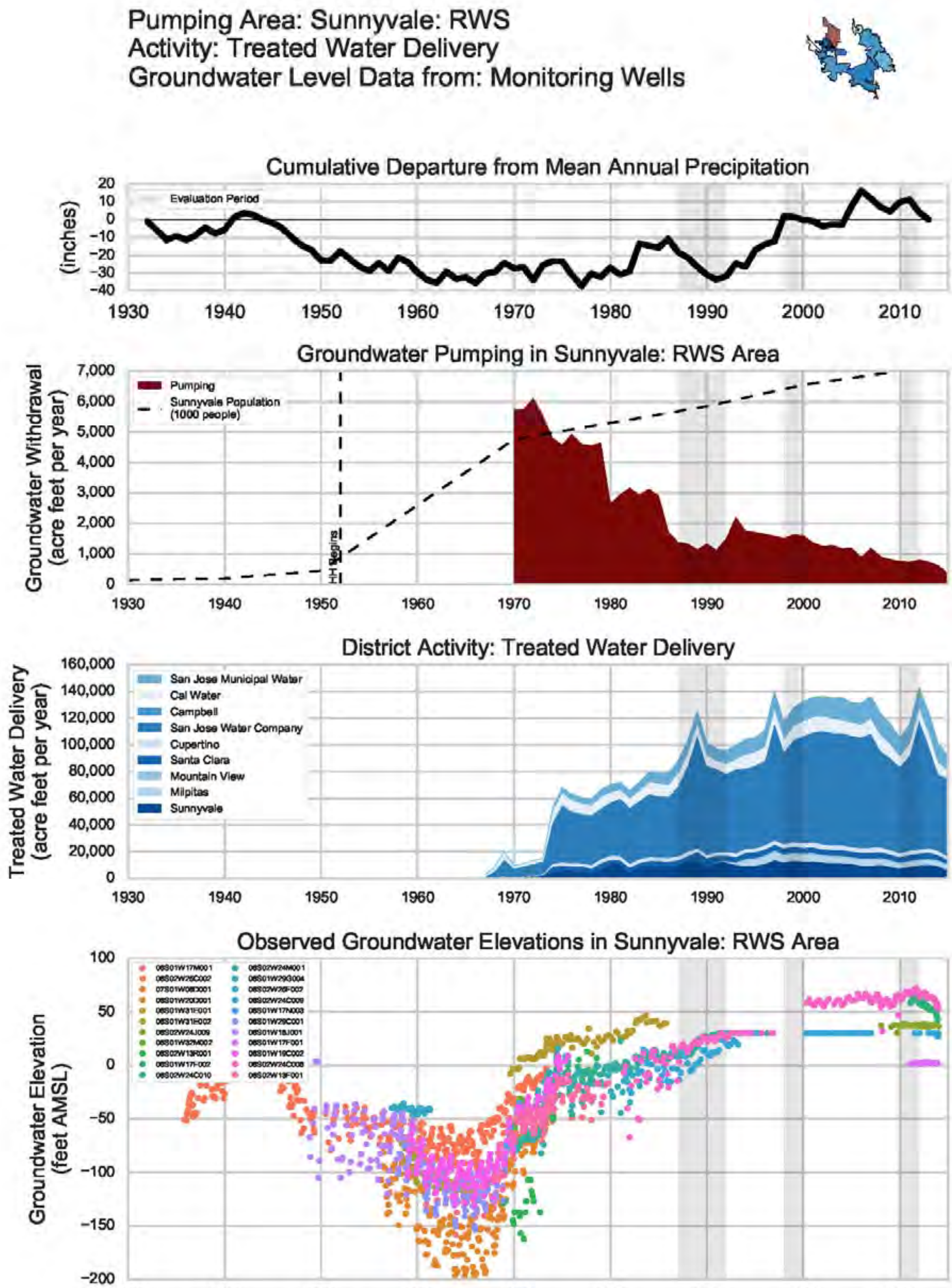

Figure 33. Example of Monitoring Well Groundwater Level Trends Demonstrating Benefits from Treated Water with Increasing Treated Water Deliveries during Overlapping Periods

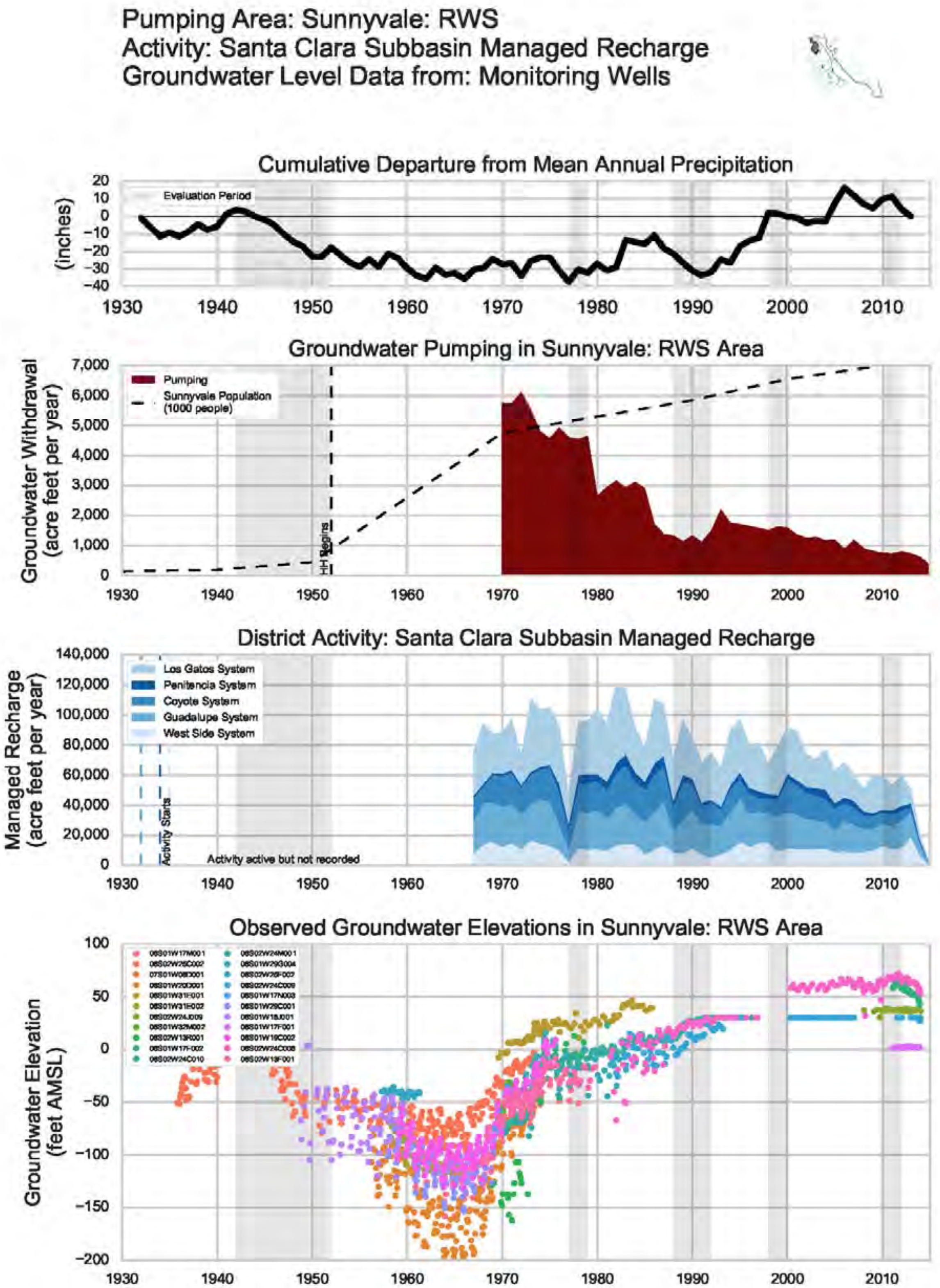

Figure 34. Example of Monitoring Well Groundwater Level Trends Demonstrating Benefits from Managed Recharge with Overlapping Periods of Stable Managed Recharge

Table 8: Pumping Areas and District Activities where Groundwater Level Trends Are Stable or Increasing Only During Evaluation Periods Overlapping with Different District Activity

Year	Pre-1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Period of Expected Stable or Decreasing Groundwater Levels																																								
Groundwater Level Trends during Evaluation Periods by Pumping Area in Santa Clara Subbasin																																								
Milpitas: RWS for Treated Water Delivery																																								
Milpitas: RWS for Managed Recharge																																								
Palo Alto: RWS for Treated Water Delivery																																								
Palo Alto: RWS for Managed Recharge																																								
Stanford: RWS for Treated Water Delivery																																								
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Cal Water Mountain View: GW for Treated Water Delivery																																								
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San Jose Muni: RWS for Managed Recharge																																								
SJ Water Company North: GW for Treated Water Delivery																																								
SJ Water Company North: GW for Managed Recharge																																								
SJ Water Company Los Gatos: Local SW for Treated Water Delivery																																								
SJ Water Company Los Gatos: Local SW for Managed Recharge																																								
San Jose Muni: GW for Treated Water Delivery																																								
San Jose Muni: GW for Managed Recharge																																								
Morgan Hill: GW for Treated Water Delivery																																								
Morgan Hill: GW for Managed Recharge																																								

Decreasing
Stable/Increasing but Overlapping Activities
Stable/Increasing Not Overlapping - Benefit Demonstrated
Increasing Attributable to Overlapping Activity -Benefit Demonstrated
Insufficient Data

Several of the areas where benefits to specific activities are not demonstrated, Mountain View, Santa Clara, and San Jose Water Company North, are surrounded by areas that have demonstrated benefits from both managed recharge and treated water deliveries and can reasonably be assumed to also benefit from both activities due to hydrogeologic connection. Figure 35 and Figure 36 show the areas where the groundwater level trend evaluation demonstrates benefits that can be specifically attributed to each of managed aquifer recharge and treated water deliveries in relation to these areas.

The Palo Alto area shows stable groundwater levels for both 1975-1982 and 1998-2002 that are overlapping periods for evaluating benefits from both managed recharge and treated water deliveries in the Santa Clara Plain. There are no other evaluation periods for managed recharge in this area and the two periods for treated water deliveries showed a decreasing trend. Likewise, the Stanford area shows stable groundwater levels for 2011-2013 that is an overlapping period for evaluating benefits from the two District activities and no other evaluation periods with sufficient data. The groundwater level trends show a benefit from District activities in these areas but the groundwater level trends for the areas cannot be used to attribute the benefit to the specific activities. In addition, since Palo Alto and Stanford are at the northwest end of the subbasin, Palo Alto and Stanford not surrounded by areas that can be evaluated to demonstrate benefits for specific District activities in the Palo Alto area.

The San Jose Water Company area in Los Gatos where the company's local surface water is delivered shows stable groundwater levels for 1979-1982, that this is an overlapping period for evaluating benefits from both managed recharge and treated water deliveries. Stable or increasing trends occur during other evaluation periods for managed recharge but only decreasing trends occur for other evaluation periods for treated water deliveries. The groundwater level trends show a benefit from managed recharge in this area but the groundwater level trends for the areas cannot be used to attribute a benefit specifically to treated water deliveries.

Monitoring wells in Morgan Hill and production wells in the Coyote service area of San Jose Municipal Water receiving only groundwater both show increasing groundwater level trends only during 1975-1982, overlapping with evaluation of managed recharge. In the evaluation of managed recharge, other periods show groundwater level trends demonstrating benefit. These areas are in the Coyote Valley area where the north Morgan Hill area between San Jose and Morgan Hill does not have groundwater level trends demonstrating benefit from treated water delivery. In addition, the treated water delivery is north of Coyote Narrows where a steep groundwater gradient potentially limits hydrogeologic connection. Therefore, it is more likely that the increasing groundwater level trends occurring during 1975-1982 are a result of managed recharge from Coyote Creek in the Coyote Valley area instead of treated water delivery to the north of Coyote Narrows.

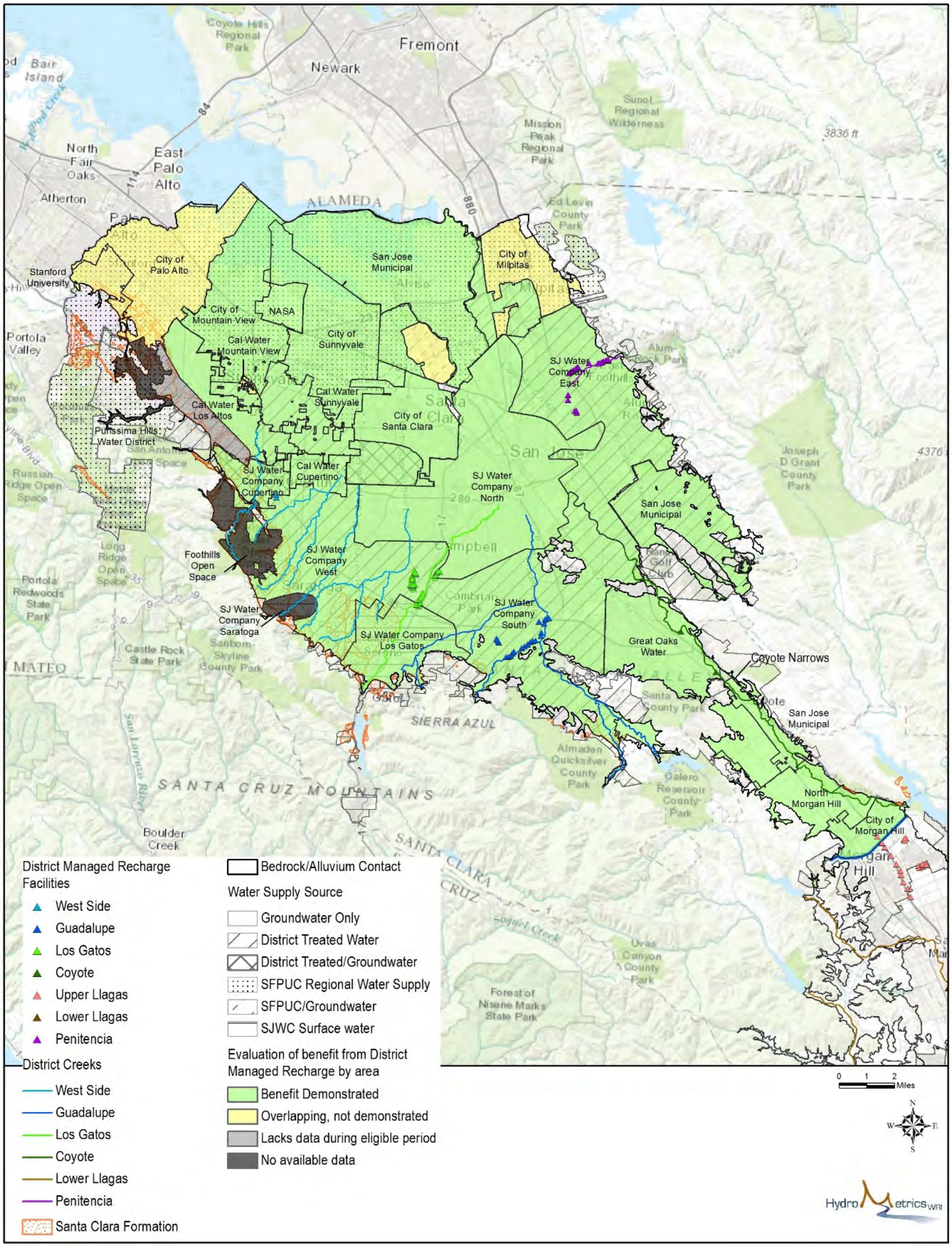


Figure 35: Results of Groundwater Level Trend Evaluation of Benefits from Managed Aquifer Recharge in Santa Clara Subbasin

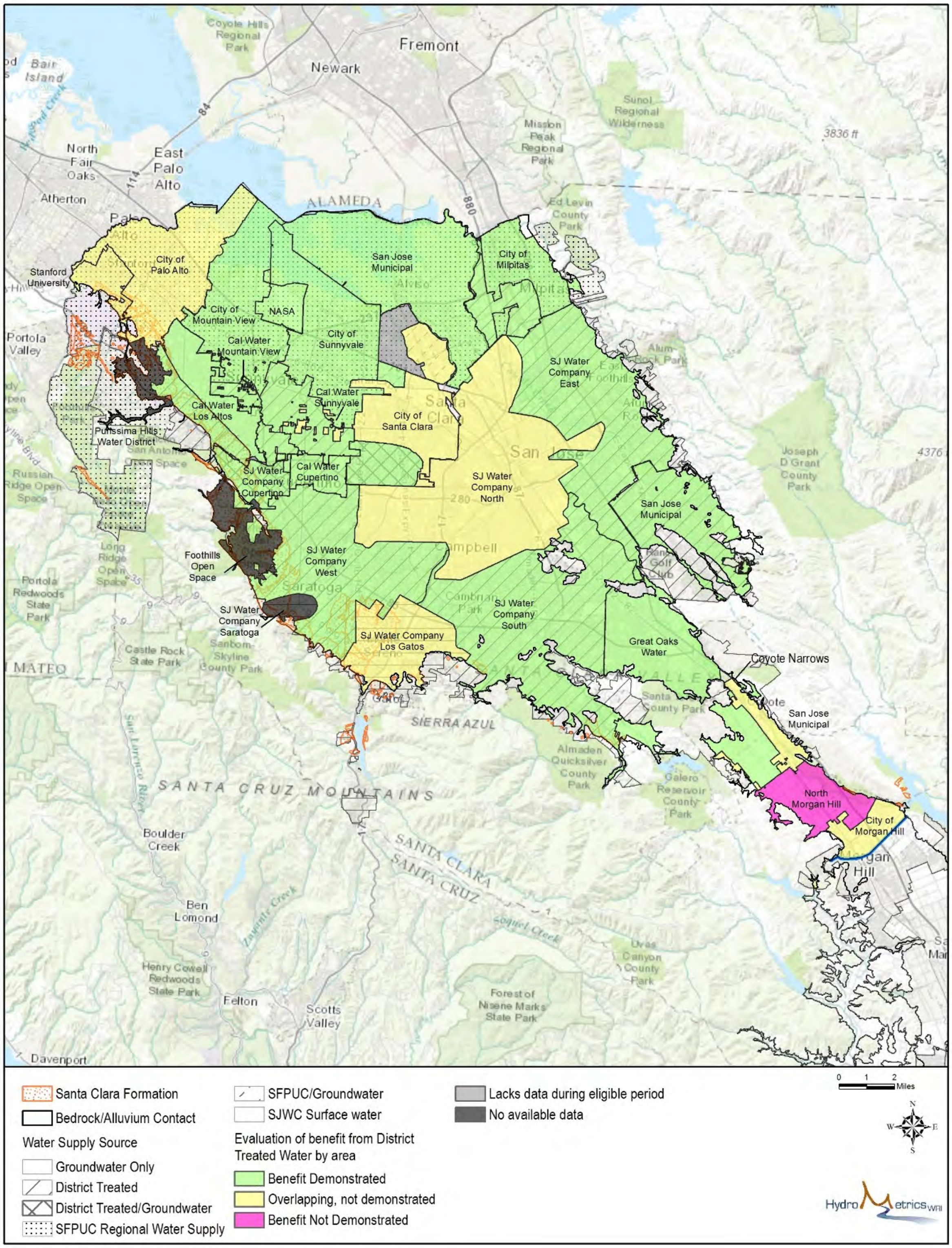


Figure 36: Results of Groundwater Level Trend Evaluation of Benefits from Treated Water Deliveries in Santa Clara Subbasin

6.3 Areas without Groundwater Level Data

6.3.1 Areas where Groundwater Level Data Unavailable during Evaluation Periods for Activities

There are two areas where groundwater level data are not available during evaluation periods for a District activity. These areas are the Los Altos area served District treated water by Cal Water and the small area of the City of Santa Clara where only SFPUC RWS water is delivered.

In the Cal Water Los Altos area where District treated water is delivered, there are no groundwater level data available for periods used to evaluate benefits from managed recharge (Appendix C). This area overlaps the Santa Clara Formation which may have limited hydrogeologic connection with managed recharge activities in the Unconsolidated Alluvium outside the Santa Clara Formation (Section 4.6).

In the small area of the City of Santa Clara where only SFPUC RWS water is delivered, there are no groundwater level data to evaluate trends during periods used to evaluate benefits from treated water deliveries (Appendix D). However, benefits from District treated water deliveries are demonstrated in hydrogeologically connected surrounding areas: Sunnyvale area where only SFPUC RWS water is delivered and City of San Jose Municipal where only SFPUC RWS water is delivered (Figure 36). Therefore, it is reasonable to assume that this area of the City of Santa Clara, even without local groundwater level data, also benefits from treated water deliveries.

6.3.2 Areas without Available Groundwater Level Data

There are areas where no groundwater level data are available. These areas include Purissima Hills, San Jose Water Company in Saratoga receiving surface water from the company's own surface water right, the Open Space area and the Uvas-Chesbro area.

Purissima Hills Water District and Open Space area overlaps with bedrock and the Santa Clara Formation, while Stanford and the surface water delivery area of San Jose Water Company in Saratoga overlap with bedrock, Santa Clara Formation, and Unconsolidated Alluvium. The Santa Clara Formation also has partial overlap with other areas including Palo Alto and San Jose Water Company in Los Gatos and there are no data to evaluate in those Santa Clara Formation areas. Bedrock is not considered to have hydrogeologic connection with managed recharge activities, while the Santa Clara Formation may have limited hydrogeologic connection with managed recharge activities in the Unconsolidated Alluvium (Section 4.6).

The Uvas-Chesbro area is west of bedrock outcrops in the Llagas Subbasin (Figure 24) which may limit the hydrogeologic connection with managed recharge of imported water that occurs east of the bedrock outcrops and groundwater level trends demonstrate benefits from managed recharge of imported water .

6.4 STATISTICAL ANALYSIS

In order to quantify the groundwater level trends used to demonstrate improvement, a Mann-Kendall test was performed for data at each well over the time period when a trend for the area of the well demonstrates improvement. The Mann-Kendall test is appropriate because it is non-parametric and does not rely on the distribution of the data set (Heisel and Hirsch, 2002). The Mann-Kendall test statistic tau represents whether there is a trend detected on a scale from -1 to 1, with -1 representing a decreasing trend and 1 representing an increasing trend. The padj statistic represents the level of significance of the tau result on a scale from 0 to 1. Appendix G summarizes the Mann-Kendall statistics results by well grouped by retailer well area.

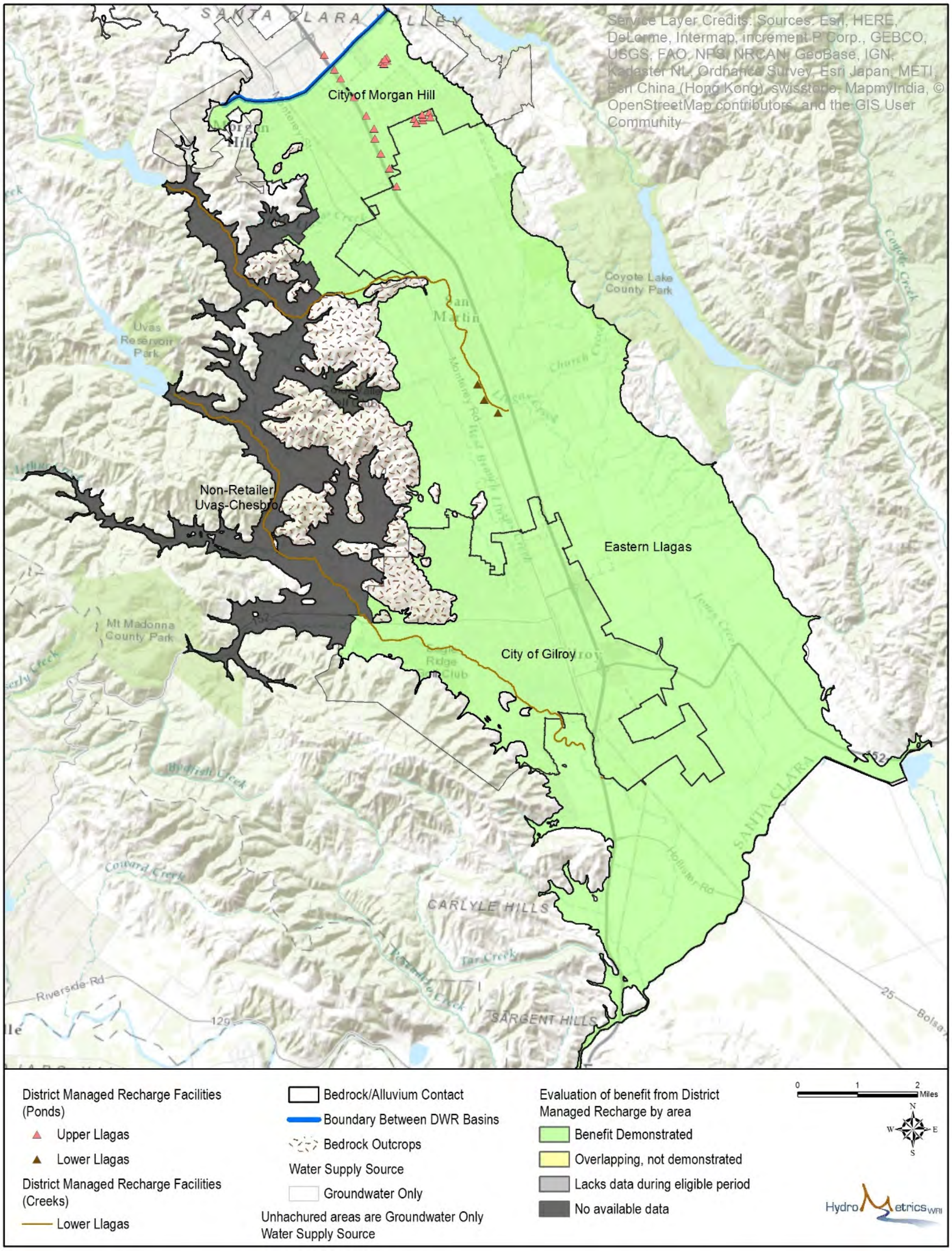


Figure 37: Results of Groundwater Level Trend Evaluation of Benefits from Managed Aquifer Recharge in Llagas Subbasin

Section 7
GROUNDWATER MODEL SIMULATIONS

7.1 GROUNDWATER MODELING APPROACH

The District ran simulations with its groundwater flow models for the Santa Clara Plain (CH2M Hill, 1992) and Llagas Subbasin (CH2M Hill, 2005) to evaluate the extent of benefits from District activities. The groundwater flow models have been calibrated to historical data and are therefore appropriate for use to supplement the groundwater level data evaluation in Section 6 in evaluating effects of District activities on groundwater flow. Groundwater modeling facilitates the evaluation of benefits from a specific District activity without confounding effects from other groundwater conditions or activities. This is accomplished by comparing model runs with the District activity to model runs with the District activity removed or reduced. The model run with the District activity is represented by a baseline simulation of historical conditions that includes the District activity. The model run removing or reducing the District activity has the same inputs as the baseline except for the District activity.

Comparing model runs with the only change being the District activity provides a line of evidence supporting groundwater level data evaluation presented in Section 6, especially in areas where data are limited or there are overlapping evaluation periods that prevent assigning benefits to a specific District activity, and where District activities such as managed aquifer recharge of local water and imported water cannot be separated in the data. The model runs can also be used to evaluate benefits from recycled water activities, which has quantities that are too small to evaluate in the groundwater level data evaluation.

Model results depend on modeling assumptions used to create the models, particularly the model domain covered. Therefore, use of the model to demonstrate the extent of benefits needs to be consistent with the groundwater level evaluation described in Section 6.

The District's Coyote Valley model is not used for this evaluation. This model's simulation of the recharge from the Coyote Creek managed recharge system is based on stream levels that are not conducive to testing the effects of reduced recharge quantities. The groundwater level trend evaluation demonstrated a benefit from managed recharge in all areas the Coyote Valley so modeling results would only affirm that conclusion. The groundwater level trend evaluation did not demonstrate a benefit from treated water deliveries in the Santa Clara Plain. The model also cannot directly simulate deliveries in the Santa Clara Plain as the model's northern domain boundary is the Coyote Narrows.

Table 9. Summary of Groundwater Model Simulations Evaluated for Study

Model	Period	Scenario No.	District Activity Evaluated	Model Implementation for District Activity
Santa Clara Plain	1970-2015	1	None (Baseline)	Historical Pumping and Managed Recharge
		2	Treated Water Delivery	Increased Pumping by 50% of Treated Water Deliveries
		5	Managed Aquifer Recharge	Eliminates District Managed Aquifer Recharge
		6	Recycled Water	Increased Pumping in Areas Receiving Recycled Water
Llagas	1987-2015	Baseline	None (Baseline)	Historical Pumping and Managed Recharge
		1	Managed Aquifer Recharge of Local Runoff	Eliminates District Managed Aquifer Recharge of Local Runoff in Upper Llagas and Lower Llagas Systems
		2	Managed Aquifer Recharge of Imported Water	Eliminates District Managed Aquifer Recharge of Imported Water in Upper Llagas System
		4	Recycled Water	Increased Pumping in Areas Receiving Recycled Water

7.2 SANTA CLARA PLAIN MODEL SIMULATIONS

The District ran simulations using the Santa Clara Plain groundwater model following the approach outlined above. One of the main assumptions implemented in this model is that the domain covers the Unconsolidated Alluvium but does not cover most of the Santa Clara Formation outcrop area. The initial modeling is documented in the District's memo (Liu and Zhan, 2016) included as Appendix H. Any necessary revisions to the initial modeling are described below. The Study uses modeling that evaluates treated water deliveries (Scenario 2), managed aquifer recharge (Scenario 5), and recycled water deliveries (Scenario 6) separately. The Study does not use Scenarios 3 and 4 (documented in Appendix F) evaluating effects of recharging only imported water and only local runoff because all managed recharge systems in the Santa Clara Plain are connected to the imported water system and can recharge both imported water and local runoff. All runs simulate historical climatic conditions from 1970-2015.

7.2.1 BASELINE

Scenario 1 simulates historical conditions from 1970-2015 for pumping and managed recharge. Results from all other scenarios are compared to this scenario to evaluate the extent of benefit from a specific District activity. This comparison is done by subtracting groundwater level results at the end of each of the other scenarios from the results at the end of this baseline run. A positive difference in the groundwater levels indicate a benefit from the District activity because the baseline run includes the District activity as fully implemented historically. The Study evaluates each map of the groundwater level difference in 2015 for demonstrated extent of benefits. Yellow represents the minimum groundwater level difference of 0.6 feet across all scenarios when compared to the baseline scenario. Dark blue represents the maximum groundwater level difference of 124 feet across all scenarios when compared to the baseline scenario.

7.2.2 REDUCED TREATED WATER DELIVERIES

Scenario 2 estimates the effects of reducing treated water deliveries by 50% by assuming that any reduced deliveries would be made up for with increased pumping. The model simulates this by increasing pumping by one half of treated water delivery quantities to simulate the decrease in in-lieu recharge from reduced treated water deliveries. The increases occur at selected wells of retailers that have received treated water deliveries. Treated water deliveries are only partially reduced because increasing pumping by the full amount alters the water budget so significantly that it causes numerical problems for the model. The run described in Appendix G (Liu and Zhan, 2016) that increases pumping from 1970-2015 also encounters numerical problems by the end of 2013 so District staff revised the run to only increase pumping for 2005-2015. Figure 38 shows the groundwater level difference between baseline Scenario 1 and Scenario 2 at the end of 2015. This figure shows that eleven years of treated water deliveries increased groundwater levels throughout the Unconsolidated Alluvium of the Santa Clara Plain, ranging from 1.9 feet to 97 feet.

7.2.3 REDUCED MANAGED AQUIFER RECHARGE

Scenario 5 eliminates all District managed recharge from 2005-2015. Figure 39 shows the groundwater level difference between baseline Scenario 1 and Scenario 5 at the end of 2015. This figure shows that eleven years of managed recharge increased groundwater levels throughout the Unconsolidated Alluvium of the Santa Clara Plain, ranging from 3.9 feet to 124 feet. The increases are distributed differently than increases from treated water (Figure 38) with the highest increases where creeks pass through unconfined areas.

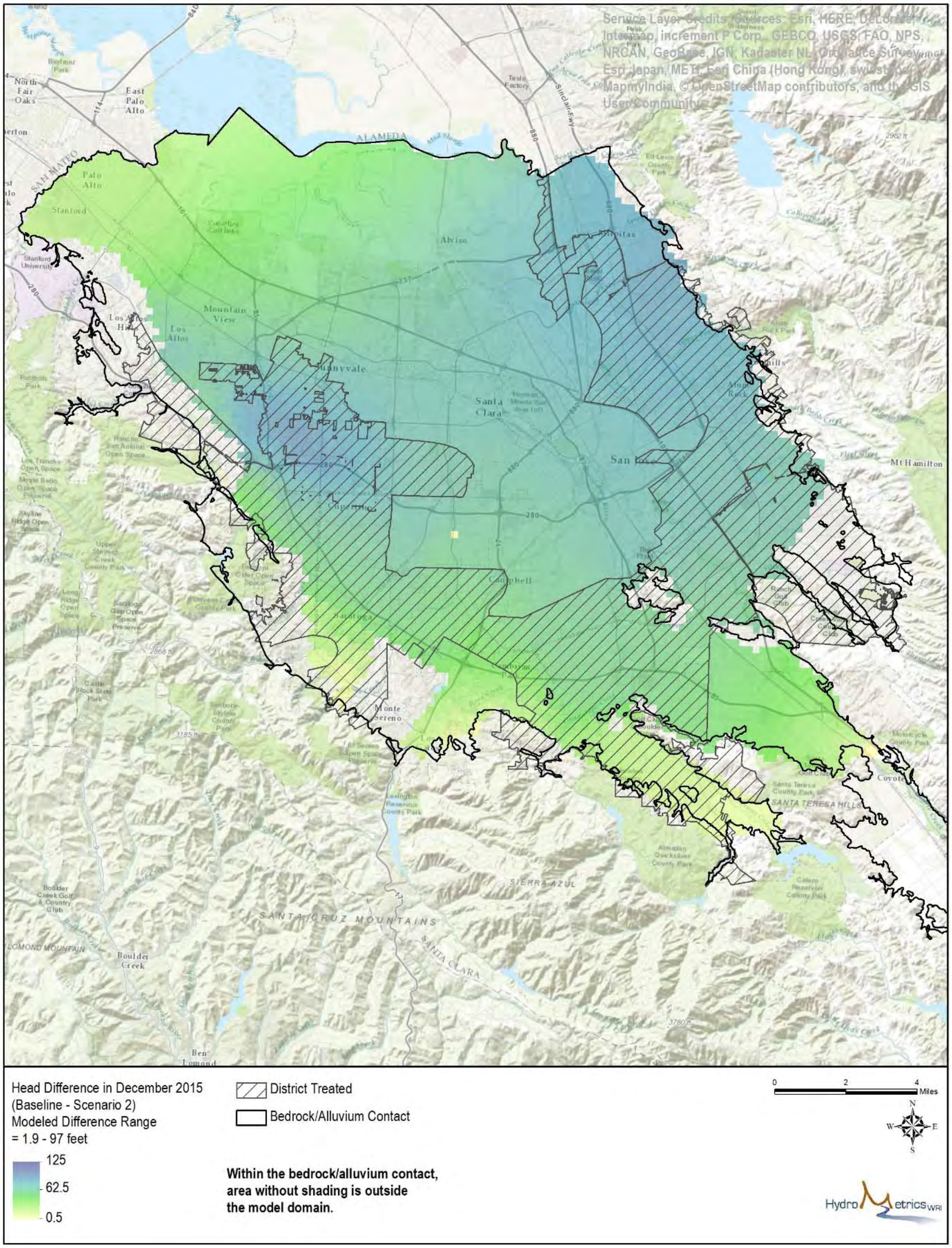


Figure 38: Simulated Groundwater Difference due to Reduced Treated Water Deliveries in Santa Clara Plain

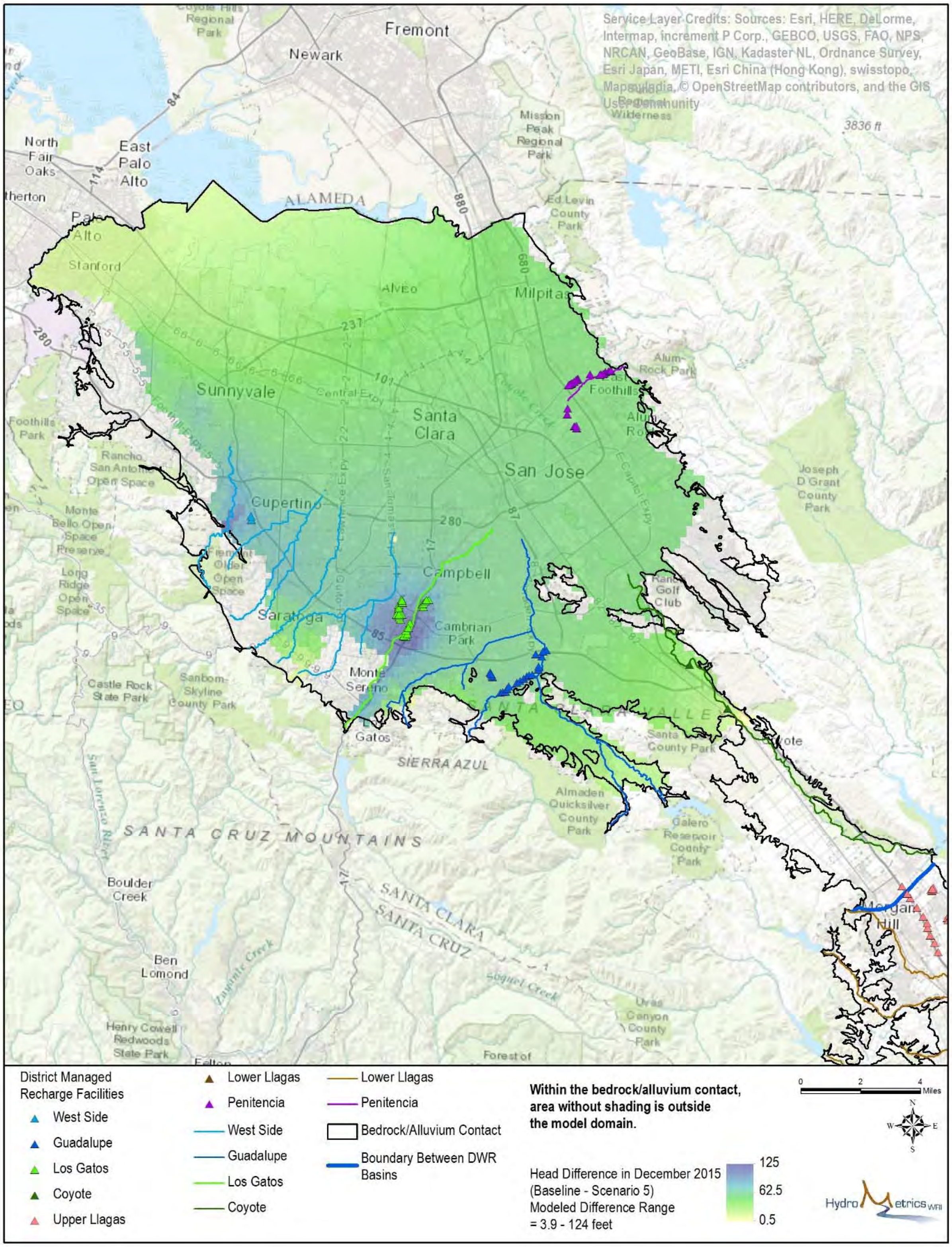


Figure 39: Simulated Groundwater Difference due to Reduced Managed Recharge in Santa Clara Plain

7.2.4 Reduced Recycled Water

Scenario 6 simulates reduced recycled water deliveries by assuming a reduction in these deliveries would be made up for with increased pumping. The model simulates this by increasing pumping by the recycled water delivery quantities. Pumping was increased at selected retailer wells in the area of the Palo Alto, Sunnyvale, and South Bay Water Recycling areas. Figure 40 shows the groundwater level difference between the baseline Scenario 1 and Scenario 6 with groundwater level increases due to recycled water deliveries throughout the Unconsolidated Alluvium of the Santa Clara Plain, ranging from 0.6 feet to 41 feet.

The figure shows groundwater level differences throughout the Santa Clara Plain are much smaller than differences for the reduced treated water (Scenario 2) and reduced managed recharge (Scenario 5) due to the smaller volume of recycled water delivered. This confirms that District in-lieu recharge activities such as recycled water and untreated surface water with relatively small deliveries have benefits throughout the Unconsolidated Alluvium but benefits will be difficult to demonstrate with groundwater level data.

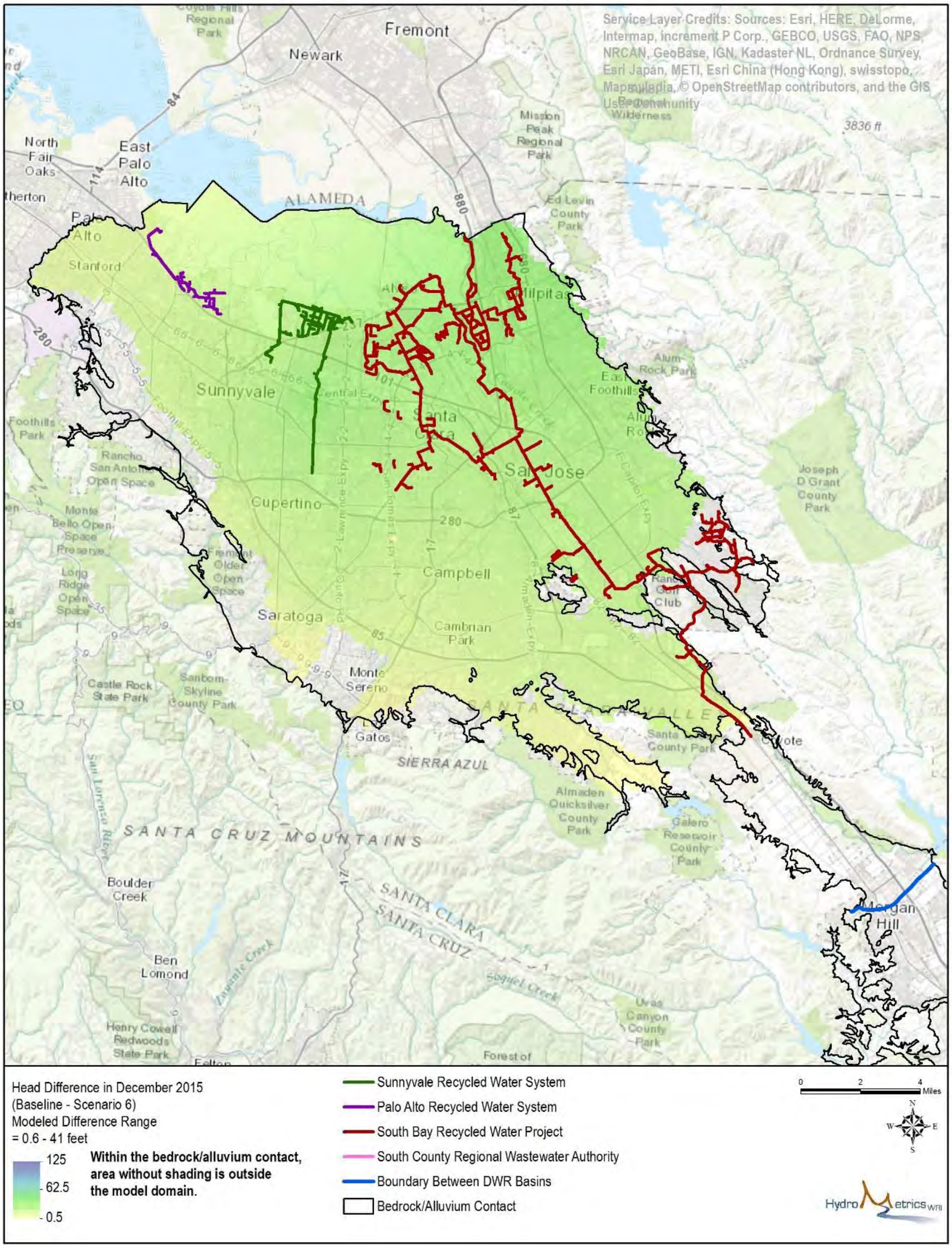


Figure 40: Simulated Groundwater Level Difference due to Reduced Recycled Water in Santa Clara Plain

7.3 Santa Clara Plain Model Results Compared to the Groundwater Level Evaluation

The Santa Clara Plain model results demonstrate how benefits from individual District activities propagate throughout the hydrogeologically connected area of the Unconsolidated Alluvium of the Santa Clara Plain. The model results confirm and supplement demonstration of benefits by the groundwater level evaluation.

7.3.1 Santa Clara Plain Model Results where Groundwater Level Trends Do Not Fully Demonstrate Benefits

The model provides supplemental information in several areas where measured groundwater level trends do not fully demonstrate benefits from one or both District activities of managed recharge and treated water deliveries. These include portions of the service areas of Mountain View, Santa Clara, San Jose Water Company, Palo Alto, and Stanford.

In most of these areas, groundwater level trends for evaluation of managed recharge or treated water only demonstrate benefits during overlapping evaluation periods when benefits from the two activities cannot be distinguished. While the groundwater level trend evaluation demonstrates benefit from a District activity, the groundwater model scenarios can demonstrate benefit from each specific District activity. In these areas, the groundwater level trend evaluation only demonstrates that the area should be in a zone of benefit while the model scenarios can attribute specific District activities to the zone.

Several areas in Mountain View, Santa Clara, and San Jose Water Company North have increasing groundwater level trends for evaluation of managed recharge or treated water only during overlapping evaluation periods when benefits from the two activities cannot be distinguished. There is also an area of Santa Clara where there are no groundwater data during periods to evaluate benefits from treated water deliveries. The modeled groundwater level differences between the baseline (Scenario 1) and both the reduced treated water delivery (Scenario 2) and the reduced managed recharge (Scenario 5) show the benefit in these areas are similar to surrounding areas. Therefore, the conclusion that evaluations of groundwater level trends in surrounding areas demonstrating benefit from both activities could be extrapolated to these areas is confirmed.

In the Palo Alto and Stanford areas, measured groundwater levels are stable only for overlapping evaluation periods used for evaluating benefits from both managed recharge and treated water deliveries. The modeled groundwater level differences between the baseline (Scenario 1) and both the reduced treated water delivery (Scenario 2) and the reduced managed recharge (Scenario 5) show similar benefits to the Palo Alto and Stanford areas, which demonstrates that this area benefits from both District activities.

In the San Jose Water Company Los Gatos area, measured groundwater level trends associated with treated water deliveries are stable only in an evaluation period that overlaps with managed recharge, making it difficult to definitively demonstrate the benefit from treated water deliveries. The modeled groundwater level differences between the baseline (Scenario 1) and the reduced treated water delivery (Scenario 2) in this area are similar to model results in other areas where groundwater level trends demonstrates benefit from treated water deliveries, which shows that this area also benefits from the treated water delivery activity.

7.3.2 Areas not Covered by Santa Clara Plain Model

The Santa Clara Plain model does not include several areas where the groundwater level data evaluation does not demonstrate benefits from a District activity or groundwater level data are not available. These areas include Coyote Valley and the Santa Clara Formation on the west side of the subbasin.

In the Coyote Valley, groundwater level trends do not demonstrate a benefit from treated water deliveries. The Santa Clara Plain model boundary is at Coyote Narrows at the north end of Coyote Valley. Therefore, the model does not provide any information on the Coyote Valley. The groundwater level trend evaluate does demonstrate a benefit from managed recharge that occurs in this area.

Groundwater level data are not available in the Santa Clara Formation, including areas of Stanford, Purissima Hills, Palo Alto, Los Altos, Saratoga, and Los Gatos. The Santa Clara Plain model does not extend to include the Santa Clara Formation, and therefore does not provide any information showing benefits extend from the Unconsolidated Alluvium into Santa Clara Formation. The model sets a mountain front recharge boundary condition at the boundary of the Santa Clara Formation and the Unconsolidated Alluvium that represents natural recharge based on climatic conditions. The boundary condition does not account for operations of District managed recharge and therefore the District does not have an operational assumption that managed recharge is occurring in the Santa Clara Formation. However, treated water deliveries do extend into areas of the Santa Clara Formation.

The Santa Clara Plain model also does not include the Evergreen area of San Jose Municipal Water, but the groundwater level data evaluation demonstrated benefits from managed recharge for that area. The District delivers treated water to that area so the area also benefits from that District activity.

7.4 LLAGAS MODEL SIMULATIONS

The District ran simulations using the Llagas Subbasin groundwater model following the approach outlined above. One of the main assumptions implemented in this model is that the domain covers the Unconsolidated Alluvium east of bedrock outcrops but does not cover most of the Uvas-Chesbro area. The District memo (Abuye, 2016) included as Appendix I documents these models. The Study uses modeling that evaluates managed recharge of local runoff (Scenario 1), managed recharge of imported water (Scenario 2), and recycled water deliveries (Scenario 4) separately. The Study does not use Scenario 3 evaluating effects of all managed recharge because recharge of local runoff and imported water are evaluated separately to account for the fact that the lower Llagas system is not connected to imported water. All runs simulate historical conditions for climate from 1987-2015.

7.4.1 BASELINE

The baseline run simulates historical conditions from 1987-2015 for pumping and managed recharge. Results from all other scenarios are compared to this scenario to evaluate the extent of benefit from a specific District activity. This comparison is done by subtracting groundwater level results at the end of each of Scenarios 1, 2 and 4 from the results at the end of this baseline run. A positive difference in the groundwater levels indicate a benefit from the District activity because the baseline run includes the District activity as fully implemented historically. The Study evaluates each map of the groundwater level difference in 2015 for demonstrated extent of benefits. Yellow represents the minimum groundwater level difference of 0.5 feet across all scenarios when compared to the baseline scenario. Dark blue represents the maximum groundwater level difference of 303 feet across all scenarios when compared to the baseline scenario.

7.4.2 REDUCED MANAGED AQUIFER RECHARGE OF LOCAL RUNOFF

Scenario 1 eliminates managed recharge of local runoff at the Upper Llagas and Lower Llagas systems from 2005-2015. Figure 41 shows the groundwater level difference between the Baseline scenario and Scenario 1. This figure shows managed recharge of local water resulted in increases in groundwater levels throughout the modeled domain of the Llagas Subbasin ranging from 25 to 303 feet. Since the model domain does not include the Uvas Chesbro area, the model does not simulate the managed recharge of local runoff that occurs in Uvas and Llagas Creeks in that area.

7.4.3 REDUCED MANAGED AQUIFER RECHARGE OF IMPORTED WATER RUNOFF

Scenario 2 eliminates managed recharge of imported water at the Upper Llagas system from 2005-2015. Figure 42 shows the groundwater level difference between the Baseline scenario and Scenario 2. This figure shows increases in groundwater levels from eleven years of managed recharge of local runoff throughout the modeled domain of the Llagas Subbasin ranging from 0.9 to 108 feet.

7.4.4 Reduced Recycled Water

Scenario 4 simulates reduced recycled water deliveries by assuming a reduction in these deliveries would be made up for with increased pumping. This was accomplished in the model by increasing pumping by the recycled water delivery quantities to decrease in-lieu recharge from recycled water deliveries. Increased pumping is distributed between 58 pumping wells with 0.5 mile of the South County Regional Wastewater Authority recycled water pipeline. Figure 41 shows the groundwater level difference between the Baseline scenario and Scenario 4. This figure shows increases in groundwater levels from recycled water deliveries throughout the modeled domain of the Llagas Subbasin ranging from 0.5 to 11 feet. However, groundwater level differences throughout the subbasin are much smaller than differences for the eliminated managed recharge of local runoff (Scenario 1) and eliminated managed recharge of imported water (Scenario 2) due to the smaller volume of recycled water delivered. This confirms that District in-lieu recharge activities such as recycled water and untreated surface water with relatively small deliveries have benefits throughout the hydrogeologically connected area but will benefits will be difficult to demonstrate with groundwater level data.

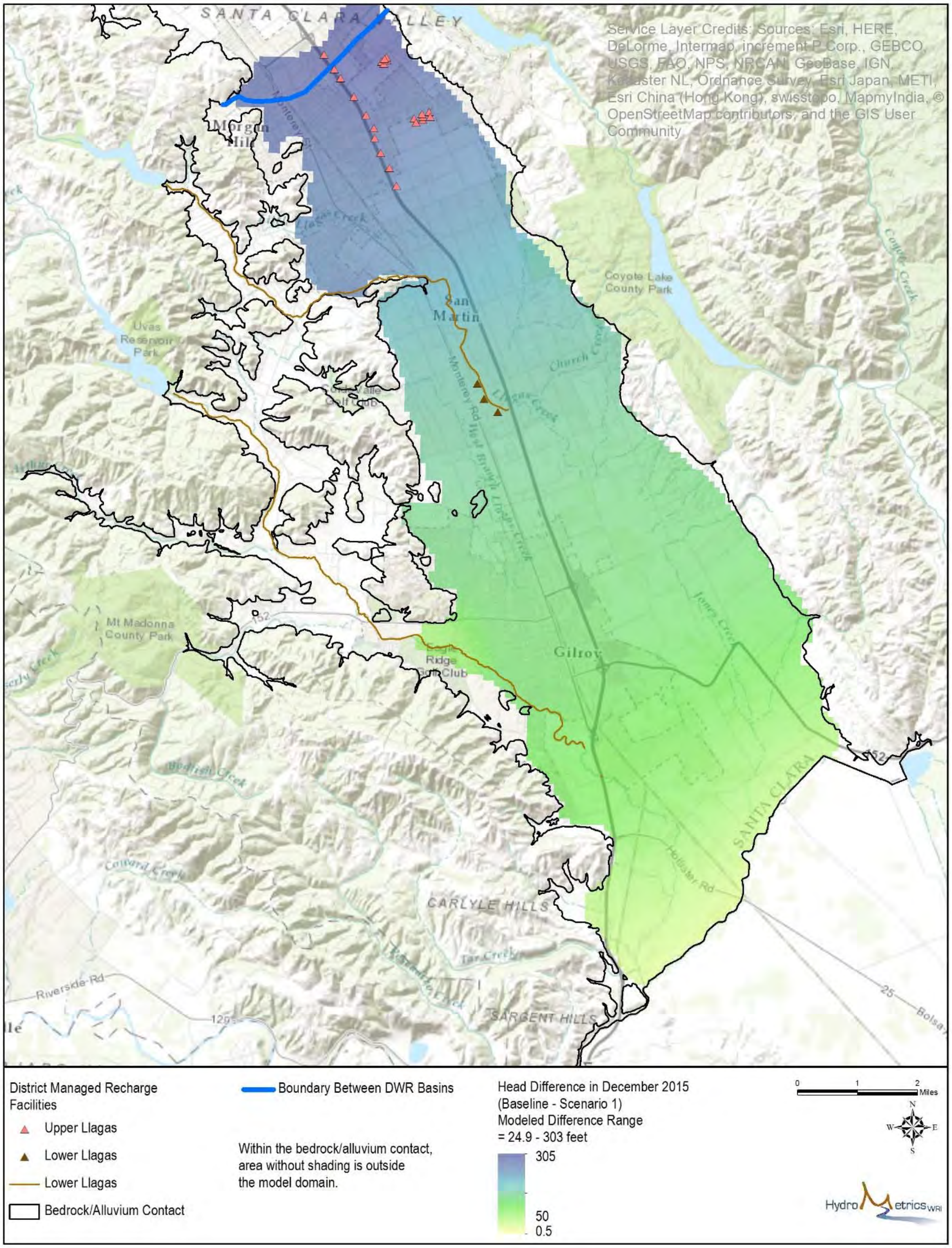


Figure 41: Simulated Groundwater Level Difference due to Reduced Managed Recharge of Local Runoff in Llagas Subbasin

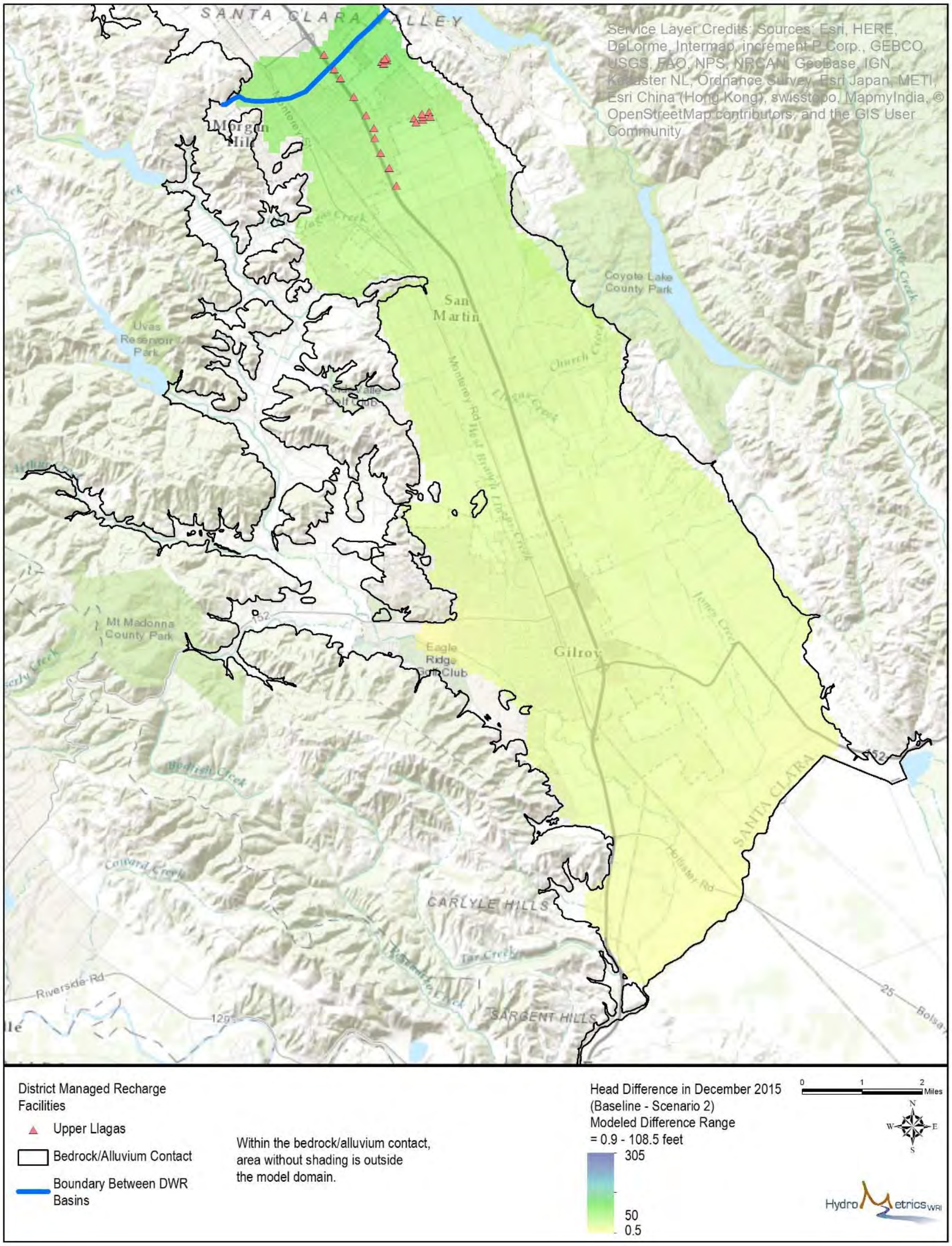


Figure 42: Simulated Groundwater Level Difference due to Reduced Managed Recharge of Imported Water in Llagas Subbasin

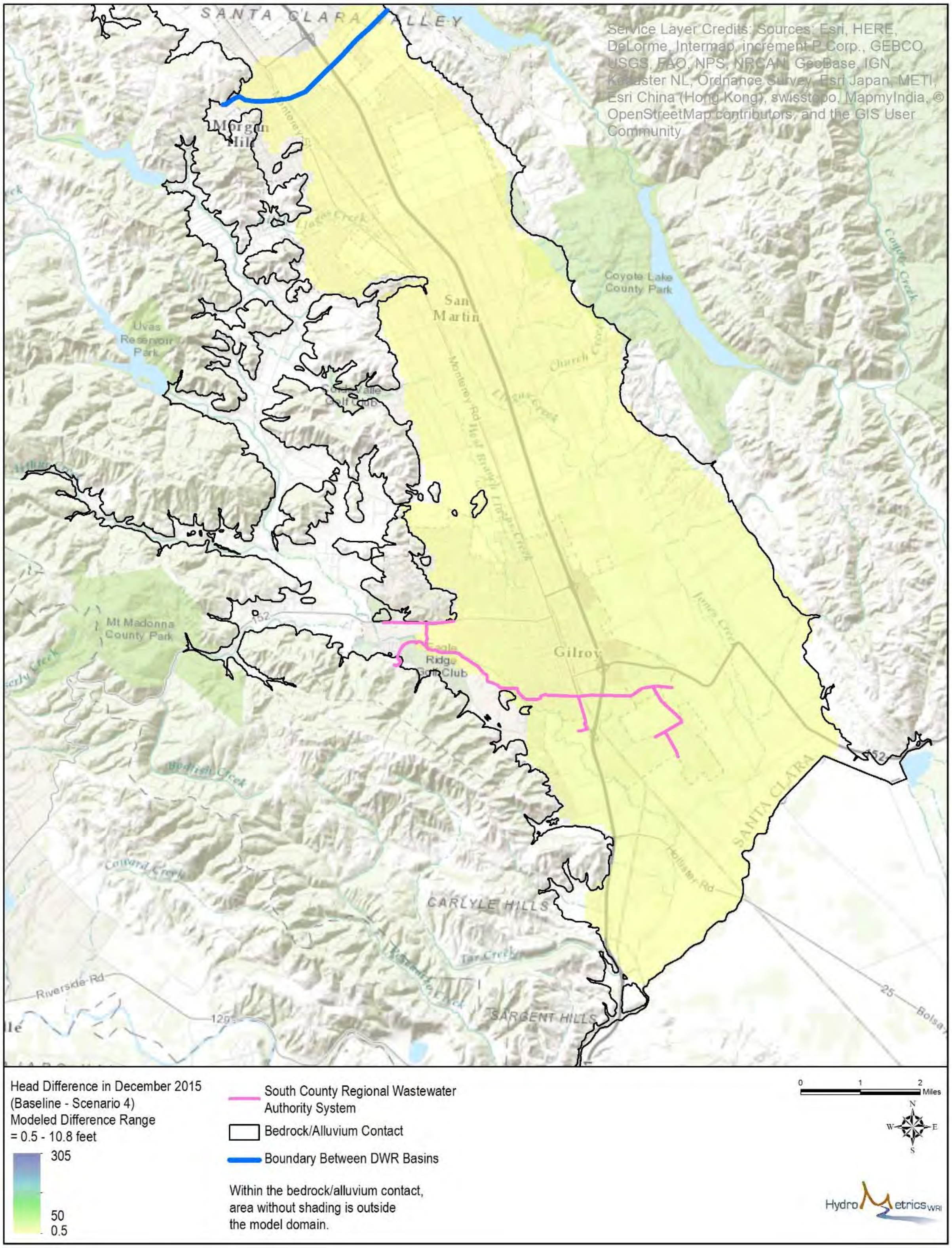


Figure 43: Simulated Groundwater Level Difference due to Reduced Recycled Water in Llagas Subbasin

7.5 Llagas Model Results Compared to Groundwater Level Evaluation

While the groundwater evaluation evaluates managed recharge of local runoff and imported water together, the model results demonstrate how benefits from managed recharge of local runoff and imported water propagate throughout the hydrogeologically connected area of the subbasin. The model results supplement demonstration of benefits in pumping areas by the groundwater level evaluation.

7.5.1 Area not Covered by Llagas Model

The model does not the cover the Uvas-Chesbro- area where the groundwater level data evaluation does not demonstrate benefits from a District activity or groundwater level data are not available. The model only simulates the area east of the bedrock outcrops in the Llagas Subbasin that separates the Uvas-Chesbro area from the rest of the basin. Therefore, the model does not provide any information showing that benefits extend from managed recharge of imported water occurring east of the bedrock outcrops to the Uvas-Chesbro area. Managed recharge of local water occurs in the Uvas-Chesbro area and is assumed to benefit hydrogeologically connected area of Unconsolidated Alluvium in that area.

Section 8
ZONES OF BENEFIT

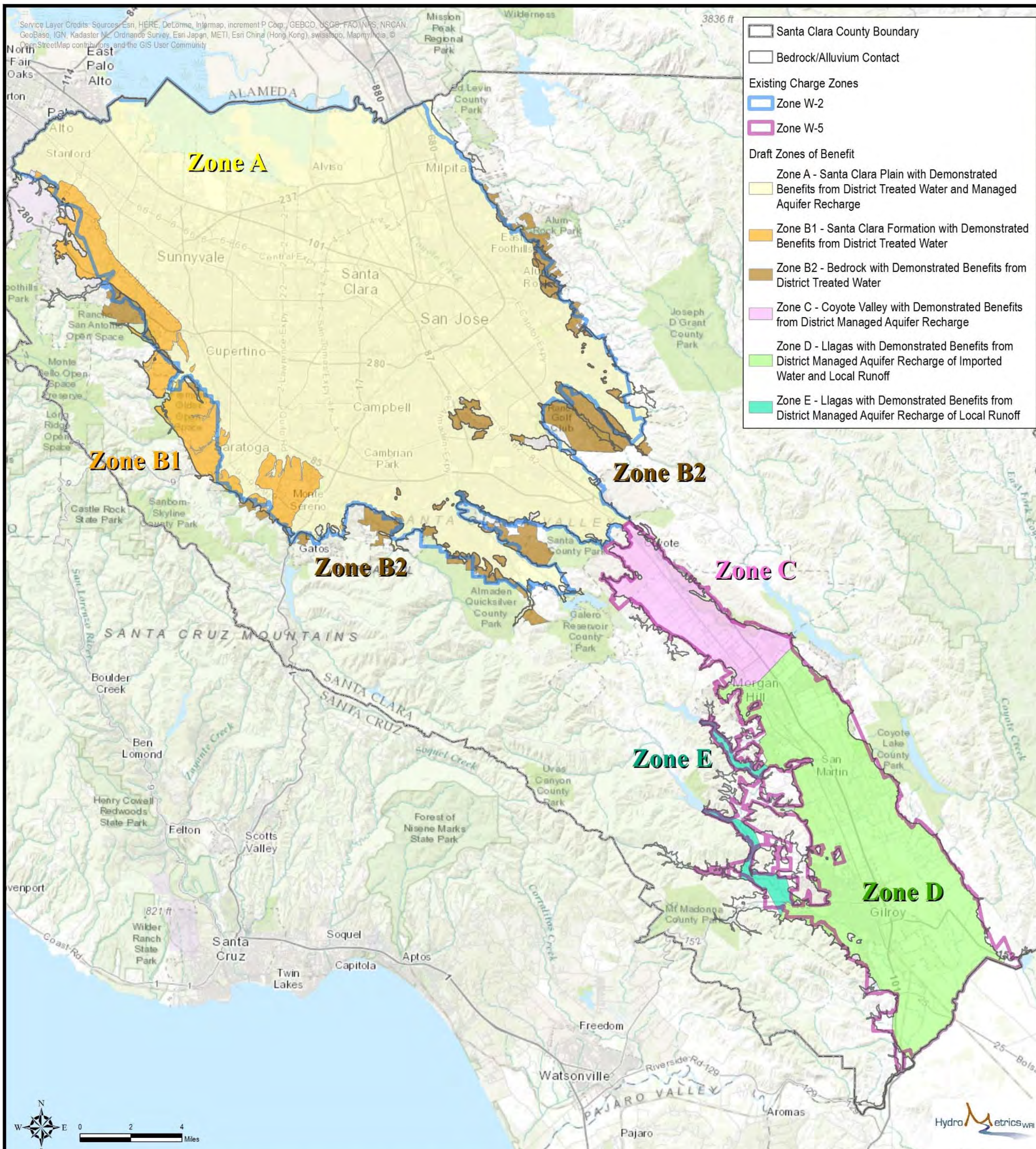
We conclude the following from the Study evaluation to guide proposed groundwater zones of benefit.

1. District recharge activities are located in alluvium that provide hydrogeologic connection throughout the Santa Clara and Llagas Subbasins.
2. District recharge activities have improved the water balance in hydrogeologically connected areas over time.
3. Groundwater level data and numerical groundwater modeling results demonstrate that benefits from District activities extend throughout hydrogeologically connected areas of Unconsolidated Alluvium where the District activities are located.
4. Although the Santa Clara Plain and Coyote Valley are currently both in Zone W-2, the groundwater level data do not conclusively demonstrate that benefits of District treated water deliveries in the Santa Clara Plain extend south into Coyote Valley as Coyote Narrows may restrict groundwater flow between the two management areas.
5. Groundwater level data and modeling results are not available to evaluate whether benefits from District activities in the Unconsolidated Alluvium of the Santa Clara Plain extend into the Santa Clara Formation located on the west side of the Santa Clara Plain.
6. District treated water delivery reduces groundwater demand in the Santa Clara Formation thereby improving the groundwater supply. The Santa Clara Formation consists of hydrogeologically connected alluvium. Therefore, District in-lieu recharge activities in the Santa Clara Formation benefit connected areas of the Santa Clara Formation.
7. Groundwater level data are not available to evaluate whether benefits from District activities in alluvium (Unconsolidated Alluvium or Santa Clara Formation) extend into bedrock. However, bedrock areas receiving District treated water supplies benefit from in-lieu recharge to those areas that reduce groundwater pumping from bedrock fractures. However, bedrock fractures may be limited in areal extent, so the benefit is not considered to extend beyond the bedrock areas receiving District treated water.
8. Groundwater level data and modeling results are not available to demonstrate that managed recharge of imported water in the Llagas Subbasin valley floor benefits the narrow alluvium along Llagas and Uvas Creeks downstream of District reservoirs and upstream of the valley floor. However, the alluvium along these creeks does benefit from District releases of local runoff for managed recharge.
9. Recycled water and untreated surface water deliveries are too small relative to other District activities to evaluate benefits with groundwater level data. Modeling results of in-lieu recharge from recycled water demonstrate that benefits from these small activities have benefits throughout hydrogeologically connected areas.

Based on these conclusions, the boundaries used to define the proposed zones are as follows:

1. Bedrock/Alluvium contact
2. DWR basin boundary approximating groundwater divide between Santa Clara and Llagas Subbasins.
3. Coyote Narrows between Santa Clara Plain and Coyote Valley.
4. Santa Clara Formation outcrops.
5. Retailer areas where District treated water is delivered
6. Narrows between bedrock outcrops in Llagas Subbasin
7. Western boundaries of Morgan Hill and Gilroy.
8. Constrictions where alluvial channels are upstream of areas hydrogeologically connected to District activities.

Figure 44 presents the proposed zones of benefit.



These mapped zones may be revised further to account for administrative requirements. These zones will also require additional revision to facilitate the development of legal descriptions for the zones. This will involve approximating the boundaries to reduce the number of line segments that require a metes and bounds description.

Zone A includes hydrogeologically connected areas of Unconsolidated Alluvium where benefits from both the District's treated water and managed aquifer recharge activities are demonstrated. This includes Unconsolidated Alluvium overlain by the specific District activities, and Unconsolidated Alluvium where data and/or groundwater model results show benefits from both activities. Zone A excludes areas of mapped Santa Clara Formation where benefits from managed aquifer recharge activities are not demonstrated. The northern boundary is the County boundary and the southern boundary is the boundary between existing Zones W-2 and W-5 at the narrows north of Coyote Valley.

Zone B1 includes areas hydrogeologically connected to where District treated water is delivered, but data or groundwater model results are not available to demonstrate benefits from District's managed aquifer recharge facilities. The hydrogeologic connection is defined by the Santa Clara Formation outcrop, which has overlap with District treated water delivery areas. The deliveries to these areas of the Santa Clara Formation provide in-lieu recharge throughout the Santa Clara Formation, which is considered a hydrogeologically connected area because groundwater flows through porous media of the Santa Clara Formation. District treated water delivery reduces groundwater demand in the Santa Clara Formation and therefore improves groundwater supply of the Santa Clara Formation. The zone includes alluvial outcrop presumed to overlie the Santa Clara Formation. Foothill Expressway is used to approximate the Santa Clara Formation underlying the alluvial outcrop in addition to lining up with the District treated water delivery area for Cal Water Los Altos that provides in-lieu benefits for this area of the zone.

Zone B2 includes areas in bedrock where District treated water is delivered because the deliveries provide in-lieu recharge for pumpers in these areas. District treated water delivery reduces groundwater pumping of bedrock fractures supplying water to wells in those areas, and therefore improves the groundwater supply of those areas. Areas in bedrock outside the delivery areas are excluded from zones because bedrock fractures may be limited in areal extent so the benefit is not considered to extend beyond the bedrock areas receiving District treated water. Zone B2 includes a number of separate areas where bedrock outcrops intersect with District treated water delivery areas.

All zones benefit from long-term water conservation and groundwater protection activities.

Zone C includes Unconsolidated Alluvium in the Coyote Valley where benefits from managed aquifer recharge are demonstrated. The northern boundary is the boundary between existing Zones W-2 and W-5 at the narrows south of Santa Clara Plain. The southern boundary is the boundary between DWR subbasins for Santa Clara Plain and Llagas that approximates the groundwater divide that hydrogeologically separates the two basins.

Zone D includes hydrogeologically connected areas of Unconsolidated Alluvium in the Llagas Subbasin where benefits from managed aquifer recharge of imported and local water are demonstrated. This encompasses Unconsolidated Alluvium where data and/or groundwater model results show benefits from both the recharge of imported water and the recharge of local runoff. The complete retailer areas of the Cities of Morgan Hill and Gilroy are included in the zone, because the city wells draw groundwater from areas that show benefits from imported water and local runoff recharge, and these benefits are extended by the ability of the Cities to distribute water throughout their delivery areas. The northern boundary is the boundary between DWR subbasins for Santa Clara Plain and Llagas that approximates the groundwater divide hydrogeologically separating the two basins. The southern boundary is based on the County line and the extent of Unconsolidated Alluvium.

Zone E includes hydrogeologically connected areas of Unconsolidated Alluvium where SCVWD managed aquifer recharge of local runoff occurs, but no data or groundwater model results are available to demonstrate benefits from District managed aquifer recharge of imported water. This area includes Unconsolidated Alluvium west of the cities of Morgan Hill and Gilroy that are deposited along Llagas Creek and Uvas Creek below the District's Chesbro and Uvas Reservoirs between bedrock outcrops. The District captures local runoff in the reservoirs and releases the water down the creeks where they recharge these areas of Unconsolidated Alluvium improving the groundwater supply of these areas. Parts of the eastern boundary are located across narrow connections between bedrock outcrops west of where data and groundwater model results are available to demonstrate benefit from imported water. Alluvial channels for tributaries that are not directly downstream of the District's reservoirs are not included in this zone.

Figure 44: Proposed Zones of Benefit

8.1 ZONE A SANTA CLARA PLAIN BENEFITS FROM MANAGED AQUIFER RECHARGE AND TREATED WATER DELIVERIES

Zone A includes hydrogeologically connected areas of Unconsolidated Alluvium where benefits from both the District's treated water and managed aquifer recharge activities are demonstrated. This includes Unconsolidated Alluvium overlain by the specific District activities, and Unconsolidated Alluvium where data and/or groundwater model results show benefits from both activities. Zone A excludes areas of mapped Santa Clara Formation where benefits from managed aquifer recharge activities are not demonstrated. The northern boundary is the County boundary and the southern boundary is the boundary between existing Zones W-2 and W-5 at the narrows north of Coyote Valley.

8.2 ZONE B1 SANTA CLARA FORMATION BENEFITS FROM TREATED WATER DELIVERIES

Zone B1 includes areas hydrogeologically connected to where District treated water is delivered, but data or groundwater model results are not available to demonstrate benefits from District's managed aquifer recharge facilities. The hydrogeologic connection is defined by the Santa Clara Formation outcrop, which has overlap with District treated water delivery areas. The deliveries to these areas of the Santa Clara Formation provide in-lieu recharge throughout the Santa Clara Formation, which is considered a hydrogeologically connected area because groundwater flows through porous media of the Santa Clara Formation. District treated water delivery reduces groundwater demand in the Santa Clara Formation and therefore improves groundwater supply of the Santa Clara Formation. The zone includes alluvial outcrop presumed to overlie the Santa Clara Formation. Foothill Expressway is used to approximate the Santa Clara Formation underlying the alluvial outcrop in addition to lining up with the District treated water delivery area for Cal Water Los Altos that provides in-lieu benefits for this area of the zone. Figure 45 shows Zone B1. Zone B1 is not considered to benefit from District managed aquifer recharge facilities because District does not quantify recharge from its facilities into the Santa Clara Formation and data and model results do not exist to show benefit in the Santa Clara Formation from the managed aquifer recharge facilities.

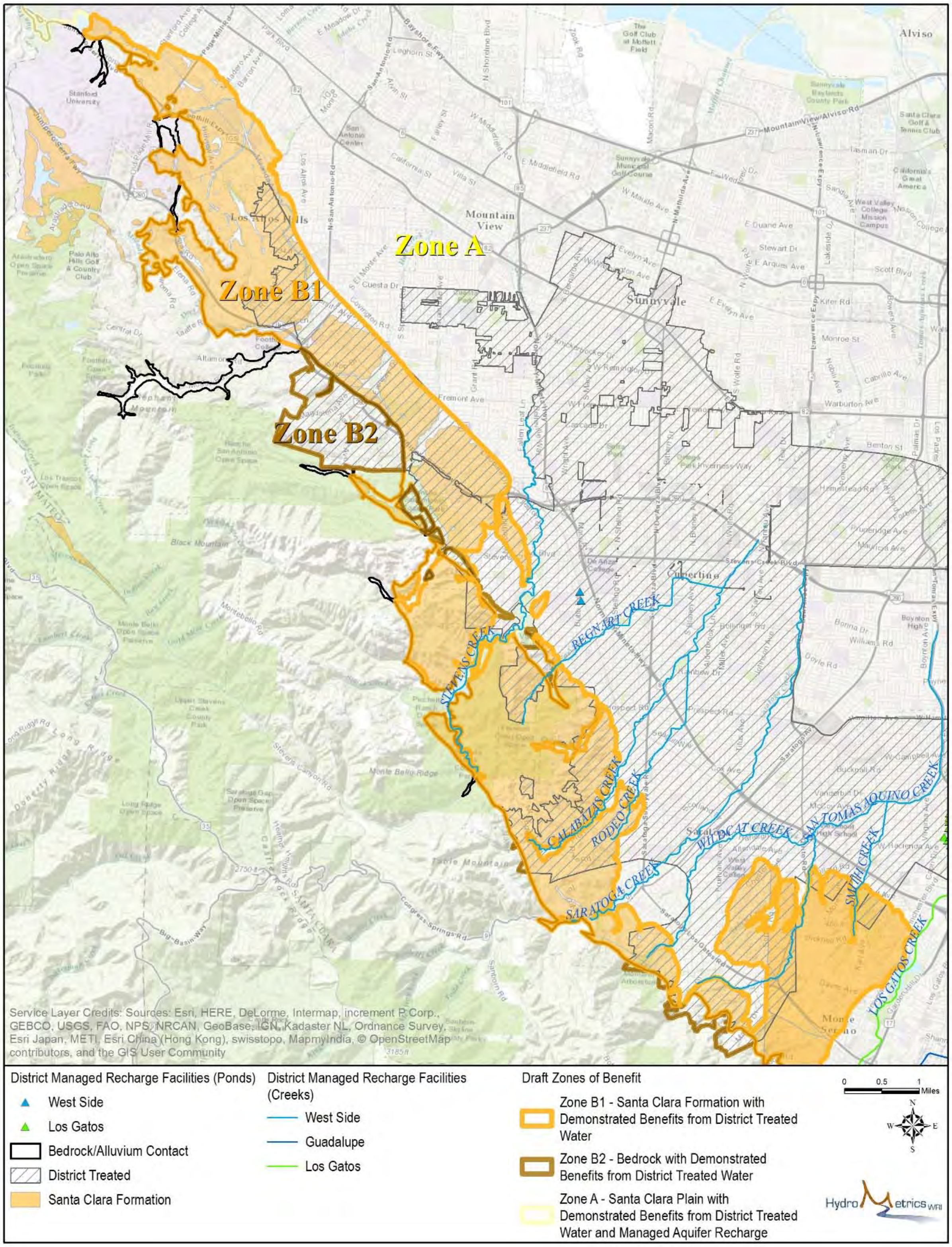


Figure 45: Zones A and B in Santa Clara Formation on Westside of Santa Clara Subbasin

8.3 Zone B2 Bedrock Benefits from Treated Water Deliveries

Zone B2 includes areas in bedrock where District treated water is delivered because the deliveries provide in-lieu recharge for pumpers in these areas. District treated water delivery reduces groundwater pumping of bedrock fractures supplying water to wells in those areas, and therefore improves the groundwater supply of those areas. Areas in bedrock outside the delivery areas are excluded from zones because bedrock fractures may be limited in areal extent so the benefit is not considered to extend beyond the bedrock areas receiving District treated water. Zone B2 includes a number of separate areas where bedrock outcrops intersect with District treated water delivery areas.

8.4 Zone C Coyote Valley Benefits from Managed Aquifer Recharge

Zone C includes Unconsolidated Alluvium in the Coyote Valley where benefits from managed aquifer recharge are demonstrated. The northern boundary is the boundary between existing Zones W-2 and W-5 at the narrows south of Santa Clara Plain. The southern boundary is the boundary between DWR subbasins for Santa Clara Plain and Llagas that approximates the groundwater divide that hydrogeologically separates the two basins.

8.5 Zone D Llagas Benefits from Managed Aquifer Recharge of Local Runoff and Imported Water

Zone D includes hydrogeologically connected areas of Unconsolidated Alluvium in the Llagas Subbasin where benefits from managed aquifer recharge of imported and local water are demonstrated. This encompasses Unconsolidated Alluvium where data and/or groundwater model results show benefits from both the recharge of imported water and the recharge of local runoff. The complete retailer areas of the Cities of Morgan Hill and Gilroy are included in the zone, because the city wells draw groundwater from areas that show benefits from imported water and local runoff recharge, and these benefits are extended by the ability of the Cities to distribute water throughout their delivery areas. The northern boundary is the boundary between DWR subbasins for Santa Clara Plain and Llagas that approximates the groundwater divide hydrogeologically separating the two basins. The southern boundary is based on the County line and the extent of Unconsolidated Alluvium.

8.6 Zone E Llagas Benefits from Managed Aquifer Recharge of Local Runoff

Zone E includes hydrogeologically connected areas of Unconsolidated Alluvium where SCVWD managed aquifer recharge of local runoff occurs, but no data or groundwater model results are available to demonstrate benefits from District managed aquifer recharge of imported water. This area includes Unconsolidated Alluvium west of the cities of Morgan Hill and Gilroy that are deposited along Llagas Creek and Uvas Creek below the District's Chesbro and Uvas Reservoirs between bedrock outcrops. The District captures local runoff in the reservoirs and releases the water down the creeks where they recharge these areas of Unconsolidated Alluvium improving the groundwater supply of these areas. Parts of the eastern boundary are located across narrow connections between bedrock outcrops west of where data and groundwater model results are available to demonstrate benefit from imported water. Alluvial channels for tributaries that are not directly downstream of the District's reservoirs are not included in this zone.

8.7 Assignment of District Activities to Zones

The Study proposes zones of benefit primarily based on District activities of managed aquifer recharge and treated water deliveries. Figure 46 shows managed recharge facilities and treated water delivery areas overlying the proposed zones of benefit.

Although the zones of benefit are based on the managed aquifer recharge and treated water deliveries that provide the largest District contributions to the water budget, other District activities provide benefits to groundwater users in the zones. Activities such as recycled water and untreated surface water deliveries can be assigned to zones they are located within, as shown in Figure 47. The modeling runs for recycled water did show groundwater level increases from in-lieu recharge provided by recycled water throughout the Zone A and Zone D areas. Similarly, planned future activities can be assigned to zones where they are planned to be located such as indirect potable reuse in Zone A.

District activities such as conservation and groundwater protection benefit all groundwater users so are assigned to all zones of benefit.

Table 10: District Activity Assignment to Zones

District Activity	Zones
Managed Recharge (Local Runoff)	A, C, D, E
Managed Recharge (Imported Water)	A, C, D
Treated Water Deliveries	A, B1, B2
Recycled Water	A, D
Untreated Surface Water Deliveries	A, C, D, E
Conservation	All
Groundwater Protection	All
Planned Indirect Potable Reuse	A

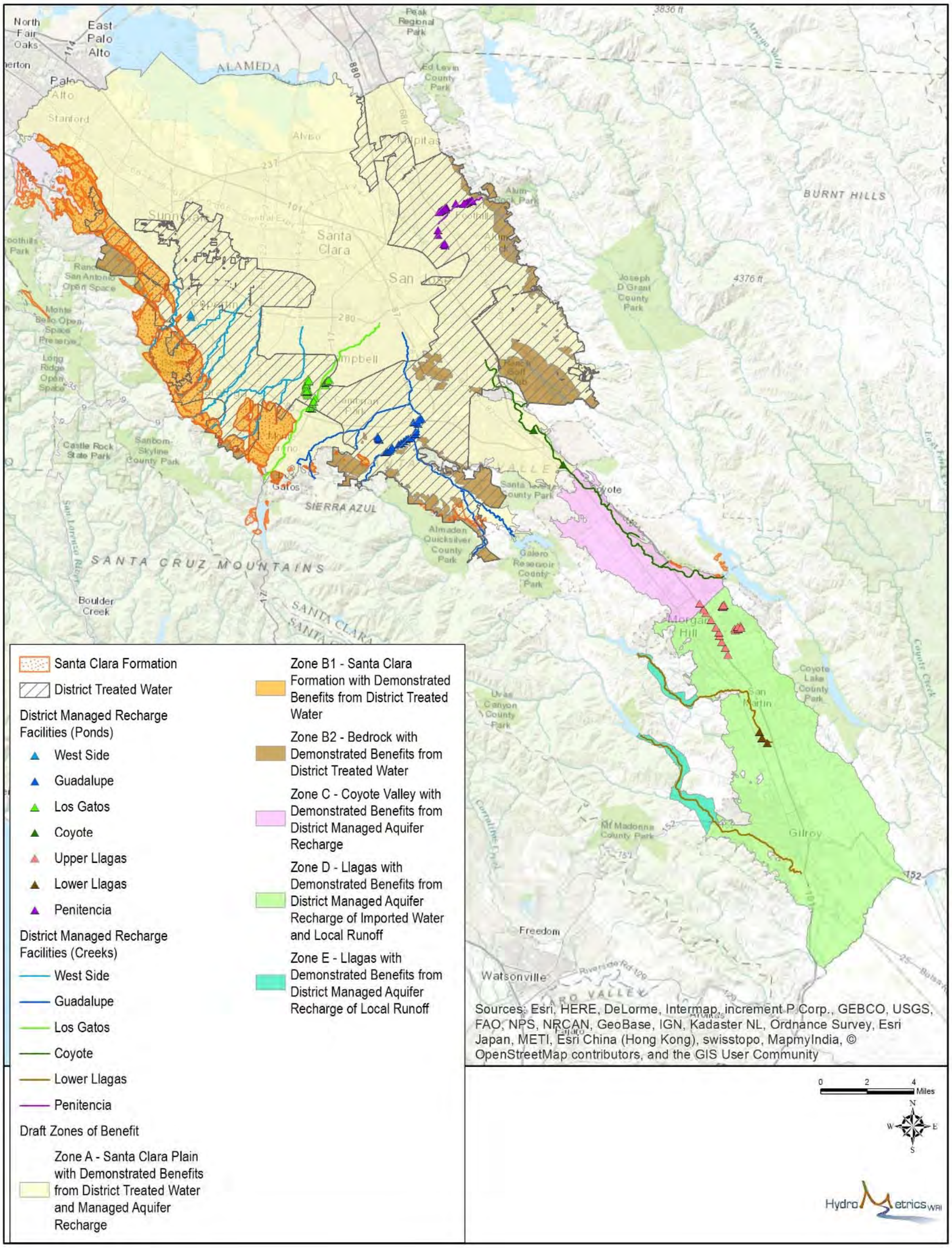


Figure 46: Managed Recharge Facilities and Treated Water Deliveries with Zones of Benefit

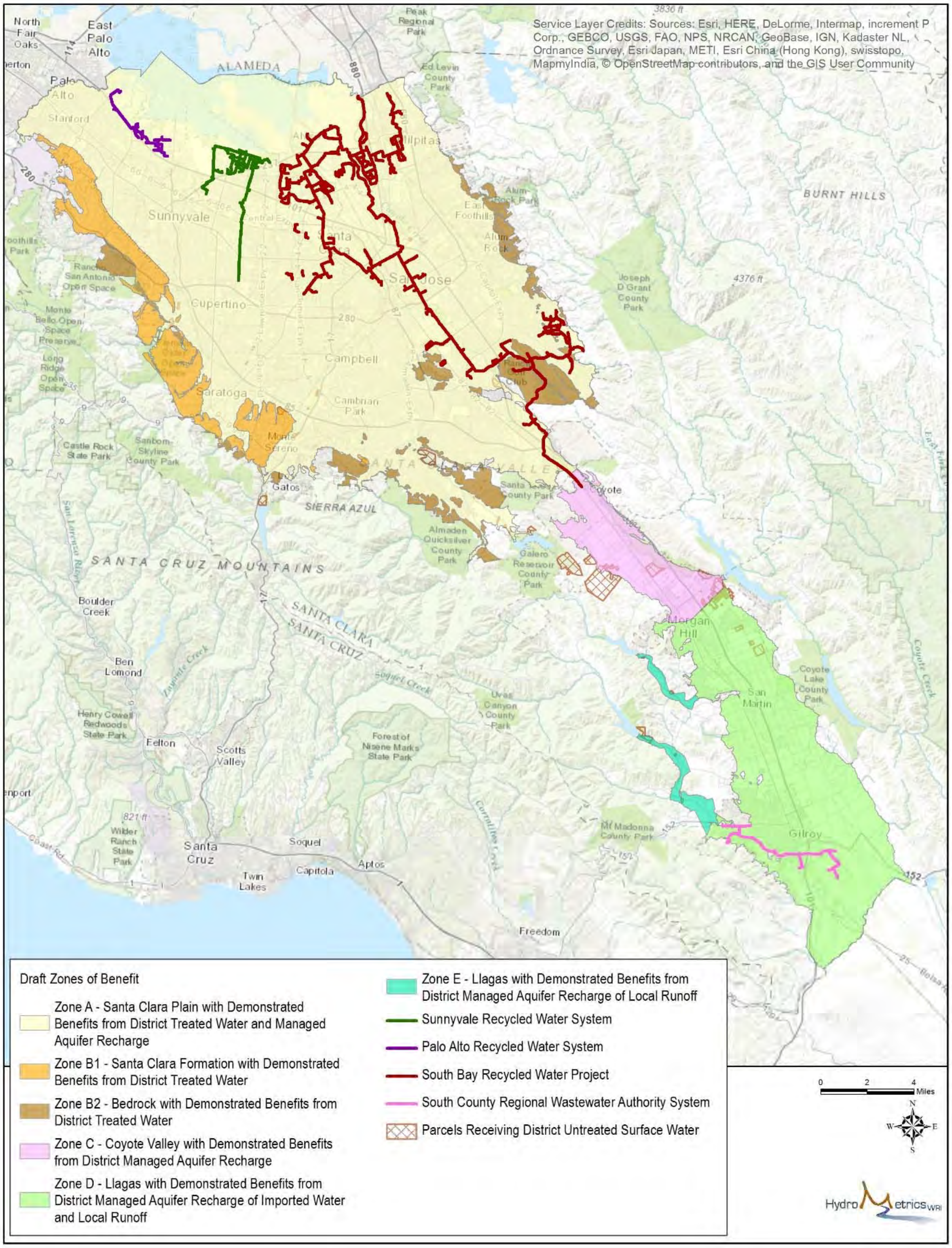


Figure 47: Recycled Water Systems and Parcels Receiving Untreated Surface Water with Zones of Benefit

Section 9
FINALIZING ZONES OF BENEFIT

9.1 ADMINISTRATIVE ISSUES

The Study recommends an increase in zones from two to six to associate zones with benefits from specific activities. However, the recommended zones are a result of a technical analysis that does not take into account the related administration issues or requirements for revised zones or increased number of zones. Any changes to the zones must be approved by the District Board of Directors, who will consider all related issues.

9.2 METES AND BOUNDS

The District needs the zones of benefit to have a legal description in order to assess groundwater charges to groundwater users. Metes and bounds will provide this legal description.

In order to facilitate creation of the metes and bounds, Towill, Inc., the surveyor subcontractor on HydroMetrics WRI's consulting team, has recommended taking steps to make changes to the zones to facilitate descriptions with metes and bounds. Since the proposed zones are based on geologic maps, the boundaries include many line segments that would each need to be described. In order to reduce requirements for metes and bounds descriptions the number of line segments making up the boundaries should be reduced and the boundaries simplified.

When the Board considers approval of the Zones and a scope to provide legal descriptions of the zones, an approach for boundary simplification will also be submitted for Board approval. One possible approach to boundary simplification is to account for available information on the uncertainty of geologic boundaries as described in Appendix J. An example of such an approach involves a two step process:

1. Simplify the boundaries based on mapped geology by applying a documented algorithm available in GIS software to reduce line segments with a specified distance tolerance.
2. Shift simplified boundaries a distance that accounts for uncertainty of geologic boundaries.

9.3 Economic Analysis

Table 11 shows the number of water supply wells in each of the proposed zones compared to the number of water supply wells in existing zones. Combining Table 10 and Table 11, along with association of all District activities with Zone W-2 and all but treated water deliveries and planned indirect potable reuse with Zone W-5, results in Table 12. Table 12 shows the number of water supply wells associated with each District activity for proposed zones compared to existing zones. This table will facilitate an economic analysis describing the change to revenue collection resulting from approving proposed zones. There is a decrease in the number of wells associated with each District activity except for treated water deliveries.

Table 11. Number of Water Supply Wells in Proposed Zones Versus Existing Zones

	Zone	Water Supply Wells By Zone	Total Water Supply Wells
Existing Zones	W-2	1,928	6,125
	W-5	4,197	
Proposed Zones	A	1,662	5,980
	B1	302	
	B2	39	
	C	534	
	D	3,069	
	E	374	

Table 12. Number of Water Supply Wells Associated with District Activities under Proposed Zones Versus Existing Zones

District Activity	Existing Zones	Proposed Zones	% Change
Managed Recharge (Local Runoff)	6,125	5,639	-8%
Managed Recharge (Imported Water)	6,125	5,265	-14%
Treated Water Deliveries	1,928	2,003	+4%
Recycled Water	6,125	4,731	-23%
Untreated Surface Water Deliveries	6,125	5,639	-8%
Conservation	6,125	5,980	-2%
Groundwater Protection	6,125	5,980	-2%
Planned Indirect Potable Reuse	1,928	1,662	-14%

Section 10
SUMMARY OF FUTURE PROCEDURES

10.1 PROCEDURE FOR WELL EXEMPTION

Appendix K proposes a process for the District to evaluate requests to exempt or re-assign production wells from a groundwater zone of benefit and, potentially exempt water produced from the well from all or part of a groundwater charge. The District Act requires the zone of benefit to be modified if a well is found to be exempt.

This process includes the following general changes from the current process for evaluating requests for exemptions from the groundwater charge zone, detailed in District Document No. SOP465-103 (SCVWD, 2011):

1. This process assesses exemption of wells from the zone of benefit and potentially modifying the zone of benefit to remove the well. The previous process provided a method for removing parcels from the zone of benefit.
2. Instead of removing parcels from a zone of benefit, an evaluation that a well should be exempt from a zone of benefit will result in modification of zones of benefit consistent with boundary simplification approach implemented for legal descriptions of the zones (Section 9.2).
3. The well may not be fully exempt from zones of benefit, and may be re-assigned with a different zone of benefit that is associated with a different set of District activities.
4. Consistent with the zone of benefit study, exemptions will be evaluated based on any relevant evidence not considered for the Study.
5. If exemption is approved to remove a well from zone of benefit, the zone of benefit will be modified based on best approximation of geology.

10.2 PROCEDURE FOR FUTURE REVIEW

Appendix L presents a process for the District to conduct future reviews of the groundwater zones of benefit.

This process is different from the current process for evaluating requests for exemptions from the groundwater charge zone, detailed in Document No. SOP465-103 in that it involves a comprehensive review of the boundaries of the zones of benefit

1. This process to review zones of benefit does not occur in response to requests for exemption from a zone of benefit from a well owner. A separate process describes exemption or re-classification of individual wells from a zone of benefit (Section 10.1).

2. Currently, reviews are only initiated at District staff's discretion, and upon receipt of new information. This new process requires a review of zones of benefit if either of the following specified situations occur:
    a. Substantial changes to the type of District activities that provide the zone's benefits
    b. Significant new hydrogeologic data become available.

    Initiating review under these specified situations, the process helps ensures the zones of benefit represent current District activities and the best available hydrogeologic information.

3. The review tasks differ based on the situation that initiates the review.

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Section 11
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