watershed areas located outside of the GSA's jurisdiction, as described in **Section 7** (Implementation Plan). These areas primarily fall within the purview of the Sonoma County General Plan.

2.6.1 General Plans

Counties and cities are required to develop and adopt comprehensive general plans to guide future local physical development, as required in California State Government Code Title 7, Division 1, Article 5, Section 65300 et seq. Each general plan must contain a statement of policies, including maps or diagrams and text, setting forth objectives, principles, standards, and plan proposals. City general plans are focused on providing guidance on growth and development in the urban setting, while the county general plan focuses on the unincorporated areas of the county. Developing and updating general plans involves significant community involvement through workshops, hearings, and public review of draft plans and policies.

General plans include eight mandatory elements, including land use, circulation, housing, conservation, open space, noise, safety, and environmental justice. Optional elements can also be included; as described herein, the County of Sonoma has included an optional water resource element in its general plan.

Land use elements must reflect the content of the other general plan elements and must account for "rivers, creeks, streams, flood corridors, riparian habitats, and land that may accommodate floodwater for purposes of groundwater recharge and stormwater management…" as identified in the conservation element (Government Code Section 65302[d][3]). Land use elements must designate the type and density of land uses within the jurisdictional boundaries of the General Plan. The housing elements must be updated on an 8-year cycle to correspond with state regional housing needs allocations (Government Code Section 65584[b]).

The Subbasin includes areas covered by the Sonoma County General Plan and the general plans of the Cities of Cotati, Rohnert Park, Santa Rosa, Sebastopol, and the Town of Windsor. Government Code Section 65350.5 stipulates that before general plans are adopted, they must review and consider GSPs.

2.6.1.1 Sonoma County General Plan 2020

In recognition of the importance of water resources within unincorporated areas of the county, an optional new water resource element (WRE) was developed and included in the Sonoma County General Plan 2020 (Sonoma County 2008). The main purpose of the WRE is to ensure that Sonoma County's water resources are sustained and protected. To achieve this main purpose, the WRE states that water resource management should consider the amount of quality water that can be used without exceeding the replenishment rates over time or causing long-term declines or degradation in available surface water or groundwater resources.

The WRE includes goals, objectives, and policies for water quality; groundwater; public water systems; conservation and reuse; importing and exporting; and watershed management. These goals, objectives, and policies include supporting local groundwater studies and management programs, and encouraging activities that protect natural groundwater recharge areas. The WRE for the Sonoma County General Plan 2020 can be reviewed at https://sonomacounty.ca.gov/PRMD/Long-Range-Plans/General-Plan/Water-Resources/.

Specific WRE goals related to groundwater include the following:

- Protect, restore, and enhance the quality of surface and groundwater resources to meet the needs of all reasonable beneficial uses.
- Manage groundwater as a valuable and limited shared resource.
- Assure that new proposals for surface and groundwater imports and exports are consistent with Sonoma County's ability to sustain an adequate supply of high-quality water for all its water uses and dependent natural resources.
- Improve understanding, valuation, and sound management of the water resources in Sonoma County's diverse watersheds.

Other water-related topics incorporated in the Sonoma County General Plan 2020 include water availability as a factor in land use map densities addressed in the Land Use Element. Land use designations based on Sonoma County's General Plan 2020 are shown on **Figure 2-8**. The open space and resource conservation element addresses riparian corridors, wetlands, wildlife protection, tree protection, fishery resources and other biotic resources, water-oriented recreation, soil erosion, forestry, and mineral resources. The public facilities and services element addresses connections to public water systems. The public safety element addresses flood hazards, fire suppression, and hazardous materials. The county's General Plan 2020 also includes a policy for the designation of community separators, which are rural open space and agricultural and resource lands that separate cities and other communities, prevent sprawl, protect natural resources, and provide city and community identity by providing visual relief from continuous urbanization.

It is anticipated that the next Sonoma County General Plan update will begin in 2022 and conclude in 2028.

2.6.1.2 Municipal General Plans

City general plans guide growth and development in the urban community, and typically involve an urban growth boundary. The UWMPs and general plans are clearly linked: UWMPs calculate future water demand based on growth and development projected in the general plan. The status of municipal general plans is as follows:

- City of Cotati – General Plan Update 2015 (City of Cotati 2015).
- City of Rohnert Park – General Plan Update 2000 – (City of Rohnert Park 2000) update in process.

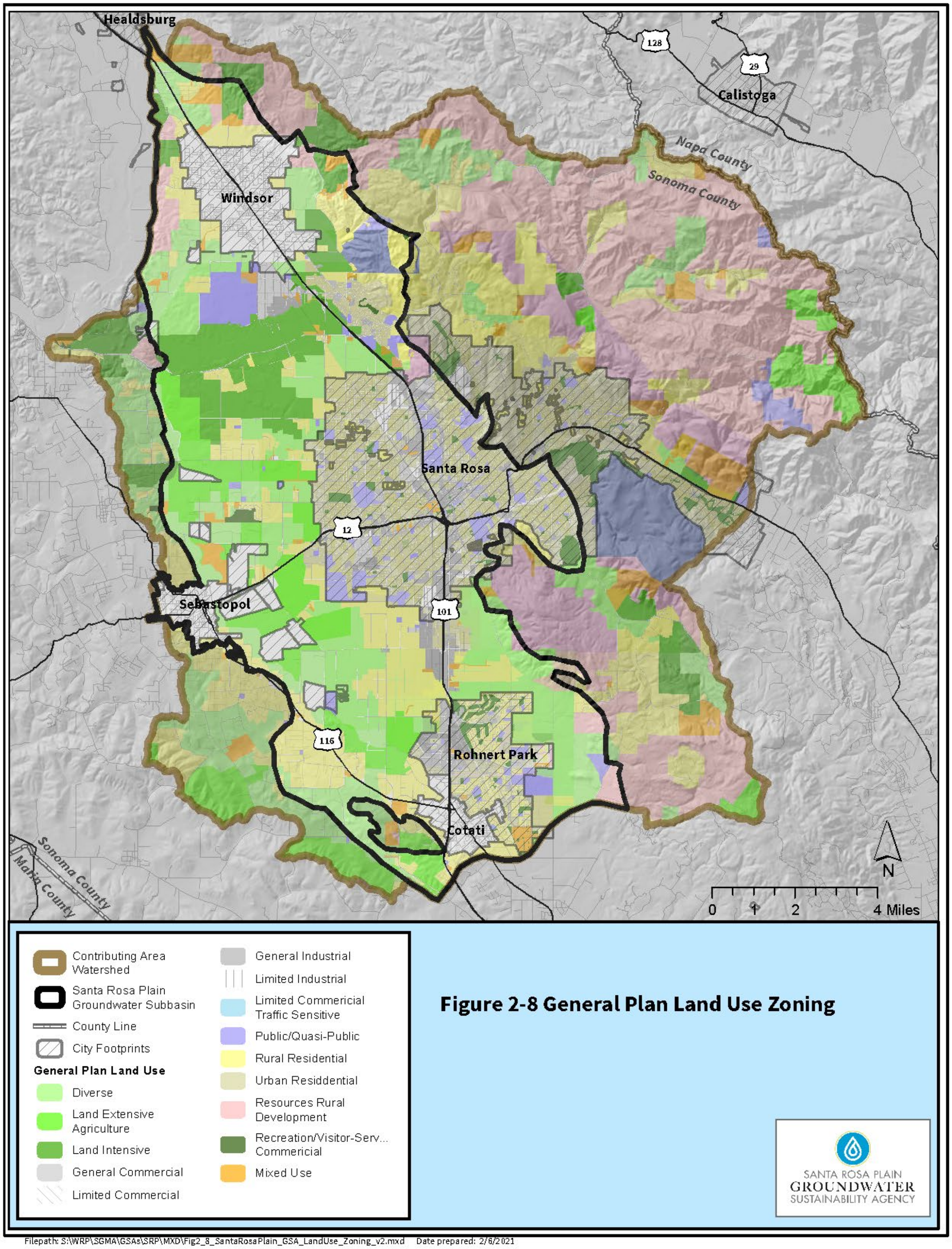

Figure 2-8. General Plan Land Use Zoning

- City of Santa Rosa – General Plan 2035 Update 2009 (City of Santa Rosa 2009). The city's General Plan 2050 is in development and slated for final review in fall 2022.
- Town of Windsor – General Plan 2040 (Town of Windsor 2018).
- City of Sebastopol – General Plan Update 2016 (City of Sebastopol 2016).

The Cities of Cotati, Rohnert Park, Santa Rosa, Sebastopol, and the Town of Windsor general plan documents contain Community Development, Environmental Resources, Local Economy, Circulation, Public Safety, Noise and Housing Elements. Each element contains goals, policies, and implementation measures that set a course for future land use in the city. Goals summarize how development and future growth should be directed to achieve the general plan vision by identifying physical, economic, and/or social ends that the community wishes to achieve.

In addition, municipal general plans include specific goals and policies related to groundwater, as shown in **Table 2-1**.

Table 2-1. Summary of Municipal General Plan Policies Specific to Groundwater

Municipality	General Plan Goals or Policies Specific to Groundwater
Cotati	• Support conjunctive groundwater use • Coordinate with and participate in planning efforts for the Santa Rosa Plain Groundwater Management Plan • Protect groundwater quality through appropriate design of septic and sewer systems • Encourage the use of flood and/or stormwater retention facilities for groundwater recharge
Rohnert Park	• Utilize purchased water supplies and reduce reliance on groundwater drawn from municipal wells, except for emergency use. • Ensure that groundwater withdrawal does not exceed safe yield. • Monitor the operation of the municipal well field on a monthly basis to ensure that production does not exceed the recharge rates quantified in the study so as to result in a substantial lowering of groundwater levels in the vicinity of the Urban Growth Boundary (Policy PF-11). • Develop a monthly municipal wellfield monitoring program that (i) identifies points of compliance; (ii) establishes the factors to be considered in determining when production which exceeds the recharge rates will result in a substantial lowering of groundwater levels ("thresholds"); and (iii) includes any information necessary to implement PF-11. • In the event that the monthly municipal wellfield monitoring program concludes that a substantial lowering of groundwater levels in the vicinity of the Urban Growth Boundary will occur because development proposed in the area outside the existing City limits as of July 1, 2000 requires production that exceeds the appropriate recharge rates, the City shall either disapprove such development or deny such development connection to the water system until such time that the program concludes that the City is in compliance with the standard established in PF-11. • Continue to collect and analyze monthly groundwater-level data to assist in management and operation of Rohnert Park's municipal wellfield. Coordinate with other agencies on regional drawdown impacts.

Municipality	General Plan Goals or Policies Specific to Groundwater
Santa Rosa	• Consider development of additional sources of water supply, possibly including utilization of the city's groundwater resources. • Protect groundwater recharge areas, particularly creeks and riparian corridors. Identify and protect other potential groundwater recharge areas. • Require provision of open space areas for storm water retention and infiltration and opportunities for groundwater recharge. • Adhere to all state, federal and regional laws and regulations to avoid groundwater contamination. • Require remediation and cleanup, and evaluate risk prior to reuse, in identified areas where hazardous materials and petroleum products have impacted soil or groundwater.
Sebastopol	• Groundwater should be managed as part of a broader integrated approach that includes surface water, conservation, water quality, reuse, environmental stewardship, and other water management strategies. • Operate the City's well system in such a manner as to not exceed the sustainable yield of the local groundwater aquifer. • Encourage new groundwater recharge opportunities and protect existing groundwater recharge areas throughout the Sebastopol Planning Area. • Promote the use of permeable surface materials and provide for ample areas of open space and naturalized land in order to decrease surface runoff and promote groundwater recharge. • Seek opportunities to expand the groundwater recharge capacity of City-owned parcels throughout Sebastopol. • Implement water conservation measures as a key strategy in sustainably managing local groundwater supplies. • Implement greenhouse gas reduction measures and participate in regional efforts to study the effects of climate change on precipitation levels as a key strategy in sustainably managing local groundwater supplies. • Continue to encourage and support federal, state, and local research on and monitoring of local groundwater conditions, aquifer recharge, watersheds and streams where needed to assess groundwater quantity and quality. • Protect the water quality obtained from City wells. • Reduce agricultural and pharmaceutical contamination of potable water supplies in the local aquifer.

Municipality	General Plan Goals or Policies Specific to Groundwater
Windsor	• Protect, manage, and improve natural creek habitats and the quality of the Town's surface water and groundwater resources. • The Town should actively support Federal and State laws pertaining to the Clean Water Act, Porter-Cologne Water Quality Control Act, and Sustainable Groundwater Management Act in attainment of water quality standards and management of surface water and groundwater. • The Town shall continue to properly abandon municipal wells that are no longer serving backup or monitoring roles and shall continue to cooperate with Sonoma County on the proper abandonment of private wells by private property owners in order to eliminate a potential pathway to contaminate the groundwater. • The Town shall operate its wells in compliance with the Sustainable Groundwater Management Act. • The Town shall determine and review alternative groundwater sources that can adequately supply the town with water during an ongoing drought. • The Town shall strive to ensure that important groundwater recharge areas are maintained as open space. • The Town has prepared a Local Hazard Mitigation Plan that contains a climate vulnerability assessment and strategies to address climate change adaptation. • The Town shall encourage the development of groundwater recharge projects of all scales to increase groundwater supplies. • The Town shall encourage rainwater harvesting design options in new development and retrofitting in existing development. • The Town shall encourage the use of low-impact development techniques for both public and private sites to aid in groundwater retention and infiltration.

2.6.2 Specific Area Plans

Specific area plans are planning documents that guide the development of a particular geographic area within the county. Any new developments or subdivisions within the defined area must be consistent with the general plan and specific plan.

2.6.3 Sonoma County Local Agency Formation Commission

The Sonoma County Local Agency Formation Commission (LAFCO) is a state-created regulatory agency that approves or disapproves proposals to expand municipal water and wastewater services outside of existing service areas. Through this power, the LAFCO is an important agency in proposals to offset groundwater use with urban water for both new and existing development in the county.

LAFCO has responsibility in four areas affecting local government in Sonoma County as follows:

1. To review and approve or disapprove proposals for changes in the boundaries and organization of the 9 cities and 54 special districts within Sonoma County, including incorporations of new cities, formation of new special districts and mergers, consolidations or dissolutions of existing cities, and special districts

2. To conduct studies, including municipal service reviews, of existing local government services with the goal of improving the efficiency of providing services

3. To establish spheres of influence, which are plans for the probable physical boundaries of each local agency, for cities and special districts within the county and to review and update those spheres of influence every 5 years

4. To assist the public and other government agencies concerning changes in local government boundaries and organization

2.7 Well Permitting Policies and Procedures

The GSA is not responsible for well permitting or groundwater pumping permits. Permit Sonoma is the Sonoma County agency responsible for administering permits for wells within the Subbasin. The Sonoma County Department of Health Services administers permits for environmental drilling and wells generally associated with contaminated sites. The purpose of the county's well-construction policies is to provide for the location, construction, repair, reconstruction, destruction, and addressing of the abandonment of all wells to protect the groundwater resource of the county because contamination may cause serious public health, safety, or economic problems.

The Sonoma County Well Ordinance contains regulations and requirements for constructing wells to prevent groundwater contamination from the surface, and between multiple water bearing zones in (Ordinance 25B).

Permit Sonoma reviews all development proposals within unincorporated areas that will rely on wells for water supply. Permit Sonoma has developed a four-tier classification system, based on geologic information and water yields, to designate general areas of groundwater availability (**Figure 2-9**). Class 1 areas are Major Groundwater Basins, Class 2 areas are Major Natural Recharge Areas, Class 3 areas are Marginal Groundwater Availability Areas, and Class 4 areas are Areas with Low or Highly Variable Water Yield (Permit Sonoma 2016).

Permit Sonoma uses this groundwater classification system in reviewing certain development and building permit applications. For example, dry season well yield tests are required in Class 4 areas prior to residential development. In addition, discretionary applications in Class 3 and 4 areas and in SGMA medium- and high-priority basins are required to include hydrogeologic reports to establish that groundwater quality and quantity are adequate and will not be adversely impacted by the cumulative developments and uses allowed in the area. The aim is to avoid causing or exacerbating an overdraft condition in a groundwater basin or subbasin.

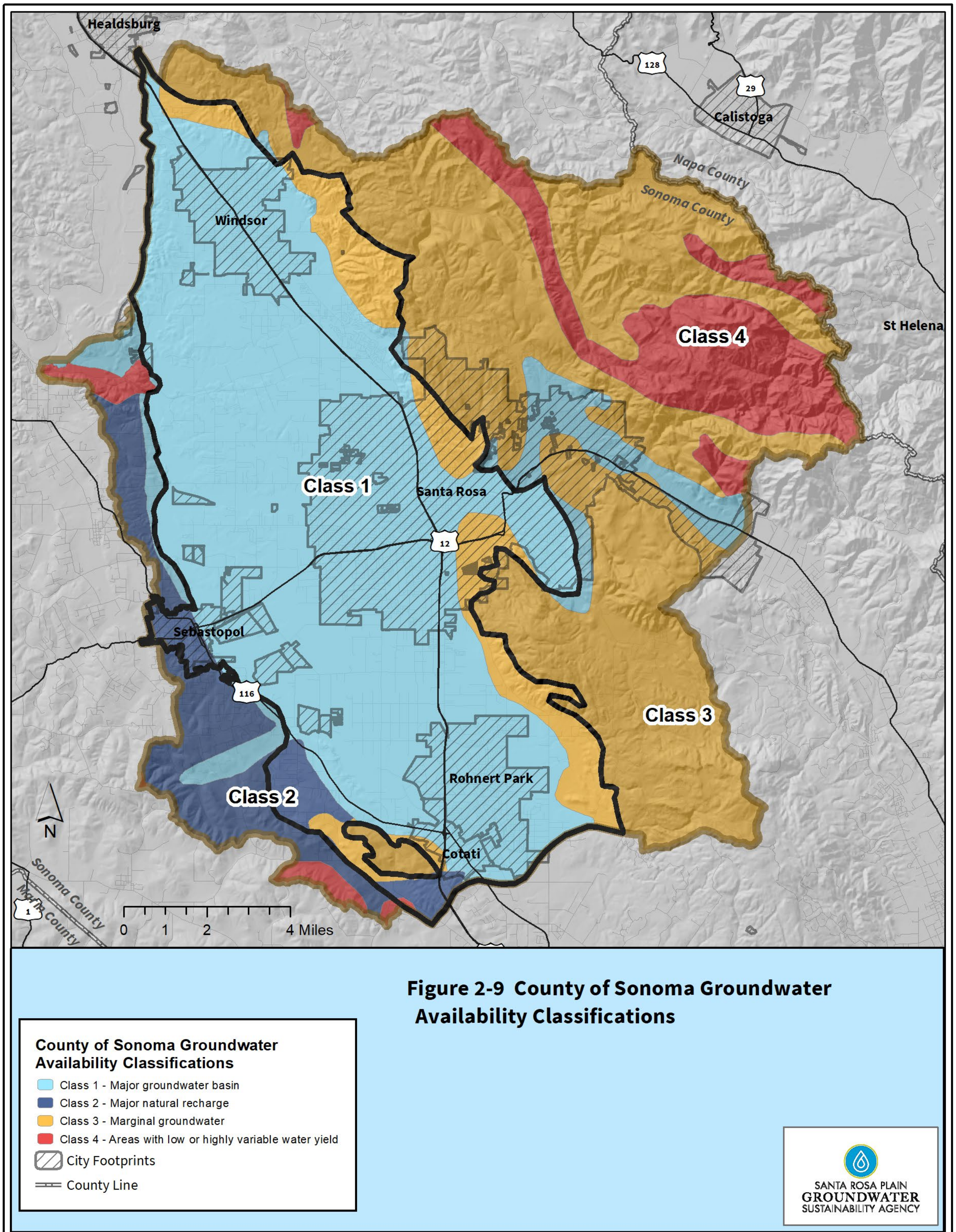

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Figure 2-9. County of Sonoma Groundwater Availability Classifications

Section 3: Basin Setting

Groundwater Sustainability Plan for
Santa Rosa Plain Groundwater Subbasin

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3 BASIN SETTING

This section provides information about the physical setting, characteristics, and current conditions of the Subbasin setting, including the identification of data gaps and levels of uncertainty. The information included within this section represents the current understanding of the Subbasin based on available data and information and serves as the basis for defining and assessing sustainable management criteria, potential projects, and management actions. This section contains four primary subsections:

- Hydrogeologic Conceptual Model (**Section 3.1**)
- Current and Historical Groundwater Conditions (**Section 3.2**)
- Water Budget (**Section 3.3**)
- Management Areas (**Section 3.4**)

This section draws upon previously published studies and reports including the following primary data sources that document the conditions of the Santa Rosa Plain Subbasin and contributing watershed areas:

- *Santa Rosa Plain Watershed Groundwater Management Plan* (Santa Rosa Plain Basin Advisory Panel 2014)
- *Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California* (Woolfenden and Nishikawa 2014)
- *Hydrologic and Geochemical Characterization of the Santa Rosa Plain Watershed, Sonoma County, California* (Nishikawa 2013)
- *Status and Understanding of Groundwater Quality in the North San Francisco Bay Groundwater Basins, 2004: California GAMA Priority Basin Project* (Kulongoski et al. 2010)
- *Evaluation of Ground Water Resources, Sonoma County, Volume 2: Santa Rosa Plain* (Herbst et al. 1982)
- *Geology and Ground Water in the Santa Rosa and Petaluma Areas, Sonoma County, California* (Cardwell 1958)

3.1 Hydrogeologic Conceptual Model

This subsection describes the hydrogeologic conceptual model (HCM), which characterizes the physical components of the surface water and groundwater systems in the basin. As defined in the GSP Regulations, the HCM should provide the following:

- General physical characteristics related to regional hydrology, geology, geologic structure, water quality, principal aquifers, and principal aquitards of the basin setting

- Contextual information necessary to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks
- A tool for stakeholder outreach and communication

As such, this subsection includes a description of the topography, geography, surface water features, soil characteristics, geologic setting and formations, principal aquifers and aquitards, role of faults, groundwater recharge and discharge area, and data gaps and uncertainties. This information is integrated into the water budget and numerical model described in **Section 3.3** (Water Budget) and monitoring networks described in **Section 5** (Monitoring Program). Additionally, figures and diagrams developed for the HCM are incorporated into community and stakeholder outreach materials.

3.1.1 Topography and Geography

The Subbasin lies generally within the Santa Rosa Plain watershed (SRP watershed or contributing watershed), defined by Nishikawa (2013) as a modified form of the Mark West Creek watershed. The Subbasin is one of six groundwater basins or portions of groundwater basins contained within the SRP watershed (Nishikawa et al. 2013a).

The Subbasin is located in the northwest trending mountains and valleys of the North Coast Ranges geomorphic province of California and is one of three coastal alluvial subbasins of the Santa Rosa Valley Groundwater Basin. The Subbasin generally occupies a relatively flat northwest trending structural depression between low-lying hills of the Mendocino Range to the west and the Sonoma Mountains and Mayacamas Mountains to the east (**Figure 3-1**).

The Subbasin lies mostly between elevations of about 50 and 150 feet above sea level (asl). The north-northwest trending axis of the valley extends for about 20 miles, from Meacham Hill on the south to near the Russian River on the north; the valley width ranges mostly from 4 to 7 miles. The Subbasin and contributing watershed surface consists of a low uneven topography, developed on alluvial flood plains, terraces, and fans eroded by west-flowing intermittent streams (Sowers et al. 1998).

The highlands surrounding the Subbasin have modest changes in elevation, with peaks generally lower than 2,500 feet asl, and most ridge lines between 500 and 1,500 feet asl. The Mendocino Range in this area is made up of mostly low, rounded hills that generally range from 200 to 300 feet asl. The Sonoma Mountains rise from near sea level to elevations of 1,000 to 2,500 feet asl southeast of Santa Rosa (**Figure 3-1**). The Mayacamas Mountains are less steep and elevations mostly vary between 500 and 2,500 feet asl. The maximum elevation of highland surrounding the Subbasin is 2,730 feet asl, at the summit of Mt. Hood in the Mayacamas Mountains.

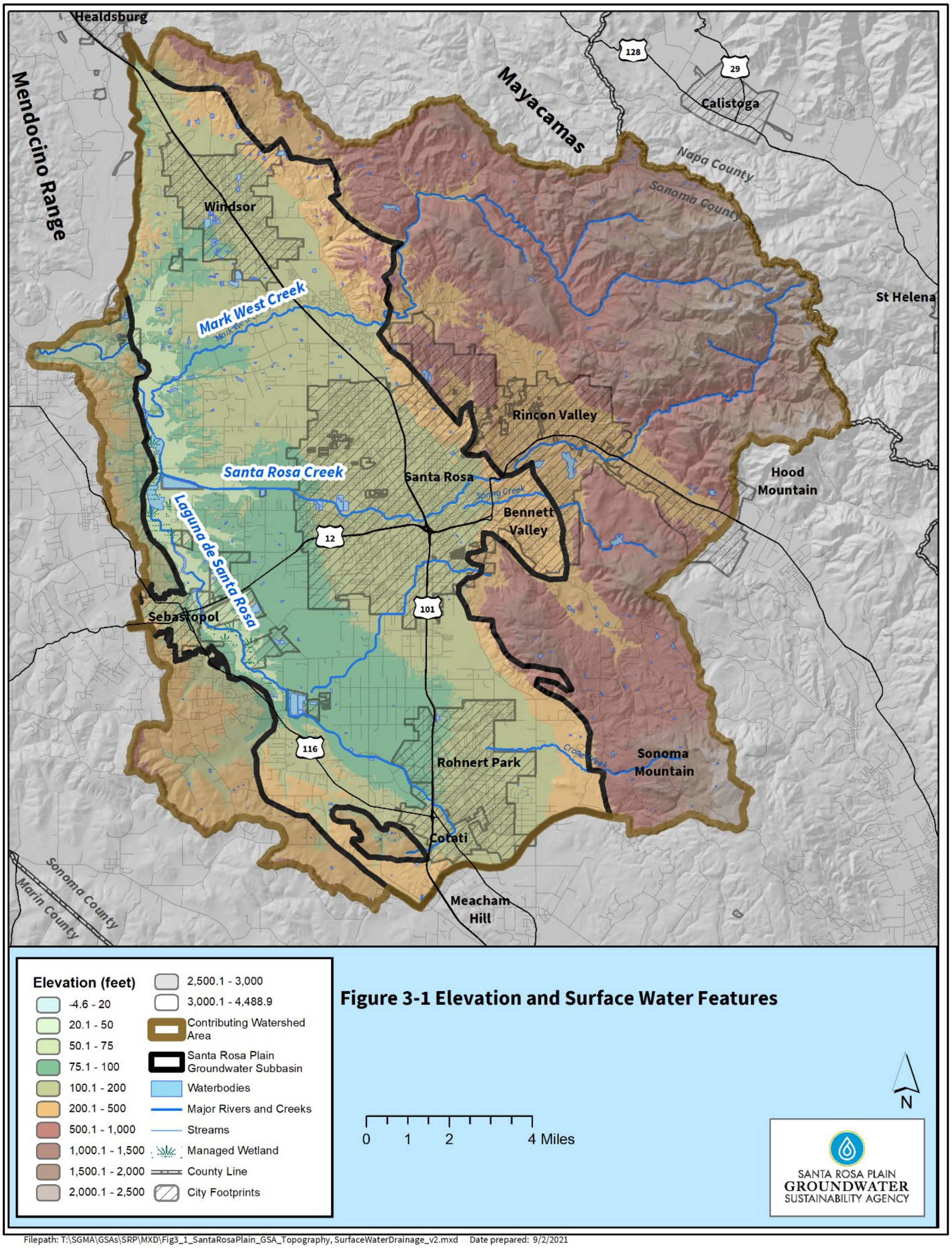


Figure 3-1. Elevation and Surface Water Features

3.1.2 Surface Water and Drainage Features

The SRP watershed is mostly within the middle Russian River watershed and includes three main drainage areas based on the National Hydrography Dataset (USGS 2006), which collectively drain an area of 262 square miles (Nishikawa 2013). These three main drainages are named for the main streams in each area: Mark West Creek, Santa Rosa Creek, and Laguna de Santa Rosa (**Figure 3-2**) (Simley and Carswell 2009). The Subbasin also contains numerous natural and artificial surface water bodies, including small lakes, ponds, and wetland areas. The following sections describe these drainage subbasins, as well as other significant surface water features.

3.1.2.1 Mark West Creek

The Mark West Creek drainage covers 86 square miles in the northern part of the SRP watershed. Mark West Creek (**Figure 3-2**), has a 29.9-mile-long channel originating at an elevation of 1,922 feet asl in the Mayacamas Mountains.

The main channel of Mark West Creek is perennial throughout much of its length (Simley and Carswell 2009), having summer flows maintained by numerous springs near the headwaters. Most of the main channel is in its natural state and much of the riparian vegetation adjacent to the Mark West Creek channel, as well as the creek bed, is undeveloped and characteristic of natural channel conditions. Some tributaries of Mark West Creek are perennial, but most are either ephemeral or intermittent and become dry during late spring to early fall (CEMAR 2014).

3.1.2.2 Santa Rosa Creek

The Santa Rosa Creek drainage subwatershed is a 77-square-mile drainage area in the central and eastern parts of the SRP watershed (**Figure 3-2**). Santa Rosa Creek is a 22-mile-long channel flowing in a westerly direction from drainage divides in the Mayacamas and Sonoma Mountains, to its confluence with the Laguna de Santa Rosa drainage channel. The source of Santa Rosa Creek is at an elevation of 1,940 feet asl near the summit of Mt. Hood.

Santa Rosa Creek originates in steep terrain of the Mayacamas Mountains, an area of mostly natural vegetative cover. The middle part of the Santa Rosa Creek drainage crosses the City of Santa Rosa and adjacent agricultural lands, while the lower part of the Santa Rosa Creek drainage mainly traverses agricultural land. Through the urbanized city landscape, Santa Rosa Creek flows in an engineered channel with concrete or earthen embankments. The upper Santa Rosa Creek and its tributary, Matanzas Creek, are perennial streams that carry diminished flows in late summer and fall (Simley and Carswell 2009). Other Santa Rosa Creek tributaries generally have engineered channels and flows are intermittent (Simley and Carswell 2009).

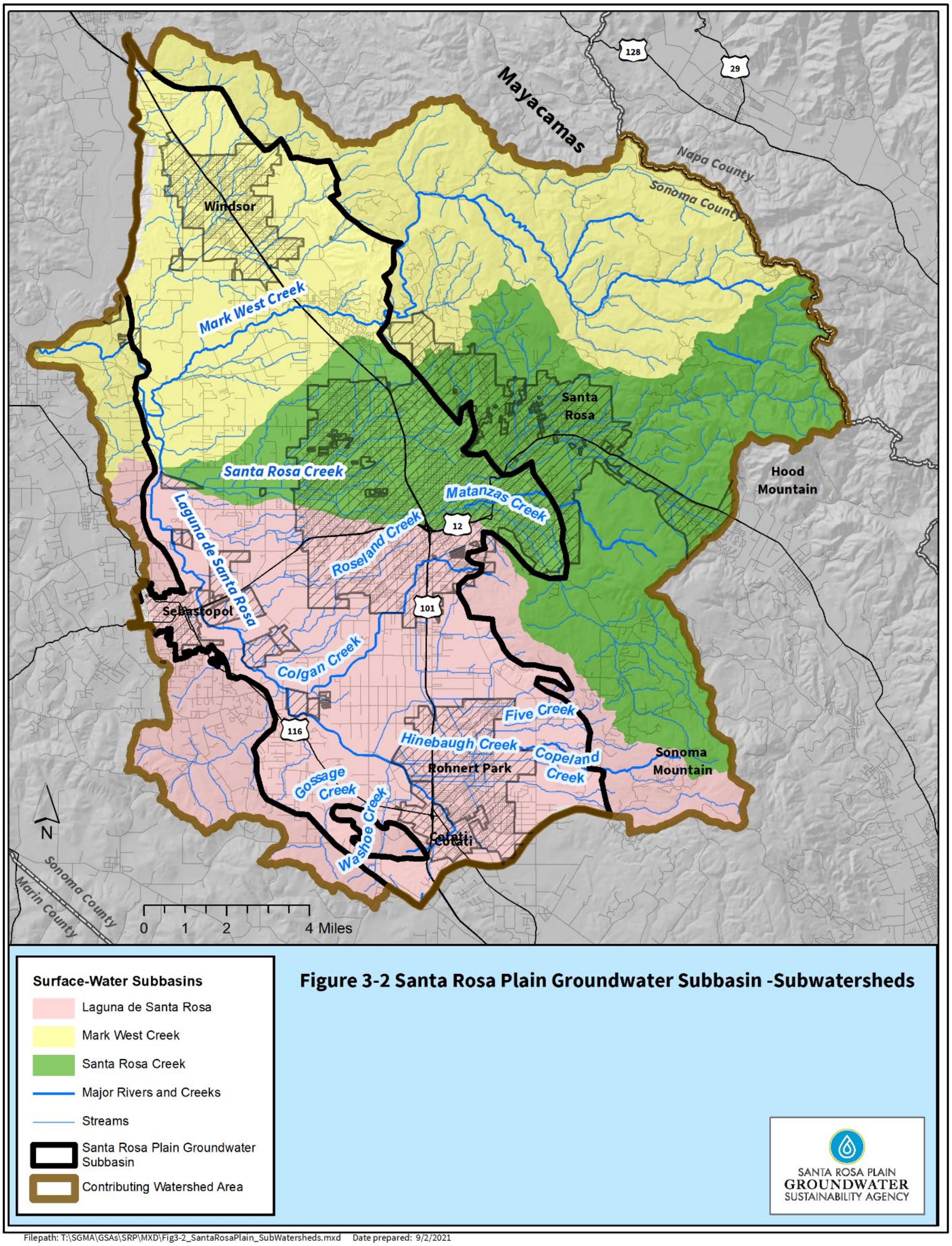


Figure 3-2. Santa Rosa Plain Groundwater Subbasin – Subwatersheds

3.1.2.3 Laguna de Santa Rosa, Peripheral Streams, and Drainages

The 22-mile-long Laguna de Santa Rosa channel and associated 88-square-mile drainage subwatershed collects and funnels precipitation and stormflows from the southern and southwestern areas of the SRP watershed upstream of the Santa Rosa Creek tributary, emptying to the north into Mark West Creek (**Figure 3-2**). The "Laguna de Santa Rosa" also refers to the general area of wetlands, ponds, and vernal pools within the area of the 100-year floodplain surrounding the main Laguna de Santa Rosa channel. The Laguna de Santa Rosa channel and floodplain together form a natural overflow subwatershed connecting Santa Rosa Creek, Mark West Creek, and the smaller creeks in the SRP watershed with the Russian River.

The Laguna de Santa Rosa channel originates at an elevation of 260 feet asl, west of Cotati and close to the southern boundary of the Subbasin (**Figure 3-2**). Much of the Laguna de Santa Rosa upstream of the Mark West Creek juncture is below an elevation of 50 feet. Important Laguna de Santa Rosa tributaries include Santa Rosa Creek, Copeland Creek, Crane Creek, Hinebaugh Creek, Five Creek, Colgan Creek, Gossage Creek, Washoe Creek, and Roseland Creek. Copeland Creek and Crane Creek have short perennial reaches (Simley and Carswell 2009) draining the Sonoma Mountains in the southeastern part of the Subbasin. Copeland Creek is perennial in its upper sections, becomes intermittent as it flows westward across the alluvial fan east of Rohnert Park, and is mostly channelized as it continues flowing westward through Rohnert Park and Cotati before joining the Laguna de Santa Rosa. Downstream of the junctions with the tributaries listed herein, the Laguna de Santa Rosa is a very low gradient drainage network defined by straight and engineered channels, canals, and drainage ditches through urbanized and agriculturally developed lands. The Laguna de Santa Rosa main channel is perennial, although summer flows can be quite small.

3.1.3 Soil Characteristics

Soil types and characteristics in the Subbasin have been mapped by USDA Natural Resources Conservation Service (NRCS), which developed a spatial database of soils for the entire United States (the Soil Survey Geographic Database or SSURGO) (USDA 2007). The SSURGO database defines 17 different soil textures (excluding variable and unknown textures) present in the Subbasin and contributing watershed, which are shown on **Figure 3-3a**. The majority of the Subbasin surface is characterized by clayey soils and loams with gravelly and cobbly loams and are more prevalent along alluvial fans and hilly areas. The southern portions of the Subbasin are characterized by more clay-rich soils. Gravelly and sandy soils are primarily limited to the low hills in the southwestern portions of the Subbasin and the western portions of the contributing watershed outside the Subbasin and along narrow stream channels within the Subbasin.

The SSURGO database also assigns saturated hydraulic-conductivity values to soil groups (**Figure 3-3b**). Saturated hydraulic conductivity is a measurement of the representative or average water-transmitting properties of soils and is a good indicator of the soil's infiltration potential. As indicated on **Figure 3-3b**, the loams and clayey loam soils that predominate the floor of the Subbasin exhibit relatively low hydraulic conductivities (slow to moderate), on the order of 0.1 to 4 feet per day.

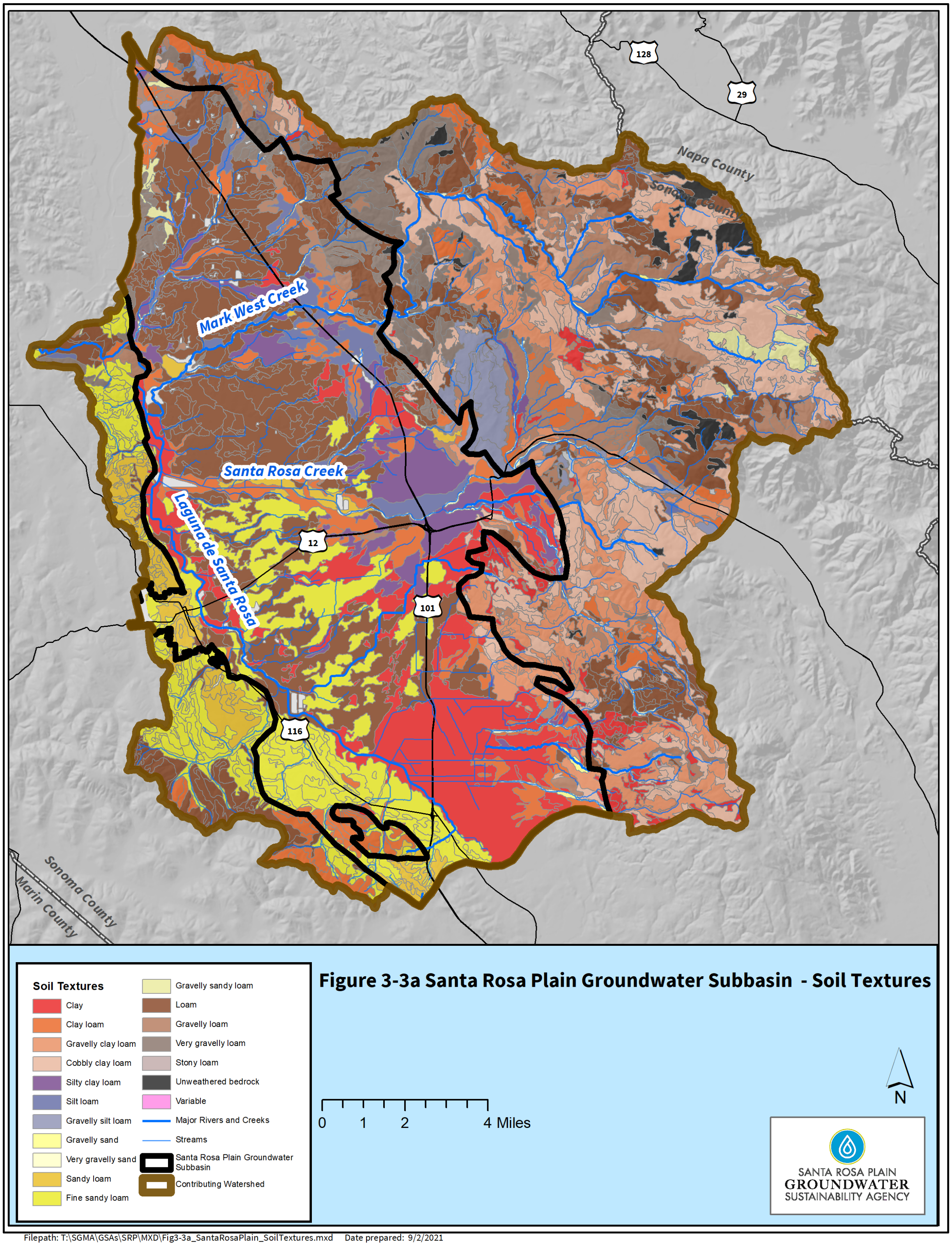


Figure 3-3a. Santa Rosa Plain Groundwater Subbasin – Soil Textures

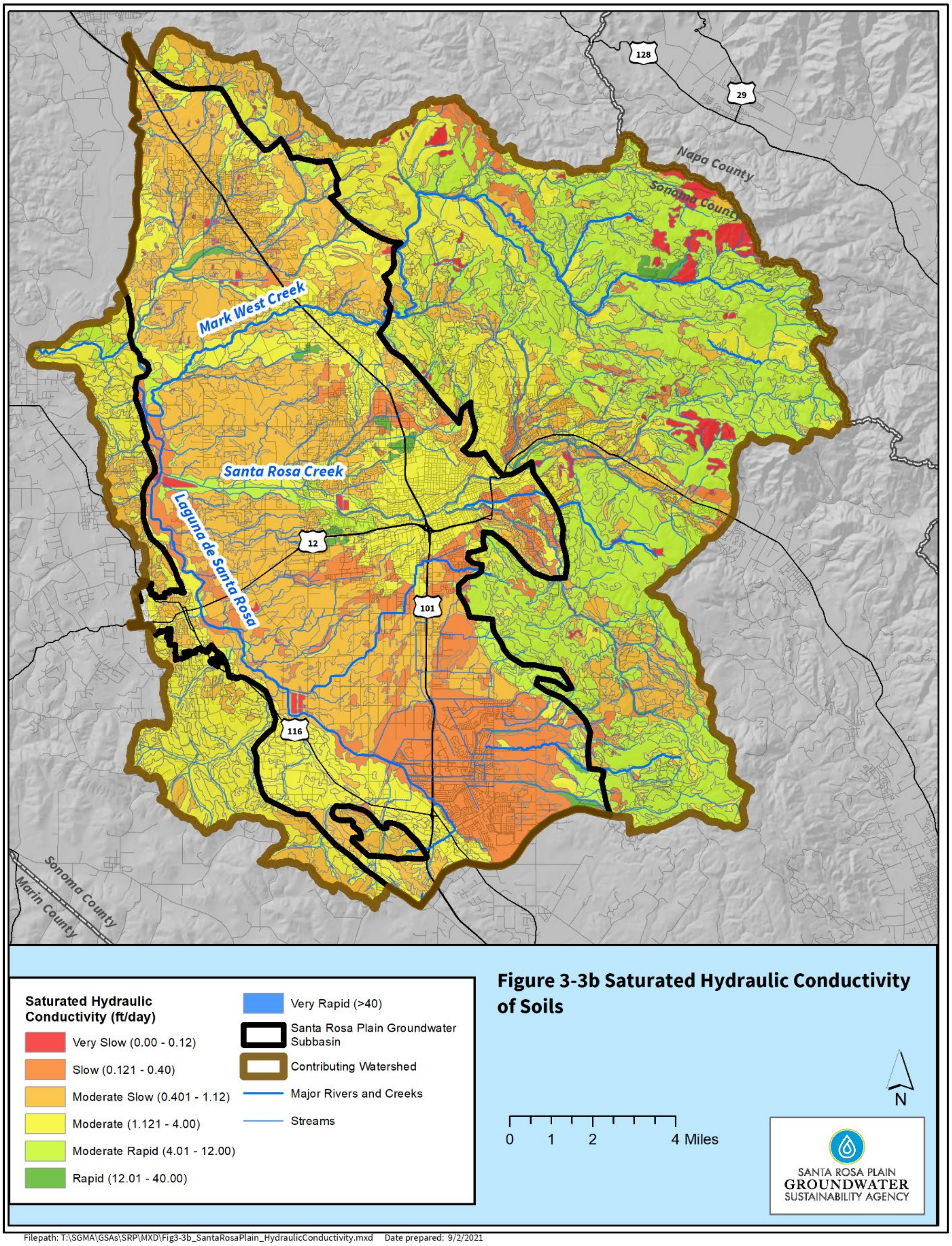


Figure 3-3b. Saturated Hydraulic Conductivity of Soils

Coarser-grained soils present in and around the Subbasin, which exhibit higher hydraulic-conductivity values (moderate rapid) on the order of 4 to 12 feet per day are predominately in the hilly areas in the southwest portions of the Subbasin, along the southeastern margins of the Subbasin, and along the lower portions of Santa Rosa Creek, Mark West Creek, and Windsor Creek. The highest saturated hydraulic conductivities (rapid to very rapid), on the order of 12 to 40 feet per day, primarily occur along and near streambed channels. At locations where subsurface storage space is available and the underlying geologic formations have sufficient permeability, these more permeable soils (moderate rapid to rapid) could be favorable for managed aquifer recharge.

3.1.4 Regional Geologic Setting

The regional geologic setting is a synopsis of work by Sweetkind et al. (2013) and Wagner and Gutierrez (2017). The Subbasin is located within a region of geologic complexity caused by long periods of active tectonic deformation, volcanic activity, and sea level changes. **Figure 3-4a** displays the regional geology of the northern Coast Ranges, including generalized geologic units and primary faults that influence the geometry of the Subbasin and the distribution of adjoining groundwater basins and upland areas. **Figure 3-4b** presents a geologic map of the watershed showing the surficial distribution of geologic units within the Subbasin and surrounding watershed areas. Geologic formations within the Subbasin are grouped into two broad categories (Mesozoic Era basement rocks and younger Cenozoic Era volcanic and sedimentary units) based on the age, degree of consolidation, and amount of deformation (such as folding, faulting, and fracturing). The Subbasin is underlain at varying depths by Mesozoic Era (more than 66 million years old) basement rocks consisting of metamorphic, igneous, and metasedimentary rocks of the Jurassic/Cretaceous-aged Franciscan Complex, Coast Range Ophiolite, and Great Valley Sequence. A mixture of younger (Tertiary and Quaternary-aged) volcanic and sedimentary rocks and unconsolidated sediments of the Cenozoic Era (less than 66 million years old) overlies these basement rocks (Sweetkind et al. 2013; Wagner and Gutierrez 2017). The inferred subsurface distribution of the geologic units is displayed on the hydrogeologic cross sections shown on **Figure 3-5.**

3.1.4.1 Geologic Structure

The Subbasin is located in the northern Coast Ranges, which are mountains with geologic structure dominated by the northwest trending San Andreas right-lateral transform fault system that includes the San Andreas fault zone to the west, and the Rodgers Creek, the Mayacama, and the Bennett Valley fault zones right-lateral strike-slip faults within or adjacent to the Subbasin. The Rodgers Creek Fault zone is approximately 0.6 mile wide and consists of a southern Rodgers Creek Fault segment that is interpreted to join with the Hayward fault to the south under San Pablo Bay (Watt et al. 2016) and a northern Healdsburg fault segment, separated by the Santa Rosa Creek floodplain. The Bennett Valley fault zone is a narrow, steeply dipping right-lateral fault. On the west side of the Subbasin, the Sebastopol Fault is a curved zone of east-side-down normal faults at the break in slope between the westside hills and valley floor. The Sebastopol Fault generally coincides with the lowest Subbasin elevations, forming the contact between Quaternary sediments and the underlying Wilson Grove Formation. An unnamed fault east of the Sebastopol Fault may be a branch from the Sebastopol, and is important for deep groundwater flow and quality (Nishikawa et al. 2013a). All of these faults have sufficient offset to juxtapose different geologic units against one another and serve as the main boundaries for the sedimentary basins beneath the Subbasin.

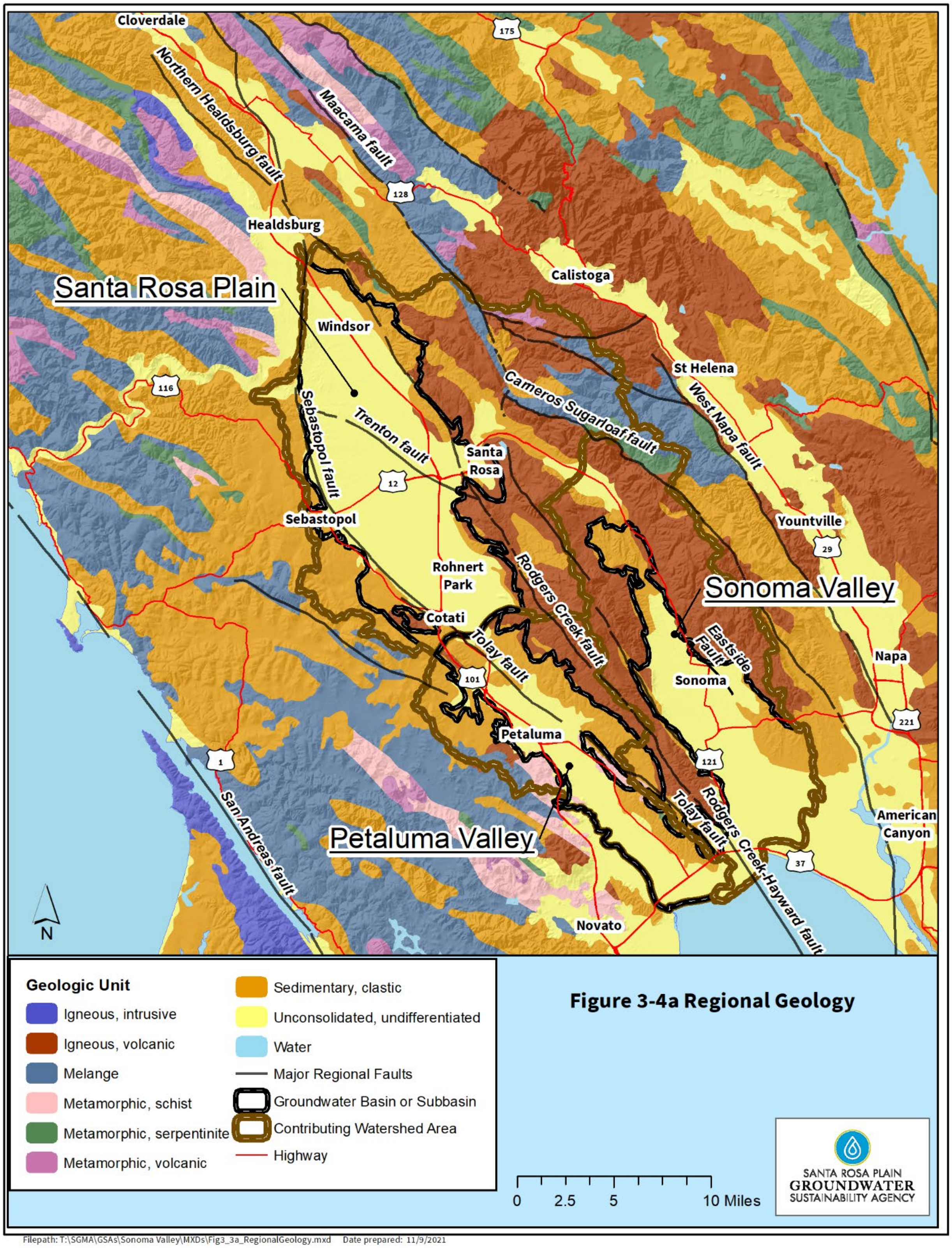


Figure 3-4a. Regional Geology

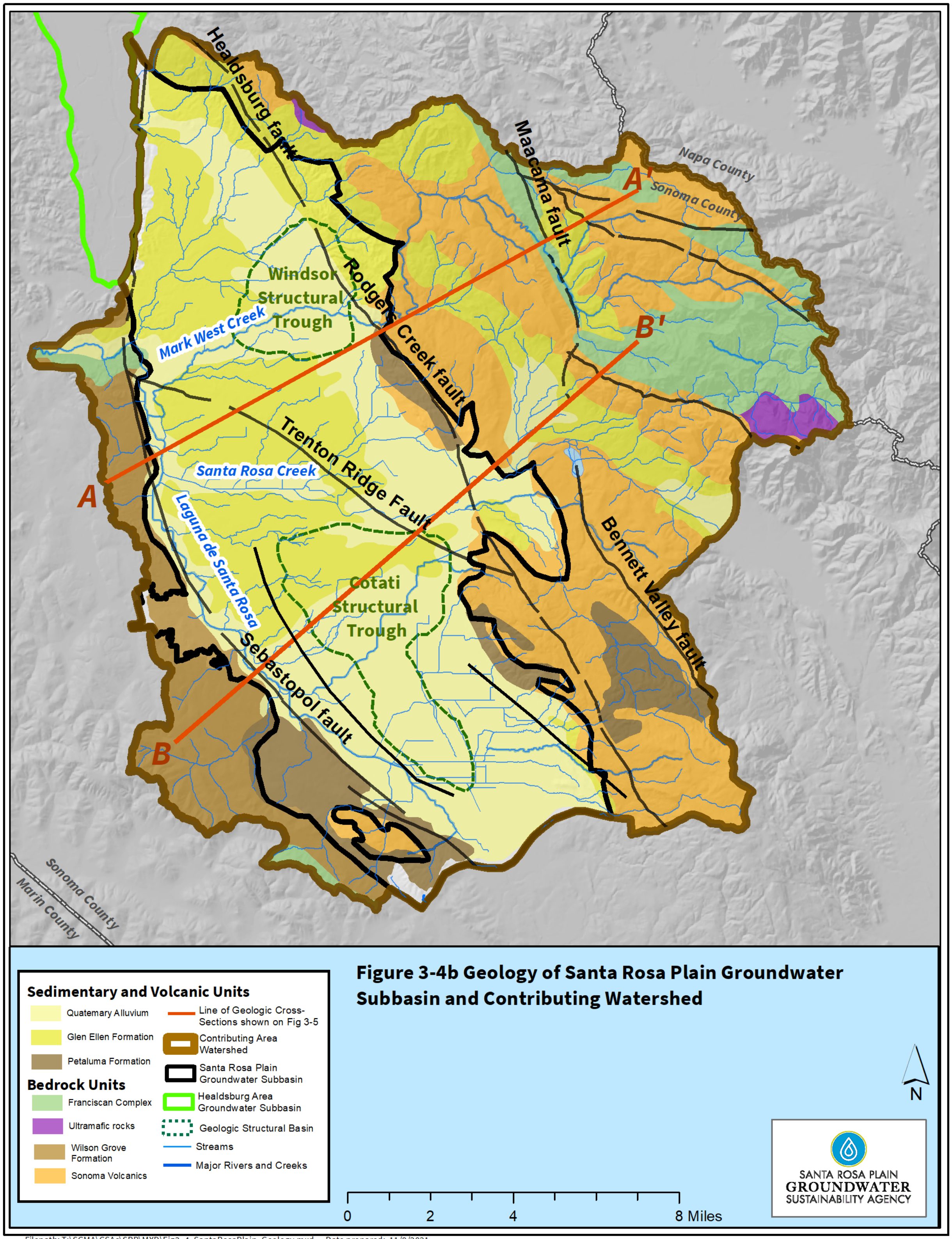


Figure 3-4b. Geology of Santa Rosa Plain Groundwater Subbasin and Contributing Watershed

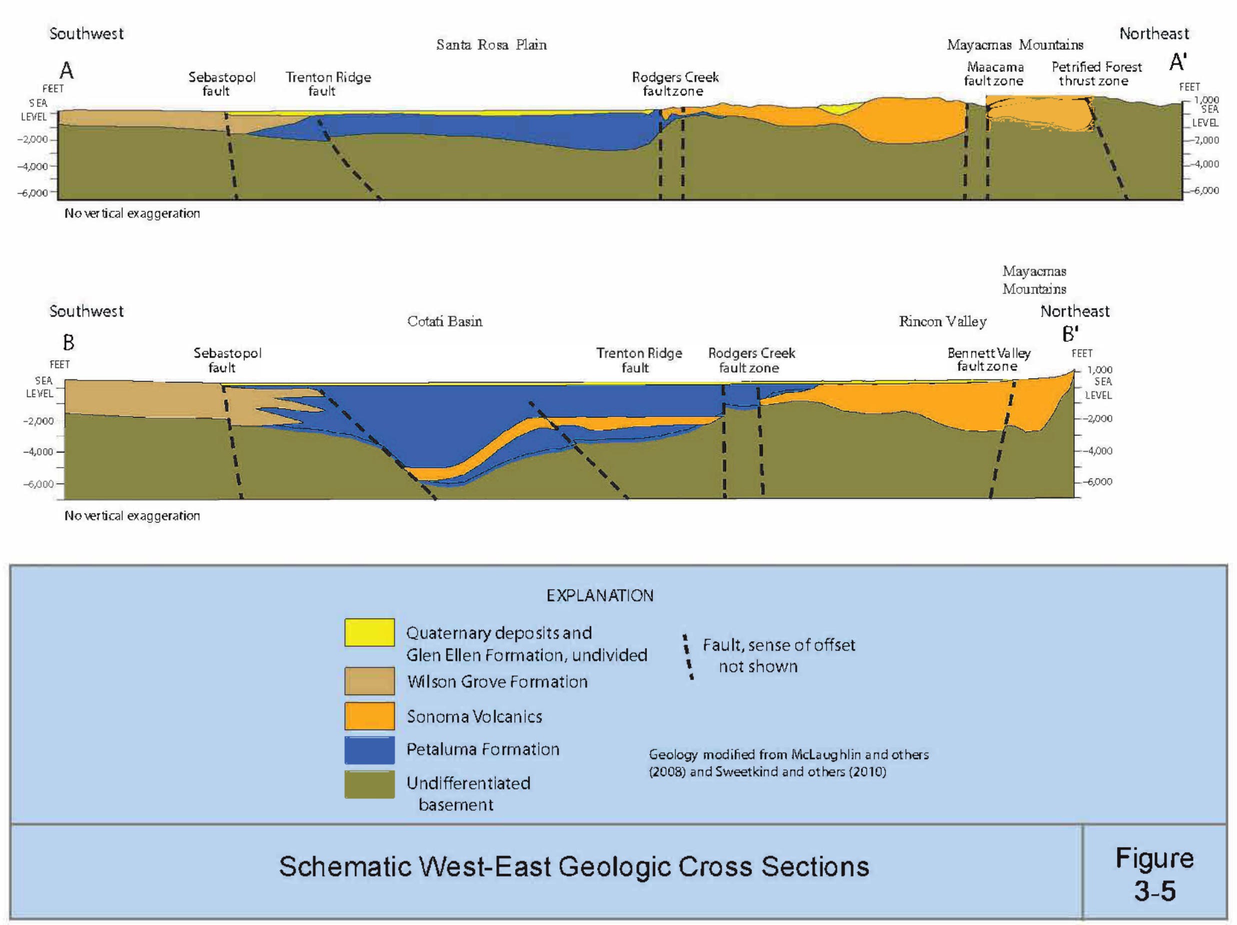


Figure 3-5. Schematic West-East Geologic Cross Sections

Analysis of gravity data reveals two steep-sided sedimentary structural troughs beneath the Subbasin: the Windsor structural trough beneath the northern portion of the Subbasin and the Cotati structural trough beneath the southern portion. These two structural troughs are modeled to range up to 10,000 feet deep and are separated by northwest to west-northwest trending, northeast dipping Trenton Ridge thrust fault, which forms a bedrock high between the structural troughs possibly as shallow as 1,000 feet below land surface (bls) (Langenheim et al. 2006, 2010; McPhee et al. 2007; Nishikawa et al. 2013a).

Available information on the effects of faults on groundwater movement and groundwater quality in the Subbasin is described in **Section 3.1.6**.

3.1.4.2 Mesozoic Era Basement Rocks

The Subbasin sits on a bedrock basement of deformed and faulted Mesozoic age rocks of the Franciscan Complex, Great Valley Sequence, and Coast Range ophiolite. The Mesozoic basement rocks are only exposed outside of the Subbasin at the northern boundary and within the east-central portion of the contributing watershed where rocks of the Franciscan Complex and Coast Range Ophiolite occur (Sweetkind et al. 2013).

Mesozoic Era basement rocks generally yield very little water, as their porosity is primarily attributed to fractures that are commonly limited in extent and water-transmitting capacity. Wells completed in the basement rocks generally produce relatively small amounts of water suitable for domestic supply. Successful domestic wells commonly produce 5 gallons per minute (gpm) or less from basement rocks in the hills and mountains within the contributing watershed area. While the basement rocks locally provide a viable, sole source supply for many households, they are not considered a significant water-supply source in the Subbasin (Santa Rosa Plain Basin Advisory Panel 2014).

3.1.4.3 Cenozoic Era Volcanic and Sedimentary Units

Groundwater resources within the Subbasin are primarily located within the Cenozoic volcanic and sedimentary units deposited over the Mesozoic basement rocks. The thick sedimentary layers and some of the volcanic rocks that overlie the Mesozoic bedrock in the Subbasin are capable of storing and yielding large quantities of groundwater. The water-bearing properties of the geologic units vary considerably as a result of changes in rock type within units and interfingering between units. This variability determines how much water can be obtained from wells in different parts of the watershed. Geologic units that are of greatest importance for groundwater resources within Santa Rosa Plain Subbasin (Sweetkind et al. 2013) are described in subsequent text in general order of decreasing age (older to younger) and include both Tertiary-aged (between 66 and 2.5 million years old) and Quaternary-aged (younger than 2.5 million years old) units.

Tertiary Volcanic Units

The Sonoma Volcanics of Miocene to Pliocene age (approximately 8 to 2.5 million years old) are a thick and highly variable sequence of volcanic rocks interbedded with volcaniclastic sedimentary deposits (sediments derived from volcanic rocks). The unit consists of thick deposits of volcanic lava flows with some interbedded volcanic ash flows, mud flows, tuffs, and volcaniclastic sedimentary deposits of tuffaceous sands and volcanic gravels. The Sonoma Volcanics cover an area of approximately 1,200 square miles in Sonoma and Napa counties and have been grouped into western, eastern, and northern groups based on their age (Sweetkind et al. 2013). The western age group occurs within the Santa Rosa Plain and contributing watershed areas and includes the Sonoma Mountain assemblage, which includes rhyolite; rhyodacite breccia interbedded with Petaluma Formation sediments; mafic andesitic and basalt flows; tuffs; and volcaniclastic sediments (Wagner et al. 2011).

The Sonoma Volcanics are exposed throughout the Mayacamas and Sonoma Mountains and along the margins of the Subbasin and extend beneath the valley floor where they are buried beneath younger geologic units. The Sonoma Volcanics are highly variable in lithology and their subsurface distribution is often difficult to discern from well drillers logs. Additionally, the upper part of the Sonoma Volcanics interfingers with sedimentary units of the Glen Ellen and Petaluma Formations in places further complicating subsurface mapping of volcanic units. The total thickness of the volcanic units is highly variable and has been estimated to be up to 3,000 feet thick (Sweetkind et al. 2013).

Tertiary Sedimentary Units

Petaluma Formation

The Petaluma Formation is a Pliocene-aged (approximately 5 million years old) sedimentary unit that was deposited in transitional continental and shallow marine environments. The unit is dominated by more or less consolidated silt or clay-rich mudstone, with local beds and lenses of poorly sorted sandstone and minor conglomerate beds and has been subdivided into an upper, middle, and lower member (Allen 2003; Holland et al. 2009). The lower member is up to 750 feet thick and is predominantly dense beds of mudstone that have the lowest hydraulic conductivity within the formation. The formation coarsens in the 3,500-foot thick middle and upper parts, in which beds of poorly sorted sands and gravels result in increased hydraulic conductivity. In general, the beds of coarser materials are thin and not of great lateral extent (Sweetkind et al. 2013).

Wilson Grove Formation

The late Miocene to late Pliocene sandstone-dominated Wilson Grove Formation is exposed in the low hills west of the Subbasin and is also continuous in the subsurface to the east for some distance, where it interfingers with the Petaluma Formation beneath Quaternary alluvial deposits and, in the northern Subbasin, with the Glen Ellen Formation. The Wilson Grove Formation is relatively thick (300 feet to greater than 1,000 feet thick), and mostly composed of weakly cemented marine-deposited sandstone, with volcanic ash intervals. The predominance of relatively clean sand and the low degree of cementation in the Wilson Grove Formation result in moderate to high hydraulic conductivity (Powell and Holland 2004).

Glen Ellen Formation

The Glen Ellen Formation is also Pliocene- to Pleistocene-aged (approximately 3 to 3.5 million years old) fluvial sedimentary unit deposited as alluvial fans and adjoining flood plains. The unit consists primarily of clay-rich stratified stream deposits of poorly sorted sand, silt, and gravel. Beds of these sediments vary from coarse- to fine-grained, commonly over distances of a few tens to hundreds of feet, both laterally and vertically, with low to moderate hydraulic conductivity (Cardwell 1958).

Quaternary Sedimentary Deposits

Quaternary alluvial deposits cover much of the flat eastern and southern valley floor and include Holocene (younger than 12,000 years) (Geological Society of America 2018) to modern stream channel and stream terrace deposits (loose alluvial sand, gravel, and silt) and surrounding late Pleistocene to Holocene undissected stream terrace deposits, older alluvium, and alluvial fan deposits. The Quaternary alluvial deposits consist of sedimentary deposits that are widespread throughout the SRP watershed, generally in proximity to and comprising minor aquifers of limited extent along modern streams and beneath alluvial fans. These deposits are dominated by alluvial fan and floodplain deposits eroded from rock exposed in the flanking hills. The deposits generally consist of mixed poorly to well-sorted sand, silt, clay, gravel, cobbles, and boulders, as interfingering, variably thin or thick beds of limited lateral extent (tens to hundreds of feet), and range from low to high hydraulic conductivity. Layers in the older alluvium add up to a thickness of about 400 feet and younger alluvium layers are generally less than 150 feet thick (Sweetkind et al. 2013).

3.1.4.4 Lateral and Vertical Extent of Subbasin

The structural setting and distribution of geologic units described in the previous section influence the Subbasin extents, which are defined by DWR, as documented in Bulletin 118 (DWR 2016a). The lateral extent and boundaries of the Subbasin are defined as follows:

- The southern boundary of Subbasin coincides with a surface watershed divide between the Laguna de Santa Rosa drainage subbasin and the Petaluma River Watershed. The boundary is also the approximate location of a groundwater-flow divide; however, no known structural or geologic features restrict flow between the two areas.
- The contact shown on **Figure 3-4b** between the topographically higher Sonoma Volcanics and the Petaluma Formation and overlying Quaternary alluvial deposits generally defines the eastern boundary of the Subbasin, with the exception of a small segment where the Rincon Valley Subbasin adjoins the Subbasin (**Figure 2-1**).
- The northwestern boundary of the Subbasin generally follows the contact between the Glen Ellen Formation and Quaternary alluvial deposits of the Russian River Valley within the Healdsburg Area Subbasin (**Figure 3-4b**).
- The remaining western boundary generally follows the contact between the Wilson Grove Formation and either the Quaternary alluvial deposits or the Petaluma Formation, with the exception of the City of Sebastopol, where the boundary follows the jurisdictional boundary of the city and extends into a portion of the Wilson Grove Formation (**Figure 3-4b**).

The base of the Subbasin is not defined based on a transition in geologic materials, such as the Mesozoic basement rocks that occur at depths exceeding 10,000 feet in some areas. Rather, the vertical extent of the Subbasin is defined based on the approximate depth at which viable water-supply aquifers are no longer present. The productive freshwater aquifers generally occur at shallower depths with the deepest wells within the Subbasin extending to approximately 1,500 feet and no existing known water wells extending deeper than 2,000 feet. At depths exceeding approximately 2,000 feet, aquifers are likely not usable for water supply due to a combination of: (1) lower well yields related to increased consolidation and cementation of aquifer materials at these depths and (2) poor-quality water related, in part, to the presence of brackish connate water and geothermally affected waters (Nishikawa et al. 2013b).

3.1.5 Principal Aquifer Systems and Aquitards

The GSP Regulations require the identification of principal aquifers and aquitards within groundwater basins. Principal aquifers are defined in 23 CCR 351 as “aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems.” These aquifers have unique and important requirements defined in 23 CCR 354, requiring the following for each principal aquifer:

- Characterization of physical properties, structural barriers, water-quality conditions, and primary uses
- Groundwater-elevation contour maps
- Hydrographs
- Change in storage estimates
- Minimum thresholds and measurable objectives
- Sufficient monitoring network, including groundwater levels and water quality

The Cenozoic volcanic and sedimentary units described in **Section 3.1.4** form a heterogeneous and continuous body of saturated materials below the water table, where groundwater occurs in pore spaces of the Quaternary alluvial deposits, Glen Ellen, Wilson Grove, and Petaluma Formations, and the Sonoma Volcanics (Sweetkind et al. 2013). The distribution, subsurface extent, and interfingering of these five primary aquifer units reflect the Subbasin's complex geologic history of tectonic deformation concomitant with volcanic activity and sediment deposition in alluvial, lake, and estuarine settings.

To characterize the aquifer systems within the Santa Rosa Plain for the purpose of implementing SGMA, two principal aquifer systems have been identified based on available data and information: the shallow and deep aquifer systems. This aquifer system characterization is consistent with grouping used for existing monitoring programs (Santa Rosa Plain Basin Advisory Panel 2014; City of Santa Rosa 2013a) and supported by findings from the USGS studies within the Subbasin (Nishikawa et al. 2013a; Woolfenden and Nishikawa 2014). Properties and features considered in grouping the shallow and deep aquifer systems into separate aquifer systems include the degree of surface water connectivity, degree of confinement, and responses to hydraulic stresses such as recharge and pumping. Although the deep and shallow aquifer systems are grouped separately, the boundary between the shallow and deep aquifer systems is not intended to represent a distinct boundary to groundwater flow. The degree of hydraulic separation between the two is variable throughout the Subbasin with some areas, such as where clay aquitard materials between the two aquifer systems are thinner or absent, exhibiting stronger hydraulic communication. The identification of the boundary between the two aquifer systems is further complicated by the complex stratigraphic relationships and high degree of heterogeneity associated with the aquifer units. The appropriateness of the principal aquifer system designation within the Subbasin will continue to be evaluated and considered as more data and information are developed during implementation of the GSP regarding the lateral and vertical characteristics and hydraulic connections between the different aquifer units.

The shallow aquifer system generally extends from the water table to depths ranging from 150 to 200 feet bls. The shallow aquifer system is present over the entire lateral extent of the Subbasin and primarily occurs within Quaternary alluvial deposits and Glen Ellen Formation.

However, in a few limited areas where these units are absent or thin near the margins of the Subbasin, the shallow aquifer system locally occurs within sedimentary units of the Wilson Grove and Petaluma Formations. The shallow aquifer system is generally present under unconfined or semiconfined conditions with semiconfined conditions generally occurring in areas of the shallow aquifer system that exhibit higher proportions of clay and silt units. In some localized and limited areas, very shallow and seasonally perched aquifers are present where infiltrating water can accumulate on very shallow lenses of clay: these are not considered to be part of the shallow aquifer system because they are not continuous in extent, not tapped for water supply, and likely do not contribute to the baseflow of streams.

Aquifer units beneath the shallow aquifer system are characterized collectively as the deep aquifer system and occur under confined or semiconfined conditions within the Wilson Grove Formation, Petaluma Formation. and Sonoma Volcanics. The deep aquifer is generally present beneath approximately 200 feet bls (that is, below the shallow aquifer system), and the thickness of individual permeable aquifer zones within the deep aquifer system is highly variable and can range from several feet to hundreds of feet in thickness (Allen 2003; Cardwell 1958; Powell and Holland 2004). In areas where multiple permeable zones occur within the deep aquifer system, these different zones can sometimes exhibit distinct features (for example, distinct water-quality signature or appreciable differences in hydraulic head) and can generally be further subdivided into upper and lower aquifers. However, the continuity of these distinct upper and lower portions is not well constrained nor correlative across the Subbasin due, in part, to the limited number of wells and lithologic information for the deep aquifer system, and the heterogeneous and discontinuous nature of the sediments.

Attributes of the shallow and deep aquifer systems, which generally correlate throughout the Subbasin and facilitate distinguishing between the two include the following:

- The shallow aquifer system generally is separated from the underlying deep aquifer system by sequences of clay, which form discontinuous aquitards that predominantly occur in either the lower portions of the Glen Ellen Formation or upper portions of the Petaluma Formation, as evidenced by noted differences in water quality (Martin et al. 2013) and estimated hydraulic properties, such as vertical hydraulic conductivity (Woolfenden and Nishikawa 2014). Generally, hydraulic conductivity is typically significantly lower in the vertical direction compared with the horizontal direction due to anisotropic flow conditions typical of layered sedimentary aquifer systems (Heath 1984). These anisotropic conditions inhibit groundwater flow vertically and cause increasing confinement of groundwater with increasing depth. The separation caused by clay aquitards in the Subbasin is likely less prevalent along the western boundary, where the sand-rich Wilson Grove Formation dominates the subsurface (Nishikawa et al. 2013).
- The shallow aquifer system is generally present under unconfined to semiconfined conditions, while the deep aquifer system is commonly present under semiconfined or confined conditions (Sweetkind et al. 2013).

- The shallow aquifer system generally exhibits stable long-term groundwater levels, while deeper aquifer system wells have exhibited appreciable periods of declining groundwater levels in certain areas of the Subbasin (Santa Rosa Plain Basin Advisory Panel 2014; SRPGMP 2017).
- While seasonal fluctuations in groundwater levels are observed in both the shallow and deep aquifer systems, rapid increases and decreases in groundwater levels within the deep aquifer system appear to correlate closely with groundwater pumping events, whereas responses within the shallow aquifer system appear more muted or delayed (Sweetkind et al. 2013).
- In many areas within the Subbasin the shallow aquifer system is locally and seasonally connected to streams and surface waters, while the deep aquifer system is not physically connected with surface waters of the Subbasin and hydraulic communication between the deep aquifer system and surface waters is expected to exhibit a muted and delayed response.
- Differences in groundwater quality between the shallow and deep aquifer zones are common (Martin et al. 2013), as indicated in **Section 3.1.5.2**.

Characteristics of the shallow and deep aquifer systems, including individual aquifer unit materials and properties, general water quality and primary uses based on available data and limitations are further described in the following subsections.

3.1.5.1 Materials and Properties of Primary Aquifer Systems

Aquifer properties include aquifer storage properties (specific yield for unconfined aquifers and storativity or specific storage for confined aquifers) and aquifer transmission properties (hydraulic conductivity and transmissivity). While these properties can be estimated using lithologic texture descriptions from well drillers' logs, they are most accurately determined by conducting aquifer tests consisting of pumping a well at a known and controlled rate for a sufficient period of time (typically several days) and observing the groundwater-level response in the pumped well and neighboring observation wells. Available aquifer test data are limited within the Subbasin (Sweetkind et al. 2013); therefore, the values for these properties are a source of uncertainty.

Shallow Aquifer System Materials and Properties

Materials and properties of the two geologic units that predominantly comprise the shallow aquifer system are described in the following paragraphs.

Quaternary Alluvium

Quaternary alluvial deposits, which blanket much of the Subbasin predominantly include alluvial fan deposits, stream channel deposits, older alluvium, and basin deposits (Wagner and Gutierrez 2017). The generally coarse-grained alluvial fan and stream channel deposits, and their proximity to modern streams, allow for rapid recharge of precipitation and runoff to the groundwater system and exchanges between groundwater and surface water. The composition of the older alluvium is variable, consisting of a mixture of fine- and coarse-grained sediments. The basin deposits, which primarily occur within the southern portions of the Subbasin are finer-grained and exhibit low permeability. Groundwater is unconfined in most places within the alluvial deposits, but semiconfined conditions exist in areas with higher proportions of clay or silt (Sweetkind et al. 2013).

The Quaternary alluvial deposits provide some water to shallow wells and contribute part of the water to deeper wells that also draw from underlying formations. Yields from wells that are completed only in alluvial deposits ranged from 1 to 650 gpm. The highest well yields are in the northern Subbasin near Mark West Creek (Sweetkind et al. 2013). The alluvial deposits are generally poorly sorted and, locally, contain large fractions of clay resulting in a range of specific yields (the amount of water a saturated aquifer will yield by gravity – or what is available to wells) between 8 and 17 percent. Hydraulic-conductivity values from two available aquifer tests range from 2 to about 51 feet per day (ft/d), and storativity values range from about 0.0013 to 0.19. The large range of hydraulic properties is consistent with the lithologic heterogeneity and varying degree of confinement of the alluvial deposits (Sweetkind et al. 2013; Santa Rosa Plain Basin Advisory Panel 2014).

Glen Ellen Formation

The relatively high content of clay-sized material, degree of compaction, and cementation tend to limit the permeability of the Glen Ellen Formation. Within the Subbasin, the Glen Ellen Formation ranges from tens of feet to several hundred feet thick (Sweetkind et al. 2013). Where sufficiently thick, the Glen Ellen Formation includes some beds of moderately to well-sorted, coarse-grained materials that have high permeability and yield appreciable amounts of water to wells.

Most wells in which the Glen Ellen Formation is the principal water-bearing unit will produce between 15 and 30 gpm (Ford 1975). The specific yield and hydraulic conductivity of the Glen Ellen Formation has been estimated to range from 3 to 7 percent (Herbst et al. 1982) and 13 to 23 ft/d (Cardwell 1958), respectively.

Deep Aquifer System Materials and Properties

Materials and properties of the three geologic units that comprise the predominantly deep aquifer system are described in the following paragraphs.

Wilson Grove Formation

Most wells screened partially or totally in the Wilson Grove Formation are within the upper stratigraphic horizons, which are coarser-grained and more permeable than deep deposits to the west. Domestic wells drilled into the Wilson Grove Formation yield on average about 20 gpm (DWR 1979). Large capacity and municipal wells can yield up to 1,000 gpm or more (Sweetkind et al. 2013). Wells drawing from the Wilson Grove Formation have estimated specific yields in the range of 10 to 20 percent (Herbst et al. 1982), higher than any of the other rocks or sediments in the Subbasin. Estimates of hydraulic conductivity and storativity from aquifer tests conducted in 11 wells in the western portions of the Subbasin range from 3 to 65 ft/d and 0.00095 to 0.08, respectively (Sweetkind et al. 2013).

Petaluma Formation

The productivity of wells drilled in the Petaluma Formation depends mostly on the total thickness of the thin, poorly sorted beds of sand and gravel perforated by the well. In general, the upper member of the Petaluma Formation is the most productive. The Petaluma Formation is at least 3,000 feet thick in places within the Subbasin. Domestic wells drilled into the Petaluma Formation yield an average of about 20 gpm and range from 10 to 50 gpm (DWR 1979). Even though the formation is dominated by clay, areas of thin, moderately to poorly sorted beds of sands and gravels can provide yields greater than 100 gpm from wells in areas of coarser-grained materials providing higher yields (Sweetkind et al. 2013). For example, in the Rohnert Park area municipal wells drawing predominantly from the Petaluma Formation have produced as much as 500 gpm.

Specific yields are typically low in the Petaluma Formation, ranging from 3 to 7 percent (Cardwell 1958; DWR 2003). Estimates of transmissivity based on specific capacities of Rohnert Park municipal wells range from 130 to 1,600 square feet per day (ft^2/d) (City of Rohnert Park 2007); however, some of the wells are perforated in interbeds of Wilson Grove Formation, Sonoma Volcanics, or both (DWR 1979).

Sonoma Volcanics

The Sonoma Volcanics exhibit a large variation in water-bearing properties, with a mixture of fractured lava beds, unwelded tuffs, and interbedded volcaniclastic sedimentary deposits generally providing the best aquifer materials (Wagner et al. 2005; McLaughlin et al 2008). Lava beds have extremely low primary permeability and only fractures, or the tops and bottoms of individual flows yield significant water. Unwelded tuffs can yield water similar to high porosity, high permeability alluvial sediments. This formation has the highest variability in water-bearing properties in the Santa Rosa Plain.

Water production from wells drilled into thick air-fall pumice units can exceed a few hundred gpm, but wells drilled into unfractured lavas or welded tuffs can produce less than 10 gpm, and dry holes are sometimes encountered. For wells penetrating the Sonoma Volcanics, previous studies suggest a range of well yields between 10 and 50 gpm (Ford 1975); however, some of the wells penetrate more than one formation, and the relative contributions are unknown. The specific yield of the Sonoma Volcanics has been reported to be in the range of 0 to 15 percent (Herbst et al. 1982) and transmissivity has been estimated to range from 0.8 to 5,300 ft^2/d. (Sweetkind et al. 2013; Santa Rosa Plain Basin Advisory Panel 2014).

3.1.5.2 General Water-Quality Characteristics

Groundwater quality is highly variable throughout the study area and is generally acceptable for beneficial uses, although constituents of potential concern pose challenges on a localized basis. Specific conductance, chloride, TDS, nitrate, and arsenic are considered water-quality constituents of potential concern in the Subbasin because some samples from wells exceeded state- or federal-recommended or mandatory regulatory standards for drinking water. In general, groundwater within the Subbasin is of mixed cation-bicarbonate-type with median dissolved solids concentrations of approximately 350 milligrams per liter (mg/L). Some distinctions between shallow and deeper aquifer system water quality include the following:

- Water samples from wells completed within the shallow aquifer system generally exhibit greater proportions of calcium and magnesium, while samples collected from the deep aquifer system exhibit greater proportions of sodium and potassium, which is consistent with increasing mineralization and ion exchange between clays and groundwater with increasing distance and depth from recharge sources (Martin et al. 2013). Typically, isotopically heavier constituents, such as nitrate and tritium, are more commonly found in the shallow aquifer system in comparison to the deep aquifer system.

- As determined by carbon-14 dating or the presence of tritium, the shallow and deep aquifers exhibit different groundwater ages, with the deep well samples all exhibiting water ages of 4,000 years or older and the shallow aquifer generally containing waters recharged within the last 50 years (Martin et al. 2013).

Further data and discussion of groundwater quality conditions and trends are included in **Section 3.2**.

3.1.5.3 Aquifer System Primary Uses

The shallow aquifer system serves a number of different users and uses with the primary extractions being from domestic water-supply wells, which provide water to rural-residential properties in the unincorporated areas of the Subbasin. In some areas, agricultural and public water-supply wells are also completed, either completely or partially, within the shallow aquifer system. The shallow aquifer system is a primary source of recharge to the deep aquifer system. It is also the source of baseflow to streams within the Subbasin, thereby providing ecosystem benefits in the Subbasin. Additionally, in some areas where groundwater levels are close to the ground surface, such as near streams and in the Laguna de Santa Rosa areas, the shallow aquifer system provides water for vegetation communities in the Subbasin.

The deep aquifer system serves a number of different users and uses. Users include a combination of rural-residential properties with domestic water-supply wells in the unincorporated areas of the Subbasin, agricultural irrigation wells used for crop irrigation, industrial, and commercial use and public water-supply wells for municipal and smaller public supply systems.

3.1.5.4 Aquitards

Generally discontinuous aquitards composed of clay deposits commonly provide some degree of hydraulic separation between the shallow and deep aquifer systems and serve to locally confine the deeper aquifer system to varying degrees of semiconfined or confined conditions. Clay aquitards are common within some portions of the Quaternary alluvial deposits, such as the basin deposits within the southern portions of the Subbasin, the Glen Ellen Formation, and clay-dominated portions of the older Petaluma Formation. These aquitards may contribute to semi-confined or confined conditions of the more permeable sand and gravel aquifer zones within the Wilson Grove and Petaluma Formations of the deep aquifer system. Due to the overall complexity of the Subbasin hydrogeology and complicated interfingering stratigraphic relations of the Petaluma Formation with the Wilson Grove Formation and Sonoma Volcanics, some wells can pass from one formation into another more than once. The interfingering of the three formations can also place relatively impermeable lavas or clay beds above more permeable sand or gravel beds, producing confined groundwater conditions (Sweetkind et al. 2013). Wells spanning unconfined and confined layers, however, can provide pathways for groundwater to flow between layers and can affect both the hydraulics and water quality of these areas.

3.1.6 Effects of Faults on Groundwater

Faults can affect water flow and well production because groundwater movement may be inhibited or preferentially increased across or within faults and fault zones. Faulting can break even very strong rocks, producing fracture zones that tend to increase permeability, and may provide preferential paths for groundwater flow. Conversely, some faults can form groundwater barriers if the faulting grinds the broken rock into fine-grained fault gouge with low permeability, or where chemical weathering and cementation over time have reduced permeability. The hydraulic characteristics of materials in a fault zone, and the width of the zone, can vary considerably so that a fault may be a barrier along part of its length but elsewhere allow or even enhance groundwater flow across it. Faults also may displace rocks or sediments so that geologic units with very different hydraulic properties are contiguous, which can affect localized groundwater flow regimes.

Faults in the Subbasin serve as major structural boundaries for geologic formations and groundwater movement. Faults have also played a major role in the geometry of the basin with the formation of the Windsor and Cotati structural troughs separated by the Trenton Ridge Fault (**Figures 3-4a**, **3-4b**, and **3-5**). Major faults, which are present along or near the boundaries of the Subbasin include the Rodgers Creek-Healdsburg Fault Zone along the eastern boundary and the Sebastopol Fault along the western boundary. The Trenton Ridge Fault and two unnamed faults present in the southern portions of the Subbasin are the main mapped faults located within the interior of the Subbasin (**Figures 3-4a** and **3-4b**). The Rodgers Creek Fault appears to act as a barrier to groundwater flow and also creates groundwater upflow or mixing along part of its length (**Figure 3-5**). The Sebastopol Fault appears to limit the lateral groundwater movement to the east. To the east of the Sebastopol Fault, an unnamed fault is at least a partial barrier to groundwater flow and appears to create upflow or mixing along part of its length (Martin et al. 2013).

The alignments of thermal springs and wells (that is, wells affected by volcanic heat sources), along and near valley-bounding faults, indicate that some faults enable deep waters to move upward to the surface or into shallow formations. West of the Rodgers Creek Fault, and directly downgradient (in the groundwater flow direction), groundwater compositions change from characteristics typical of recent rainfall replenishment to those of hydrothermal or connate water (water included during accumulation of the rock or sediment materials). These changes suggest that the fault orientation and activity may be directing groundwater downward and causing deep mixing of older and more recently replenished waters, or may be evidence of groundwater upwelling. The Sebastopol Fault may be acting as a barrier to shallow flow, but does not appear to impede flow at greater depths.

3.1.7 Groundwater Recharge and Discharge

3.1.7.1 Groundwater Recharge

The principal sources of recharge to groundwater systems within the SRP watershed are direct infiltration of precipitation and infiltration from streams (Sweetkind et al. 2013). Minor sources of recharge include infiltration from septic tanks, leaking water-supply pipes, leaking storm drainpipes, irrigation water in excess of crop requirements, and crop frost-protection applications. The shallow aquifer system receives most of this recharge. Recharge that reaches the deeper aquifer zones is less well-defined and appears to come from a combination of leakage from overlying shallow aquifers and mountain-front recharge along the margins of the valley. The amount of groundwater recharge and discharge is estimated a number of ways through direct measurement, approximation incorporating some literature-based variables, and with the use of the groundwater model.

Previous estimates of groundwater recharge in the Santa Rosa Plain have primarily included qualitative assessments. Natural recharge potential mapping of the Subbasin and contributing watershed was conducted that incorporates soil permeability, slope, and shallow geologic unit permeability (0 to 50 feet bls) (Todd Engineers 2012). The weighting of each parameter—slope (20 percent), soil (30 percent), and geology (50 percent)—is generally based on other similar studies and guidance (Sesser et al. 2011; DWR 1982; Muir and Johnson 1979) and sensitivity analysis. The natural recharge potential map developed by Todd Engineers (**Figure 3-6**) ranks the very high to very low relative potential for natural groundwater recharge from rainfall infiltration. The term recharge potential is used because the actual recharge rate also depends on other factors such as the distribution, intensity and duration of precipitation, the locations of streams and other surface-water bodies, and the connection to deeper aquifers (which were not incorporated into that study). Areas showing a higher recharge potential using this desktop approach are generally located within the flatter areas of the Glen Ellen Formation and the areas underlain by the Wilson Grove Formation. Potential constraints or limitations that are not directly incorporated into the analysis include the presence of shallow or perched groundwater, natural springs, and existing groundwater quality.

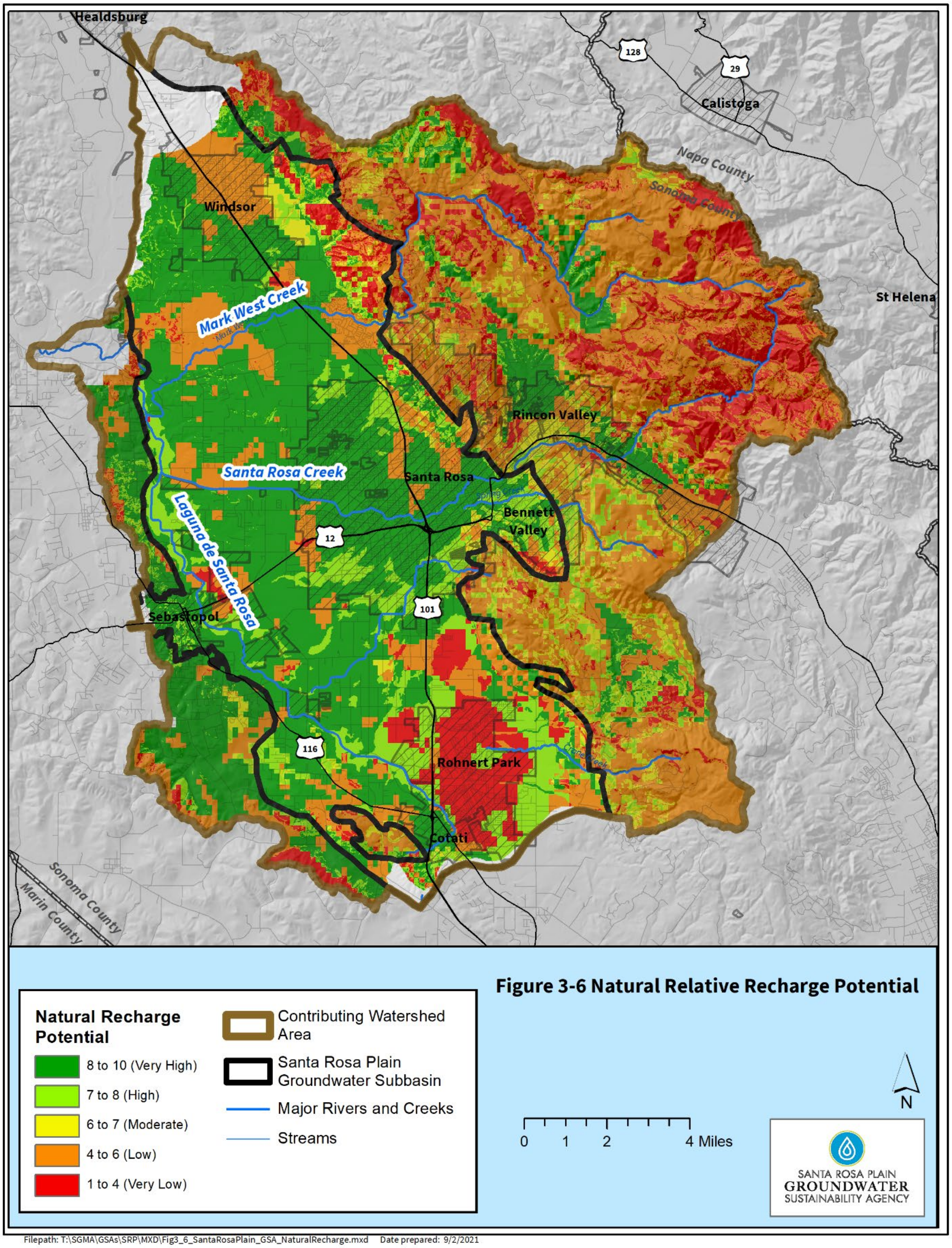


Figure 3-6. Natural Relative Recharge Potential

3.1.7.2 Groundwater Discharge

Groundwater discharge occurs in the Subbasin as stream baseflow (gaining streams), discharge at springs and seeps, underflow to neighboring groundwater basins, and discharge at interconnected wetlands. Groundwater also discharges through evapotranspiration (ET) from phreatophytes and groundwater pumping. These two components of groundwater discharge are described in **Section 3.3** (Water Budget).

Based on USGS' National Hydrography Dataset and NWIS, there are 17 mapped springs and seeps in the contributing watershed (**Figure 3-7**). On the west side of the Subbasin, groundwater discharges from the Wilson Grove Formation through springs and seeps, and on the east side springs are relatively common discharging from the Sonoma Volcanics and Glen Ellen Formation (Sweetkind et al. 2013).

3.1.8 Data Gaps and Uncertainty

While the information and data presented in this HCM incorporates the best available information and datasets, it is recognized that all HCMs will contain varying degrees of uncertainty that can be improved through additional data collection and analysis. Addressing the following primary identified data gaps would improve and reduce uncertainty of the HCM for the Subbasin and will be considered and prioritized in **Section 6** (Projects and Actions) and **Section 7** (Implementation Plan).

3.1.8.1 Aquifer and Aquitard Continuity and Properties and Role of Fault Zones

As described in preceding sections, the geologic complexities of the Subbasin and limited high quality subsurface lithologic data limit the understanding of the lateral and vertical continuity and properties of aquifers and aquitards in the Subbasin. Developing the following information would improve our understanding of aquifers and aquitards:

- Improving estimates of the annual volume of groundwater recharge and discharge, including pumping.
- Filling three-dimensional data gaps in the monitoring network for each primary aquifer in the Subbasin. Depth-dependent water-level and water-quality data are needed to improve understanding of the hydrogeology and aquifer systems, which could be improved through construction of dedicated nested monitoring wells in key areas.
- Gaining a better understanding of the role of faults within and along the boundaries of the Subbasin, with a focus on the role of the Sebastopol Fault, Trenton Ridge Fault, and Unnamed Fault. Potential methods for addressing this data gap could include the performance of aquifer tests and geophysical surveys, geochemical sampling, and analyses in the vicinity of these faults.
- Developing better information on basin boundary characteristics, such as the direction and magnitude of fluxes across Subbasin boundaries, including boundaries between the Subbasin and adjoining groundwater basins and boundaries between the Subbasin and the

upper contributing watershed areas outside of the Bulletin 118 basins. Potential methods for addressing this data gap could include the construction of dedicated nested monitoring wells and/or performance of aquifer tests and geophysical surveys in the vicinity of the boundaries.

3.1.8.2 Recharge and Discharge Areas and Mechanisms and Surface Water/Groundwater Interaction

Improved understanding of recharge and discharge mechanisms within the Subbasin for both the shallow and deep aquifer systems will support the appropriate selection of projects and actions needed for the Subbasin, this includes:

- Gaining an improved understanding of the interconnection of streams to the shallow aquifer system, including seasonal variability and how groundwater pumping can affect streamflow. Additional shallow monitoring wells near stream courses paired with stream gages and meteorological stations can help advance this understanding.
- Conducting geochemical or tracer studies, which can help better understand both recharge and discharge mechanisms to both the shallow and deep aquifer systems, as well as surface water/groundwater interaction within the Subbasin.

3.2 Current and Historical Groundwater Conditions

This subsection describes the current and historical groundwater conditions within the Subbasin and contributing watershed areas. As described in the GSP Regulations, "Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following":

- Groundwater-elevation Data: Contour maps, hydrographs
- Change in Storage Estimates: Annual and cumulative changes, including groundwater use and water year (WY) type
- Seawater Intrusion: Maps and cross sections for each principal aquifer
- Groundwater Quality: Issues that may affect supply and beneficial uses, map of contaminant sites and plumes
- Land Subsidence: Extent and annual rate
- Interconnected Surface Water: Timing of depletions, map of Groundwater Dependent Ecosystems (GDE)

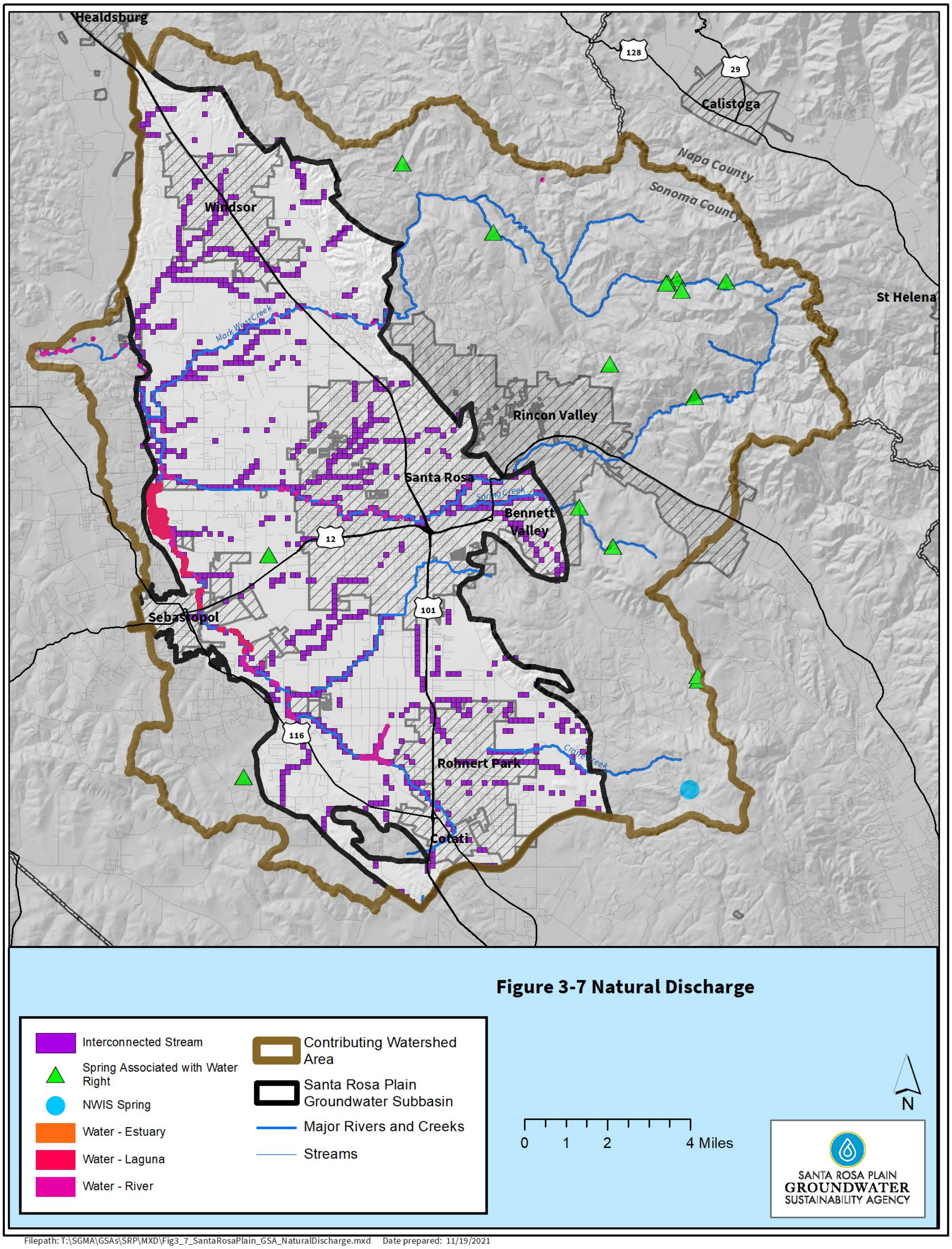


Figure 3-7. Natural Discharge

To assess and evaluate the listed conditions for the Subbasin and contributing watershed areas, this subsection includes a description of the following conditions based on available information and data:

- Climate conditions and trends
- Groundwater-elevation data and trends
- Estimates of storage changes
- Groundwater quality data and trends
- Land-surface subsidence data and trends
- Surface water conditions and trends
- Assessment of interconnected surface water and GDE

3.2.1 Climatic Conditions and Trends

Regional climate patterns in the Northern California region encompassing the SRP watershed are characterized by Mediterranean conditions with cool, wet winters; warm, dry summers; and a strong coastal influence on climate that moderates temperature extremes (Sloop et al. 2009). Distributions of temperature and rainfall display high spatial and temporal variability due to the combination of coastal and inland weather systems. The intersection of these variable weather patterns with the rugged topography of the Coast Ranges results in a broad variety of microclimates.

The Mediterranean climate in the SRP watershed influences water demands by separating the year into wet and dry seasons. During the dry season outdoor irrigation demands, particularly for agriculture, are not met by precipitation. Approximately 93 percent of the annual precipitation normally falls during the wet season (October to May), with a large percentage of the rainfall typically occurring during three or four major winter storms. Precipitation is highly affected by atmospheric rivers, which concentrate rainfall and runoff along narrow bands in the atmosphere. Nearly 50 percent of precipitation in the Sonoma County area is due to atmospheric rivers (Dettinger et al. 2011). The quantity of rainfall over the contributing watershed increases with elevation, with the greatest precipitation over the highest ridges, reaching nearly 50 inches per year in the Mayacamas and Sonoma Mountains (**Figure 3-8**).

Mean annual precipitation in the Santa Rosa Plain has been assessed using both observed data from Climate Station Santa Rosa (USC00047965), which is located in downtown Santa Rosa at an elevation of 109 feet (National Geodetic Vertical Datum of 1929 [NGVD 29]), as well as annual averages calculated using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) for the SRP watershed. The Santa Rosa station has operated from 1903 to present, with periods of missing and incomplete records. The yearly average precipitation measured from this station from WY 1903 through WY 2020 is 29.81 inches (**Table 3-1**), compared with 33.3 inches, as calculated by PRISM. This calculation is based on the annual WY standard nomenclature, which begins on October 1 and ends the following calendar year on September 30.

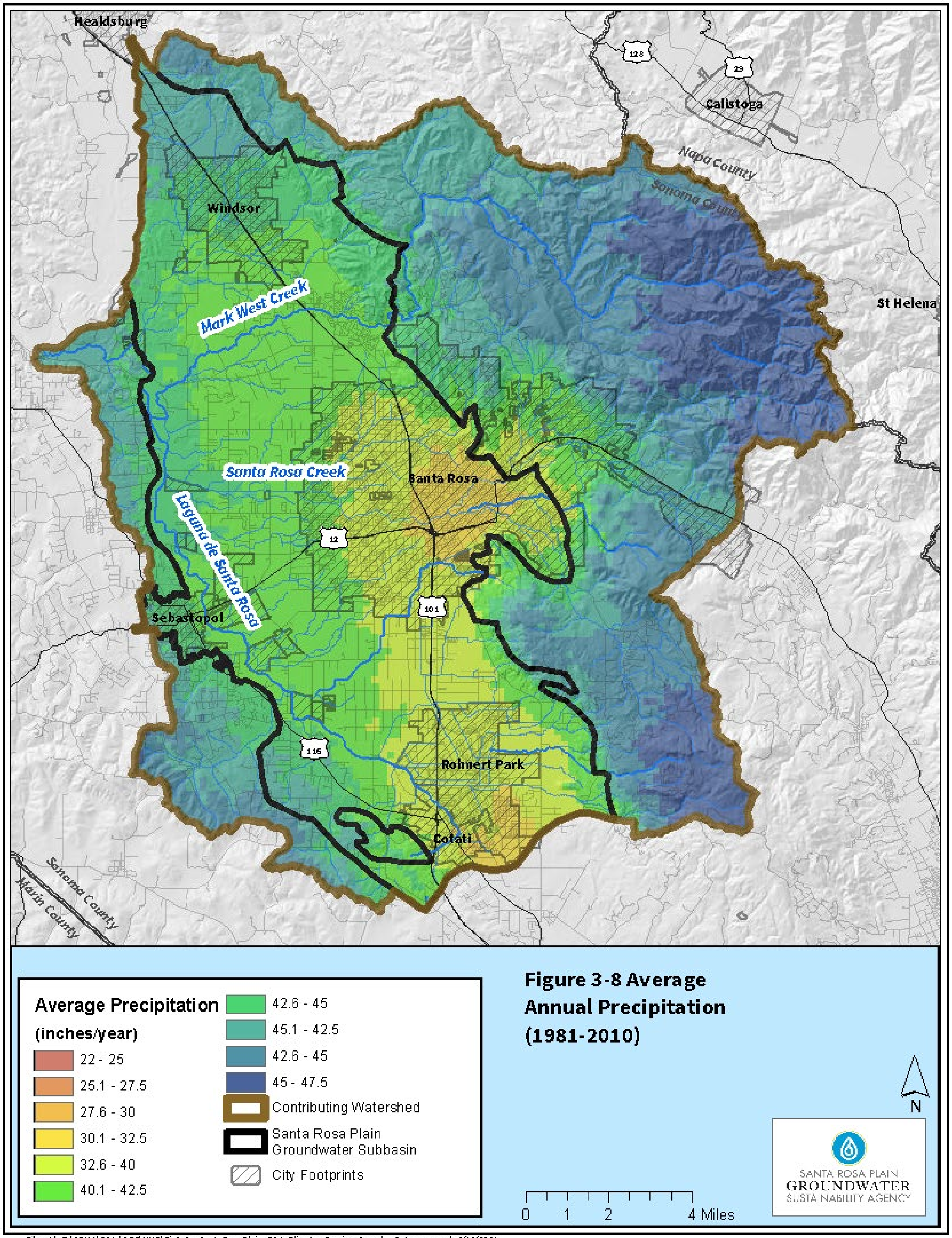


Figure 3-8. Average Annual Precipitation (1981-2010)

Table 3-1. Climate Station Santa Rosa Yearly Average Rainfall

Water Year	Annual Rainfall (Inches)	Completeness of data
WY-1903	28.78	85.8%
WY-1904	48.54	100.0%
WY-1905	31.62	100.0%
WY-1906	25.42	77.0%
WY-1907	33.90	94.5%
WY-1908	17.84	82.2%
WY-1909	39.31	95.1%
WY-1910	26.58	86.3%
WY-1911	29.49	94.5%
WY-1912	21.45	100.0%
WY-1913	21.11	100.0%
WY-1914	31.85	52.9%
WY-1915	42.53	75.1%
WY-1916	30.24	75.7%
WY-1917	19.18	52.3%
WY-1918	20.45	60.5%
WY-1919	25.26	38.4%
WY-1920	12.84	25.7%
WY-1921	38.97	32.6%
WY-1922	23.69	33.7%
WY-1923	29.94	51.2%
WY-1924	13.96	93.7%
WY-1925	42.13	89.3%
WY-1926	31.30	100.0%
WY-1927	42.54	98.4%
WY-1928	28.47	94.5%
WY-1929	17.38	86.6%
WY-1930	26.95	100.0%
WY-1931	13.27	98.6%
WY-1932	24.22	100.0%
WY-1933	20.95	100.0%
WY-1934	20.91	100.0%
WY-1935	35.35	100.0%
WY-1936	29.93	99.7%
WY-1937	26.39	100.0%
WY-1938	39.32	99.7%
WY-1939	15.29	100.0%
WY-1940	38.59	100.0%
WY-1941	51.82	100.0%
WY-1942	40.63	100.0%
WY-1943	32.43	100.0%
WY-1944	23.27	100.0%
WY-1945	28.18	100.0%
WY-1946	25.86	100.0%
WY-1947	20.24	100.0%
WY-1948	28.45	100.0%
WY-1949	19.89	100.0%
WY-1950	25.06	99.5%
WY-1951	32.09	100.0%
WY-1952	37.56	100.0%
WY-1953	32.62	99.5%
WY-1954	28.40	97.3%
WY-1955	20.58	100.0%
WY-1956	43.99	99.5%
WY-1957	23.31	100.0%
WY-1958	43.49	100.0%
WY-1959	21.58	100.0%
WY-1960	24.39	99.7%
WY-1961	24.77	98.9%
WY-1962	21.41	98.4%
WY-1963	35.34	100.0%
WY-1964	20.31	100.0%
WY-1965	31.49	91.8%
WY-1966	25.12	100.0%
WY-1967	41.96	100.0%
WY-1968	26.66	100.0%
WY-1969	41.19	100.0%
WY-1970	38.46	100.0%
WY-1971	31.28	100.0%
WY-1972	17.63	100.0%
WY-1973	42.95	100.0%
WY-1974	42.25	100.0%
WY-1975	28.05	100.0%
WY-1976	16.92	100.0%
WY-1977	12.13	99.5%
WY-1978	27.98	100.0%
WY-1979	4.99	50.4%
WY-1980	37.76	100.0%
WY-1981	22.60	99.7%
WY-1982	48.48	100.0%
WY-1983	55.74	99.7%
WY-1984	30.82	92.9%
WY-1985	26.90	92.9%
WY-1986	42.57	100.0%
WY-1987	19.00	99.7%
WY-1988	21.70	99.5%
WY-1989	26.67	99.7%
WY-1990	21.43	100.0%
WY-1991	22.72	100.0%
WY-1992	24.32	100.0%
WY-1993	37.95	100.0%
WY-1994	21.43	100.0%
WY-1995	47.78	100.0%
WY-1996	38.43	100.0%
WY-1997	33.91	100.0%
WY-1998	53.01	100.0%
WY-1999	32.72	100.0%
WY-2000	30.68	100.0%
WY-2001	21.91	100.0%
WY-2002	35.17	100.0%
WY-2003	34.92	100.0%
WY-2004	29.38	100.0%
WY-2005	37.77	100.0%
WY-2006	45.72	100.0%
WY-2007	20.85	100.0%
WY-2008	24.14	100.0%
WY-2009	22.62	100.0%
WY-2010	32.05	100.0%
WY-2011	39.14	100.0%
WY-2012	23.22	100.0%
WY-2013	29.36	100.0%
WY-2014	14.90	100.0%
WY-2015	24.05	100.0%
WY-2016	32.17	100.0%
WY-2017	60.32	100.0%
WY-2018	25.12	100.0%
WY-2019	48.12	100.0%
WY-2020	19.23	100.0%

Average Rainfall (1903WY-2020WY) : **29.81**

Note: Rainfall totals derived from daily precipitation measurements recorded at National Climatic Data Center station #7965, currently located at the Sonoma County Airport (Lat. 38.503, Long. -122.810). Some years do not contain a complete record, which is described in the "Completeness of data" column.

For the purposes of comparing and classifying WY types for the GSP, data from PRISM and historical data were used from Sonoma Valley, Santa Rosa Plain, and Petaluma Valley to develop an aggregated WY classification for all three basins. The methodology and results are provided in **Appendix 3-A**.

Future climate change projections are described in **Section 3.3** (Water Budget).

3.2.2 Groundwater Elevations and Trends

Changing patterns of land use, surface water use, groundwater pumping, and climate changes can cause changes in groundwater levels and movement directions. This subsection describes historical and current groundwater-elevation conditions and trends based on available data from the monitoring programs described in **Section 2.4**. While records for some wells extend back to the 1950s, the majority of available groundwater-level data are from the last 10 to 15 years. Data presented and evaluated as part of this section include the following:

- Historical groundwater-level contour maps (**Figures 3-9a** and **3-9b**)
- Recent groundwater-level contour maps for each principal aquifer (**Figures 3-10a** through **3-10h**)
- Long-term groundwater-level hydrographs (**Figures 3-11a** through **3-11d**)
- Groundwater-level trend maps (**Figure 3-12a** and **3-12b**)
- Short-term groundwater-level hydrographs (**Figures 3-13b** through **3-13i**)

3.2.2.1 Groundwater-level Contour Maps

Historical groundwater-elevation contour maps of groundwater levels in the Subbasin (**Figure 3-9a**) show overall groundwater spring flow directions and trends for 1951 through 2007. The contours presented on these maps, which are provided to present overall patterns, do not distinguish between wells completed in the shallow and deep aquifer systems and are considered composites of both principal aquifer systems. The dominant direction of groundwater flow in the spring of 1951 was from the east toward the west (**Figure 3-9a**). The influence of Mark West and Santa Rosa Creeks also appear as upstream deflections in the contours, indicating segments of these watercourses were likely being fed from groundwater discharge (gaining stream condition) at that time.

Groundwater-elevation contours for spring 1990 (**Figure 3-9a**) show substantial groundwater-level declines from 1951 conditions. There were groundwater-level declines exceeding 100 feet in the Rohnert Park-Cotati area and approximately 20 feet of groundwater-level decline west of the City of Santa Rosa (**Figure 3-9a**). The declines in the southern portions of the Subbasin are primarily attributed to increases in municipal groundwater pumpage associated with population growth through the 1980s and 1990s, exacerbated also by the droughts in 1976-77 and 1987-92 (**Figure 3-9b**).

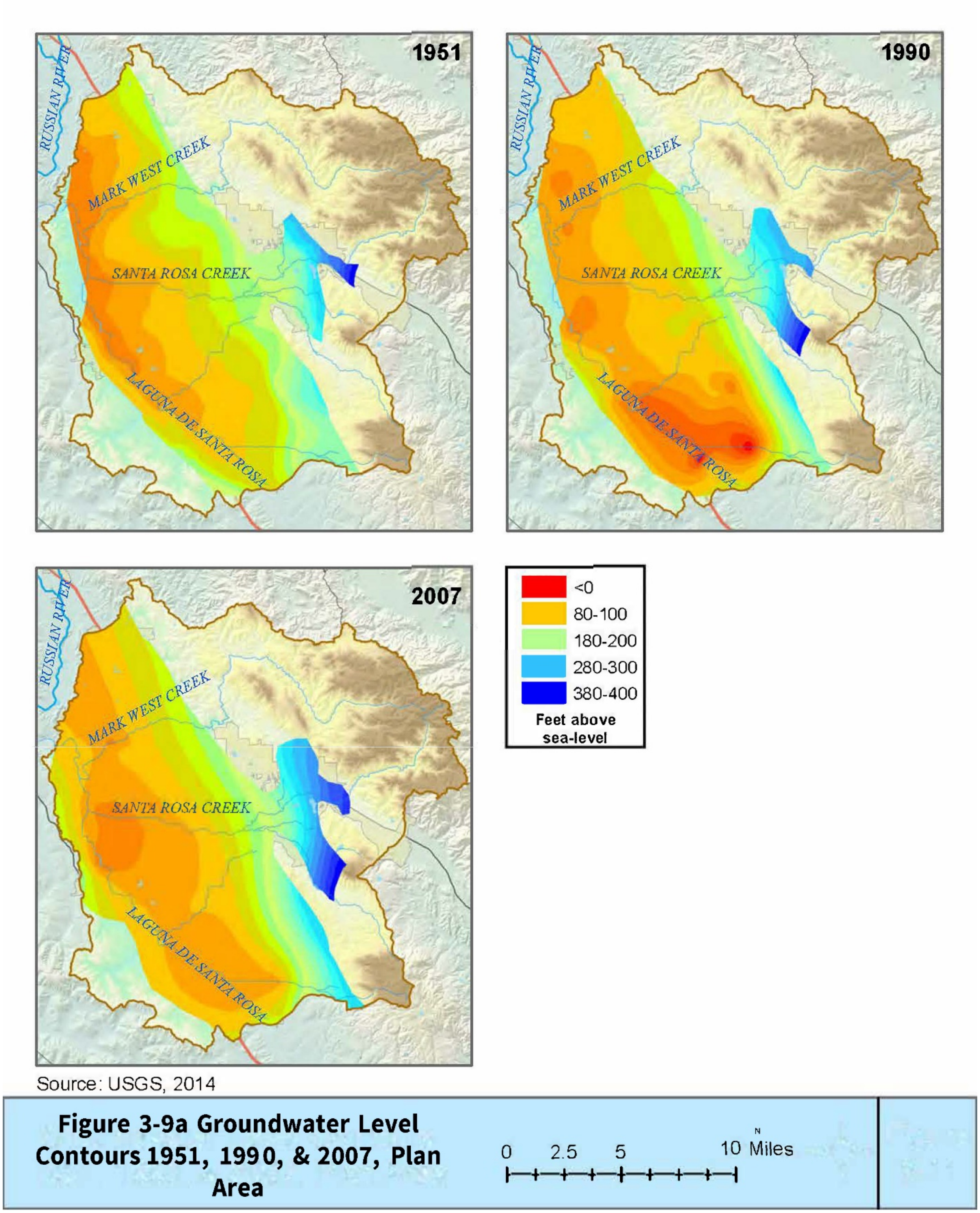


Figure 3-9a. Groundwater-level Contours 1951, 1990, and 2007 Plan Area

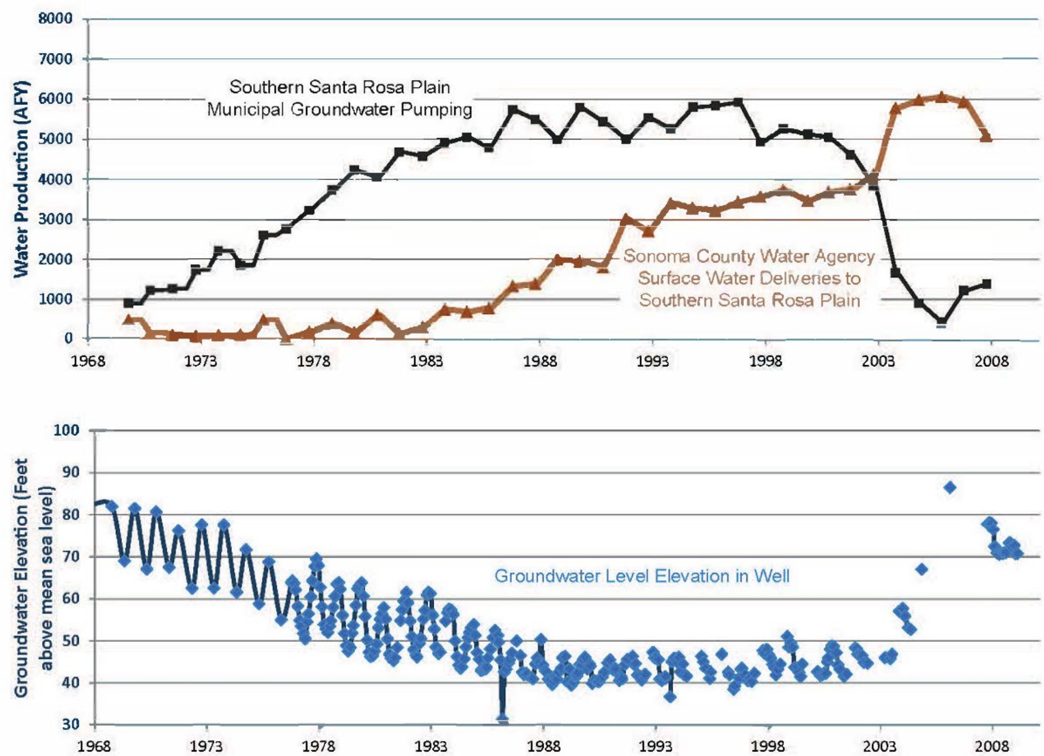
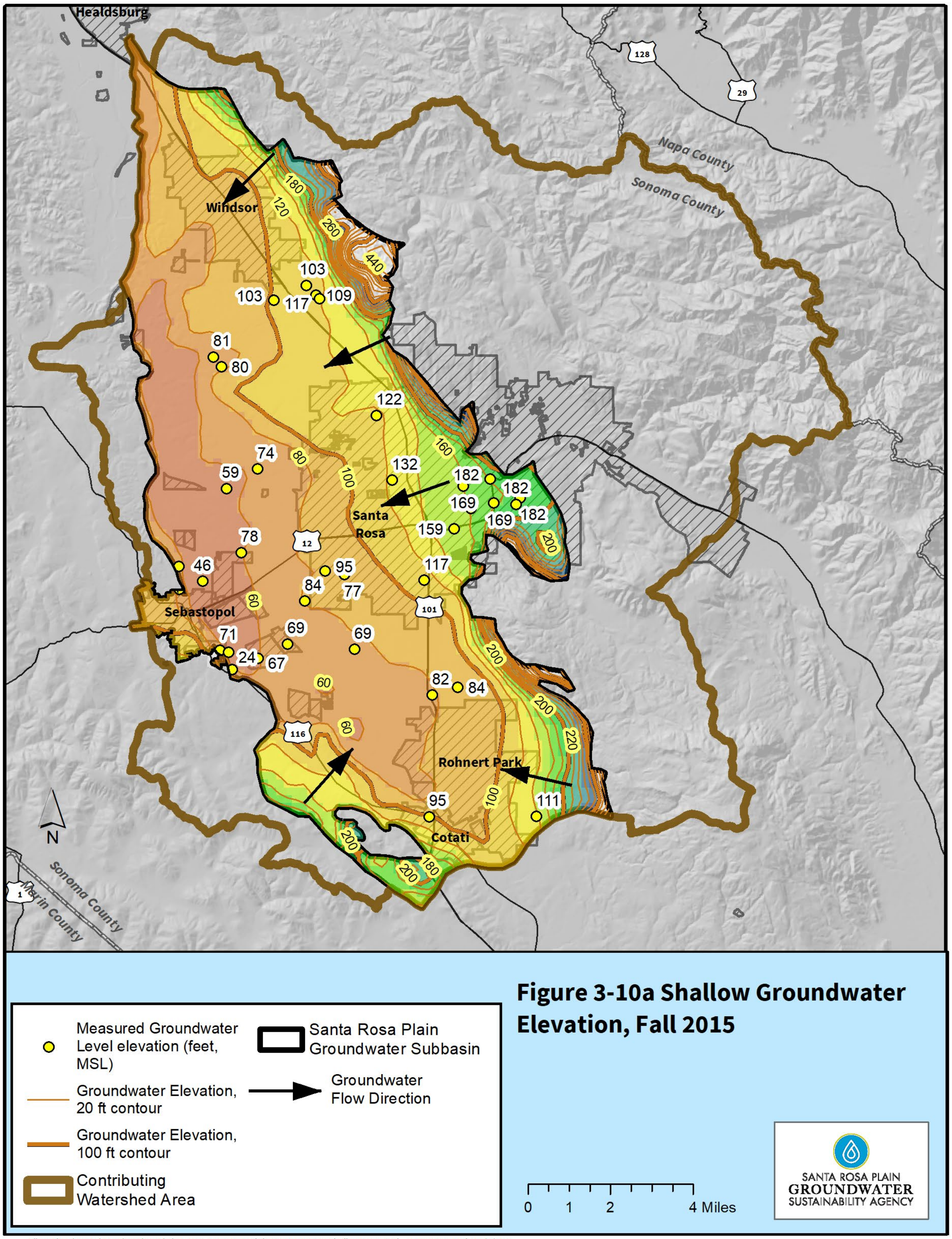


Figure 3-9b Total Annual Pumping, Southern SRP, Surface Water Deliveries, and Groundwater Levels, 1968-2008

Figure 3-9b. Total Annual Pumping, Southern SRP, Surface Water Deliveries, and Groundwater Levels, 1968-2008

Groundwater-elevation contours for spring 2007 (**Figure 3-9a**) show higher water levels in the Rohnert Park-Cotati area, which coincided with a substantial pumpage reduction at City of Rohnert Park wells, primarily due to increased imports of Russian River water provided by the Sonoma Water, as well as increased conservation and recycled water use. The reduction of the 1990s groundwater depression suggests that reduced pumping in the Rohnert Park-Cotati area allowed groundwater levels to recover to elevations typical of the early 1970s.

More recent groundwater-elevation maps prepared for the Groundwater Management Plan and for this GSP contour the shallow aquifer system and deeper aquifer system separately based on water-level data from the shallow and deep aquifer system wells, respectively. Groundwater-elevation contour maps for the shallow and deep aquifers for the fall and spring seasons of 2015 and 2018 are shown on **Figures 3-10a** through **3-10h**.



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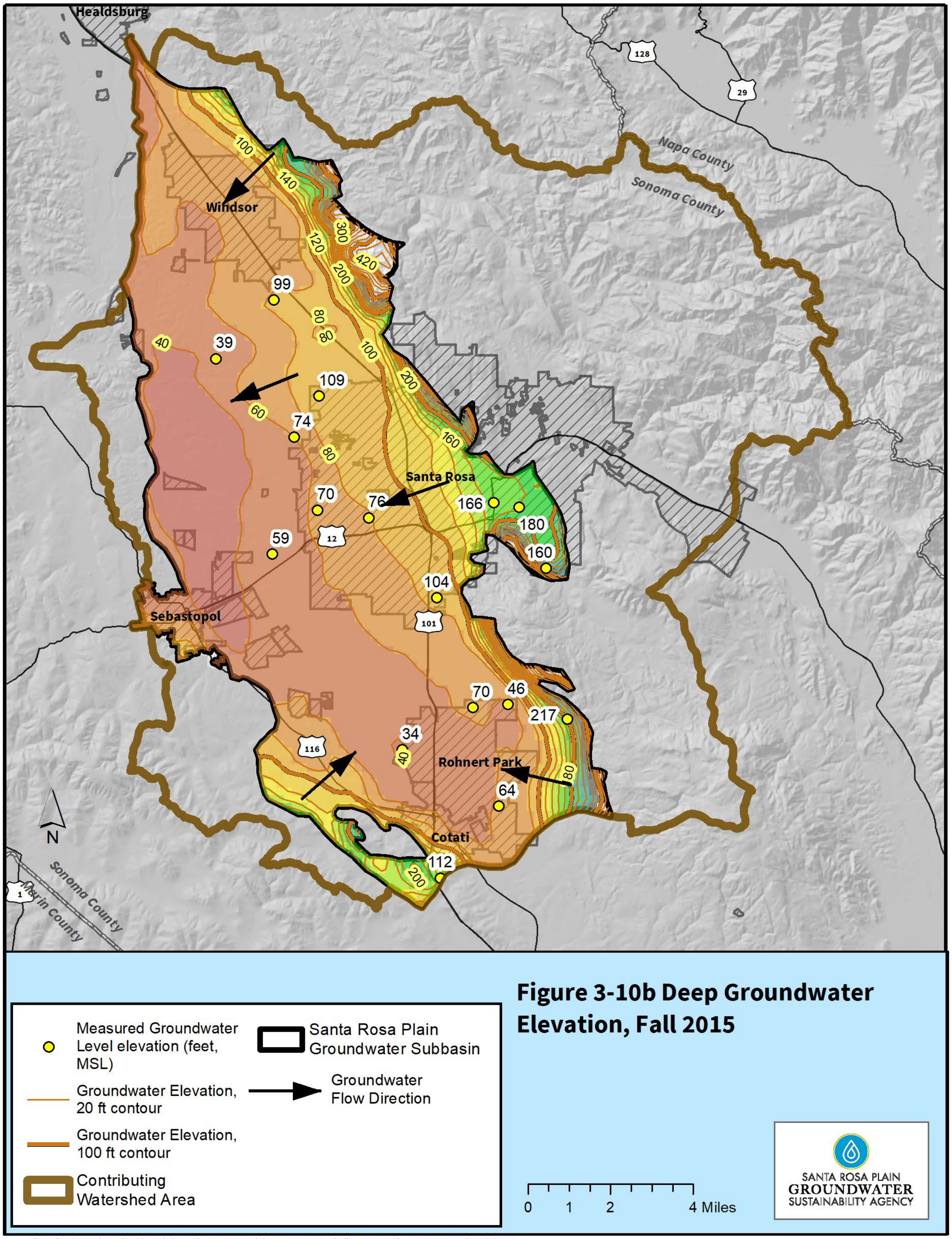
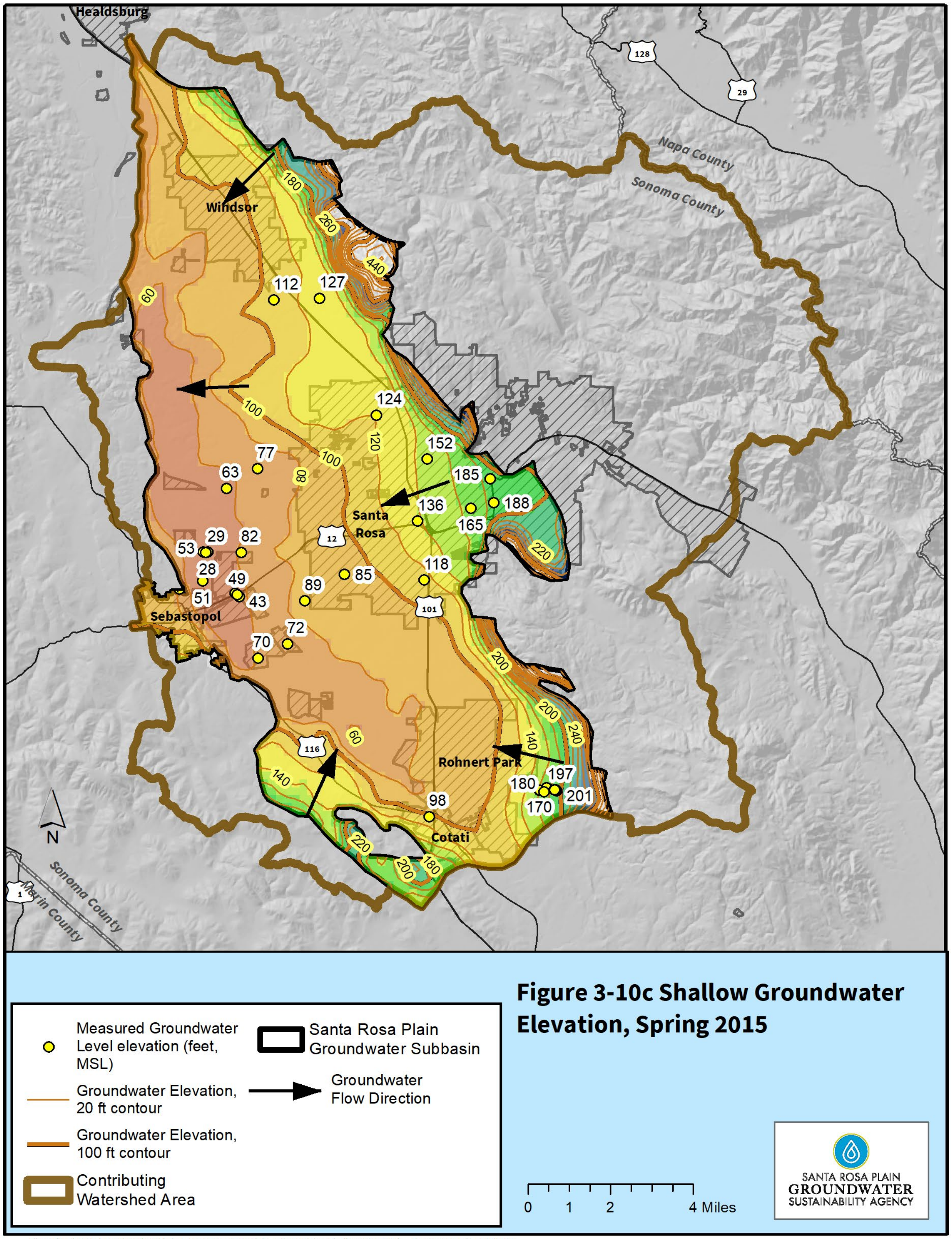
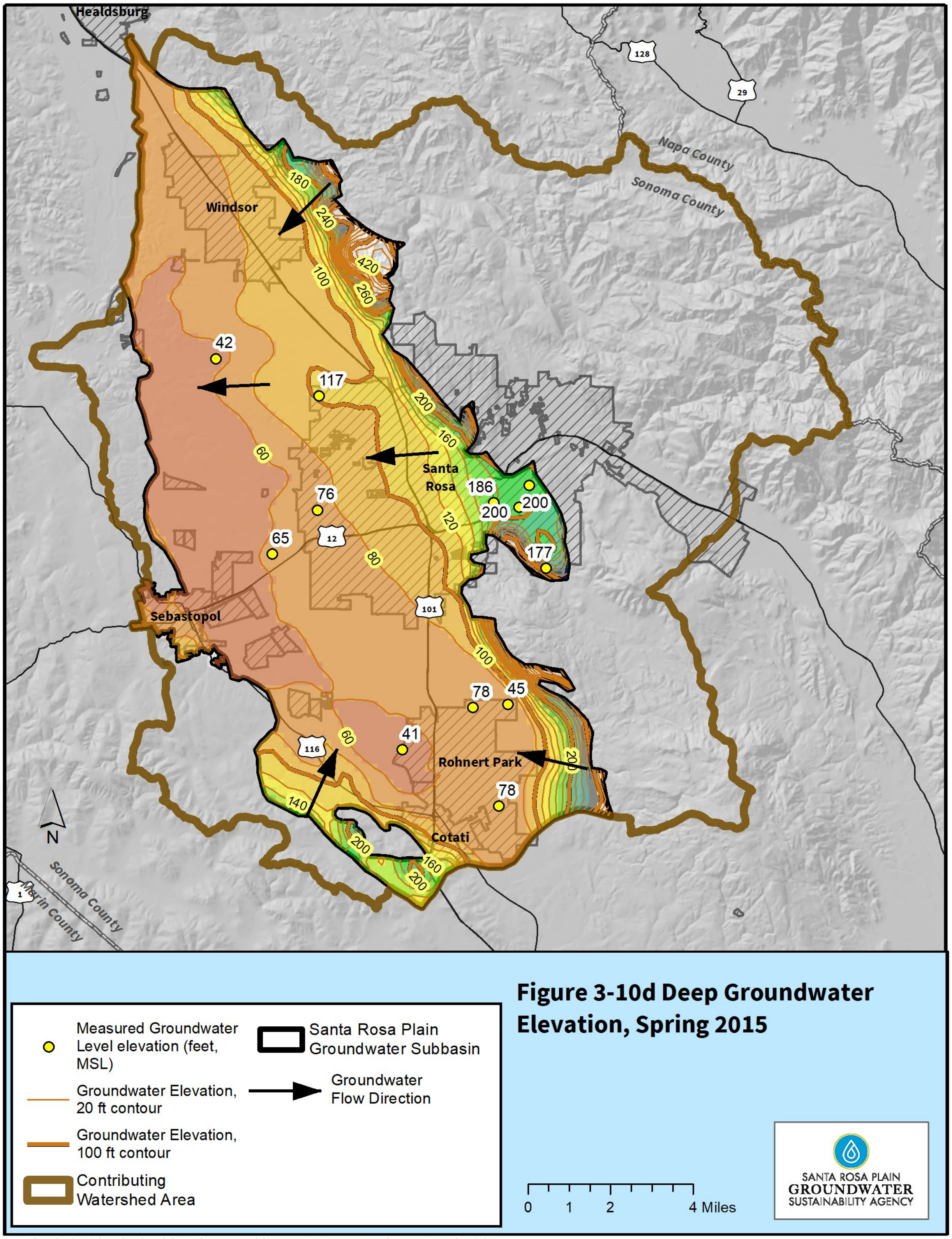
Figures 3-10a. Shallow Groundwater Elevation, Fall 2015



Figures 3-10b. Deep Groundwater Elevation, Fall 2015



Figures 3-10c. Shallow Groundwater Elevation, Spring 2015



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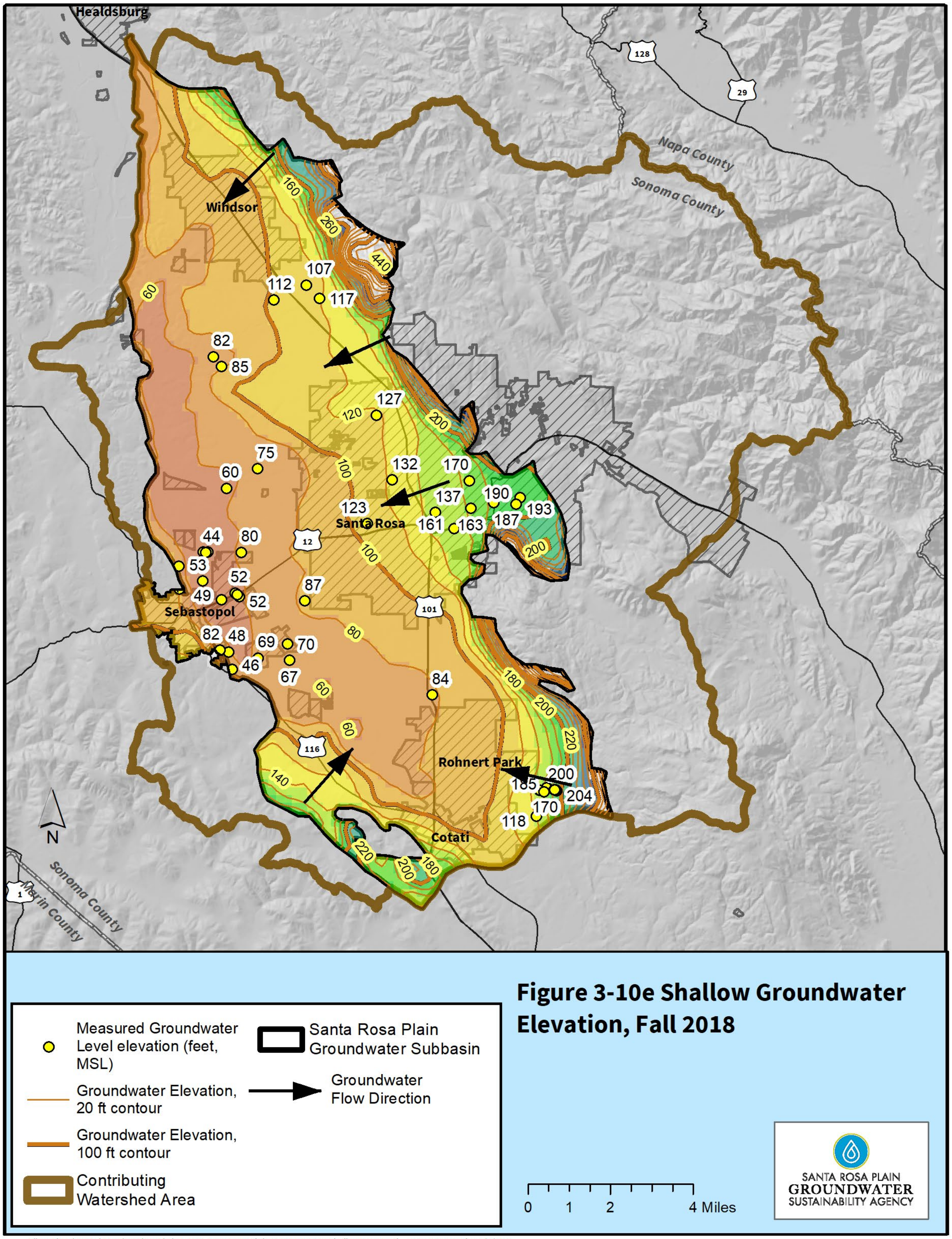
Figures 3-10d. Deep Groundwater Elevation, Spring 2015



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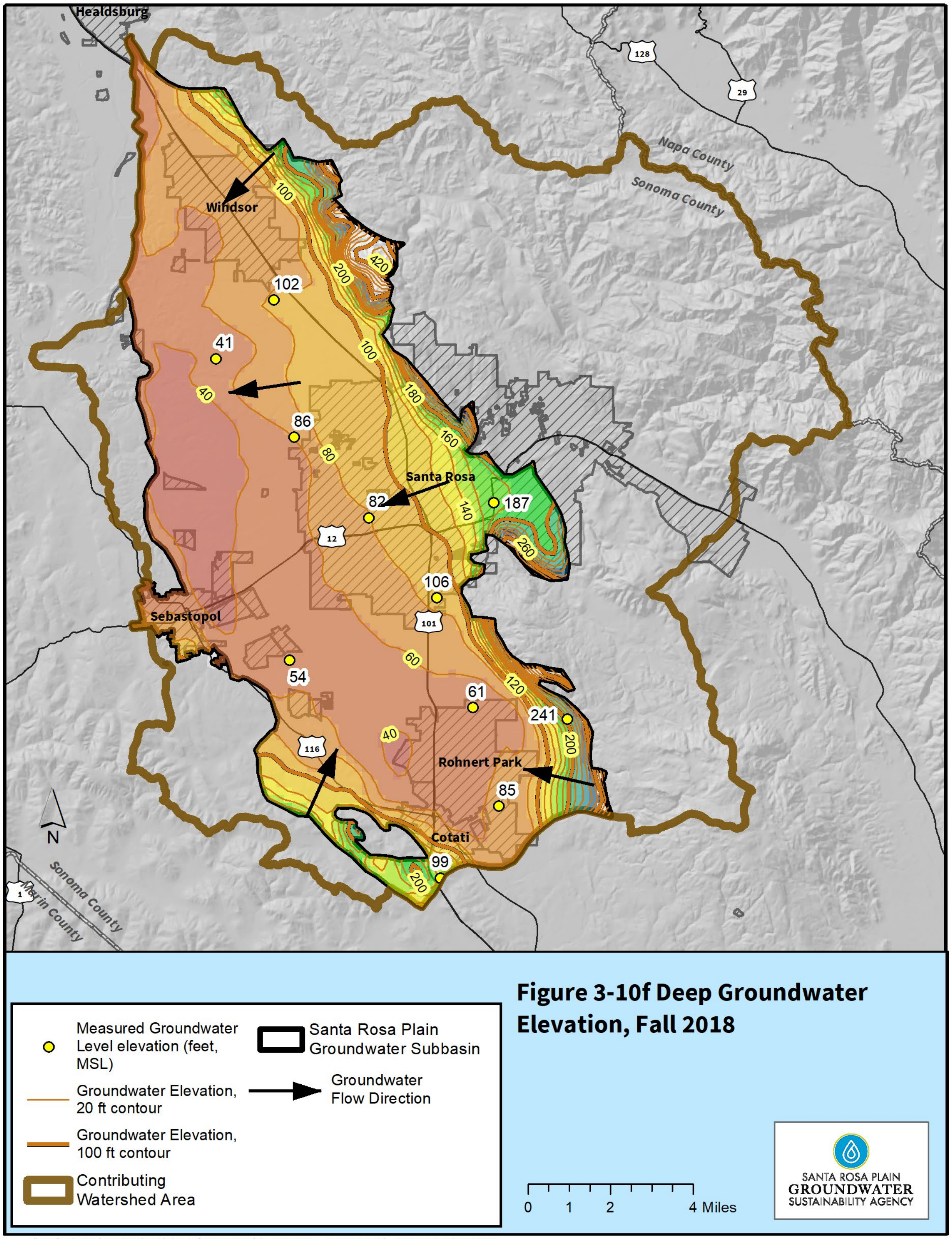
Figures 3-10e. Shallow Groundwater Elevation, Fall 2018



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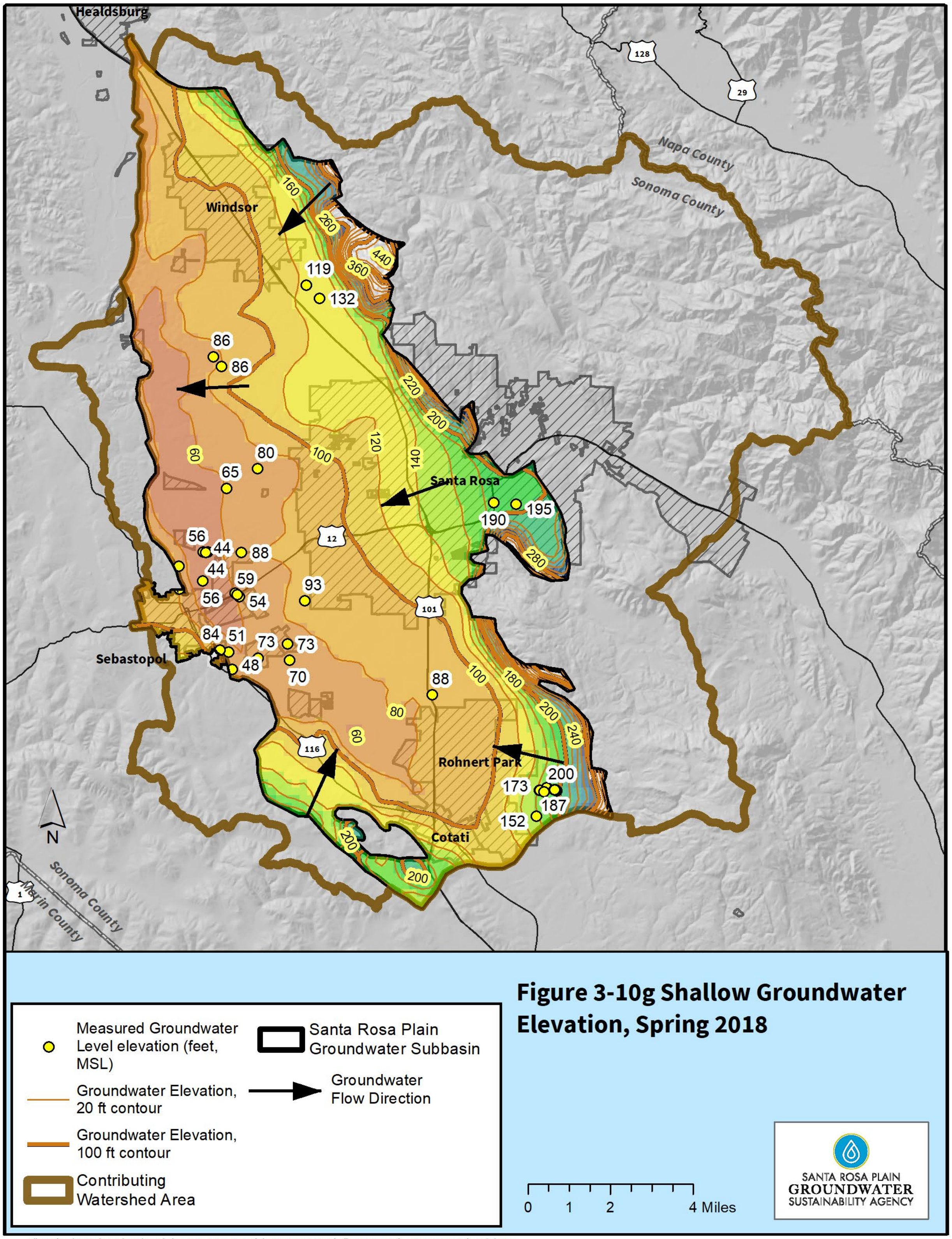
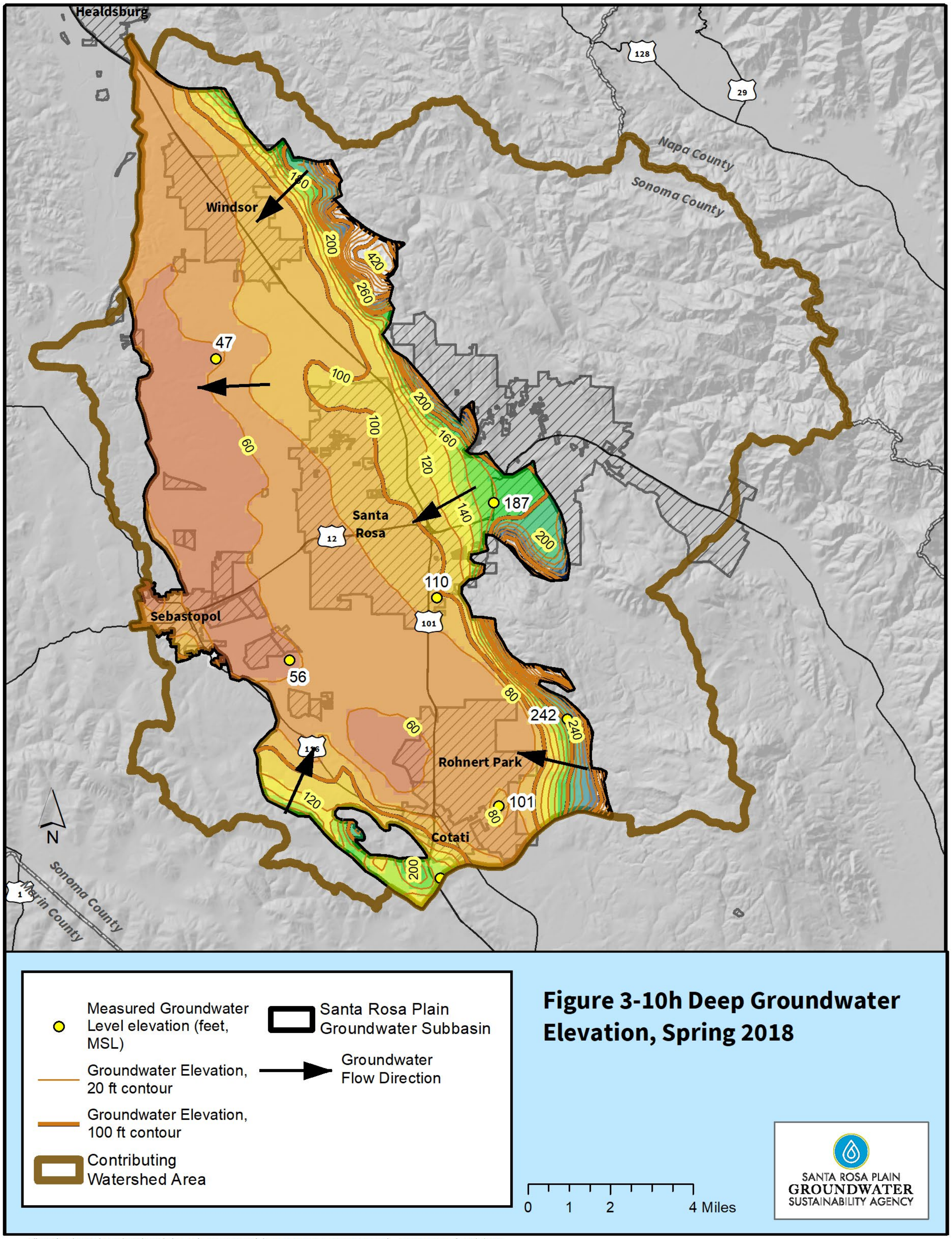
Figures 3-10f. Deep Groundwater Elevation, Fall 2018



Figures 3-10g. Shallow Groundwater Elevation, Spring 2018



Figures 3-10h. Deep Groundwater Elevation, Spring 2018

Groundwater-elevation contour maps for the shallow aquifer indicate that groundwater in the Subbasin generally flows westward from recharge areas in the Sonoma and Mayacamas Mountains, toward the Laguna de Santa Rosa, the primary discharge area (**Figures 3-10a**, **c**, **e**, and **g**). From the south end and west side of the valley, groundwater flows northwesterly and east, respectively toward the Laguna de Santa Rosa. The spring water levels are slightly higher in the WY 2018 (**Figure 3-10c**), which follows the wet WY 2017, compared to the shallow water levels in 2015, which occurs in the midst of a below-average period of precipitation (**Figure 3-10g**). The deep aquifer generally mirrors that of the shallow aquifer, but with smoother changes in groundwater elevation (**Figures 3-10b**, **d**, **f**, and **h**). Comparison between the shallow and deep aquifer system groundwater-elevation contour maps indicates that groundwater elevations in the deeper zone aquifers are approximately 10 to 40 feet lower than groundwater elevations in the shallow aquifer system in the Subbasin (**Figures 3-10b**, **d**, **f**, and **h**). Such vertical differences induce a downward flow from the shallow to the deeper aquifer. Comparing these recent measurements with the historical contour maps described previously suggest two groundwater pumping depressions in the southern and western portions of the Santa Rosa Plain have continued to exhibit recovery of groundwater levels.

It is important to note that groundwater elevations measured in nearby wells can be highly variable due to differences in well design (that is, the depth and length of well-screen intervals) and the spatial variations in aquifer materials (which can vary abruptly due to the complex geologic conditions and numerous fault zones present in the Subbasin). Therefore, the associated groundwater-level contour maps represent generalized groundwater flow patterns and should not be used to interpret more localized or site-specific conditions.

3.2.2.2 Groundwater-level Trends

Temporal changes in groundwater levels were evaluated for both long-term (wells with 10 or more years of data) trends and short-term (for example, seasonal) trends using data collected from the monitoring program. In general, longer-term trends were evaluated using data collected on a monthly to semiannual basis and short-term trends were evaluated using data collected on a more frequent basis (for example, monthly to hourly or less) using data from wells instrumented with pressure transducers.

Long-term Trends

Representative hydrographs for selected wells distributed throughout the Subbasin are shown on **Figures 3-11a** through **3-11d**. Additionally, hydrographs for all wells included in the groundwater-level monitoring program are provided in **Appendix 3-B**. These hydrographs present the change in groundwater elevation (vertical axis in feet) over time (horizontal axis in years).

As indicated on **Figures 3-11a** through **3-11d**, nearly all of the hydrographs indicate relatively stable groundwater-level conditions over time or increasing trends with the exception of wells within the southern portion of the Subbasin. A few hydrographs in the Cotati area show a decline in groundwater levels for the late 1970s and 1980s, which reached an historic low in the early 1990s, followed by recovery in the early 2000s (**Figure 3-11a**).

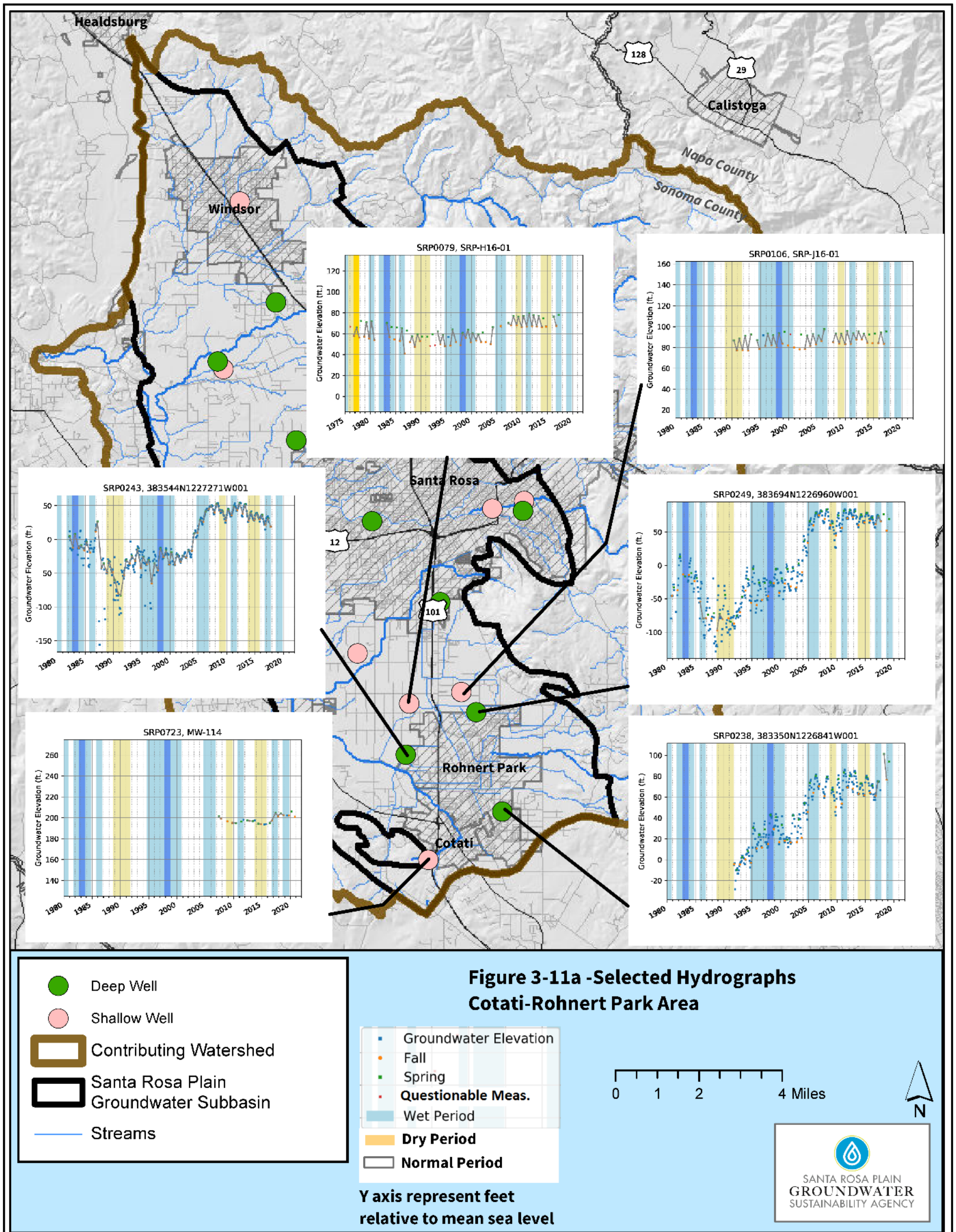


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Figure 3-11a. Selected Hydrographs Cotati-Rohnert Park Area

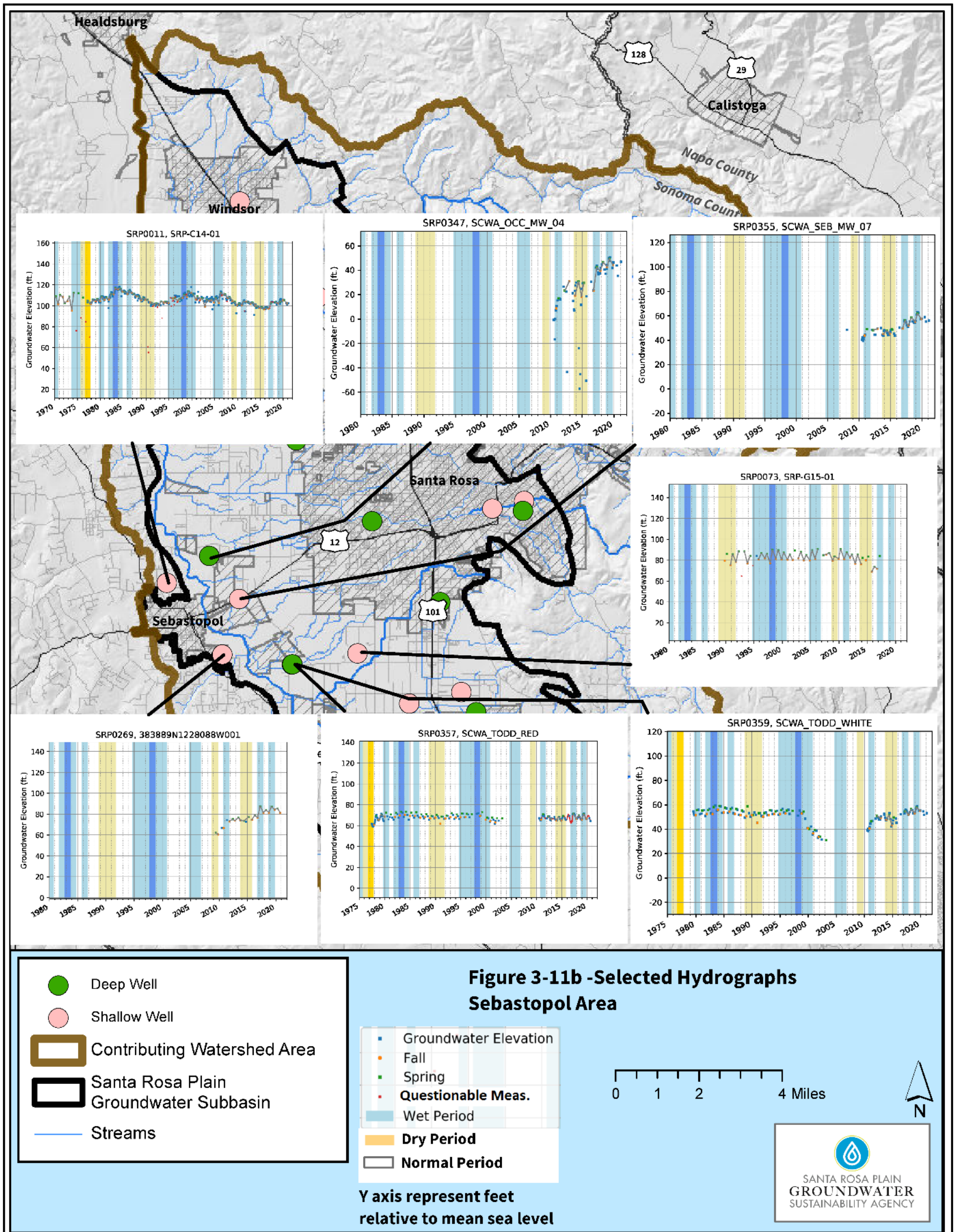

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Figure 3-11b. Selected Hydrographs Sebastopol Area

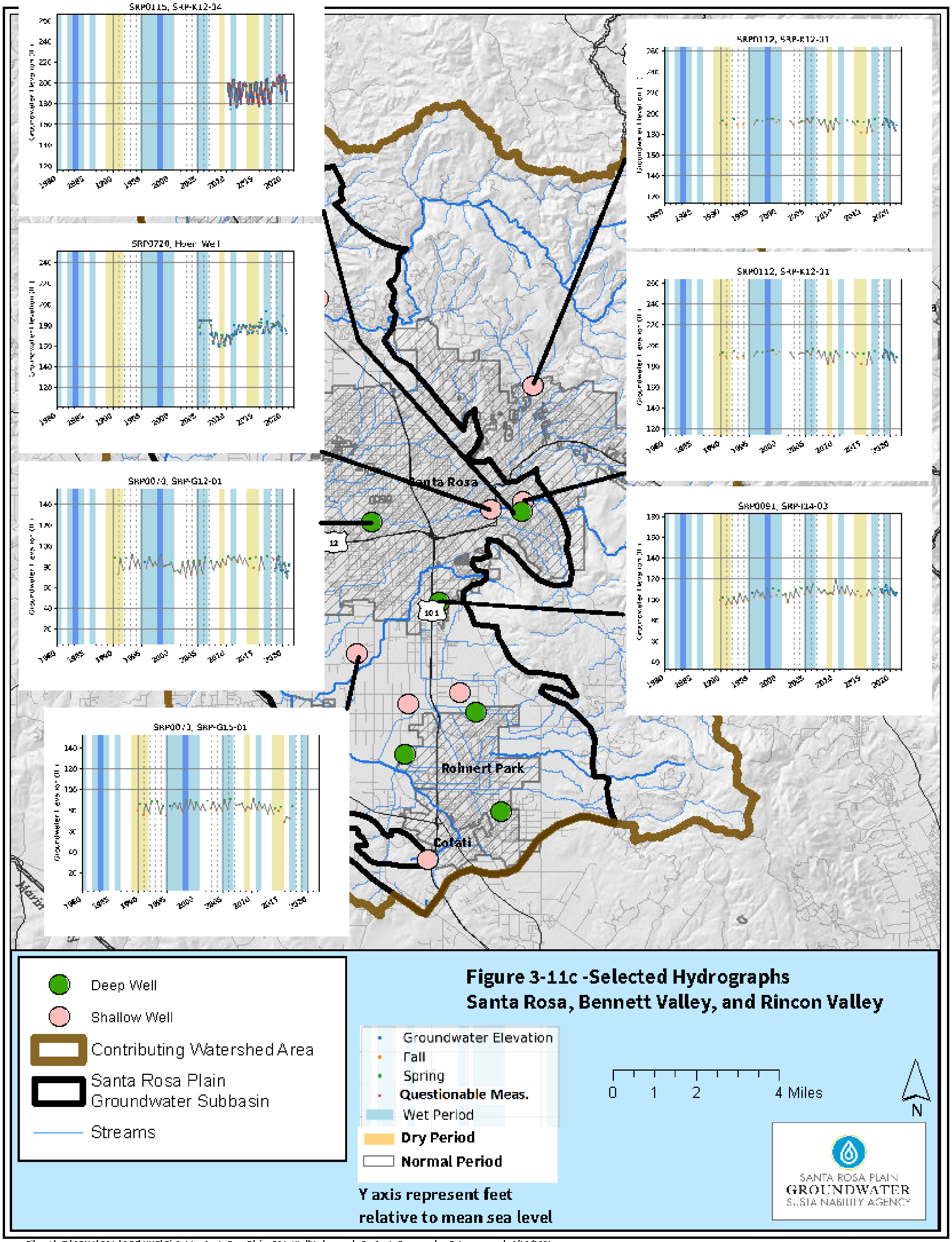

Figure 3-11c. Selected Hydrographs Santa Rosa, Bennett Valley, and Rincon Valley

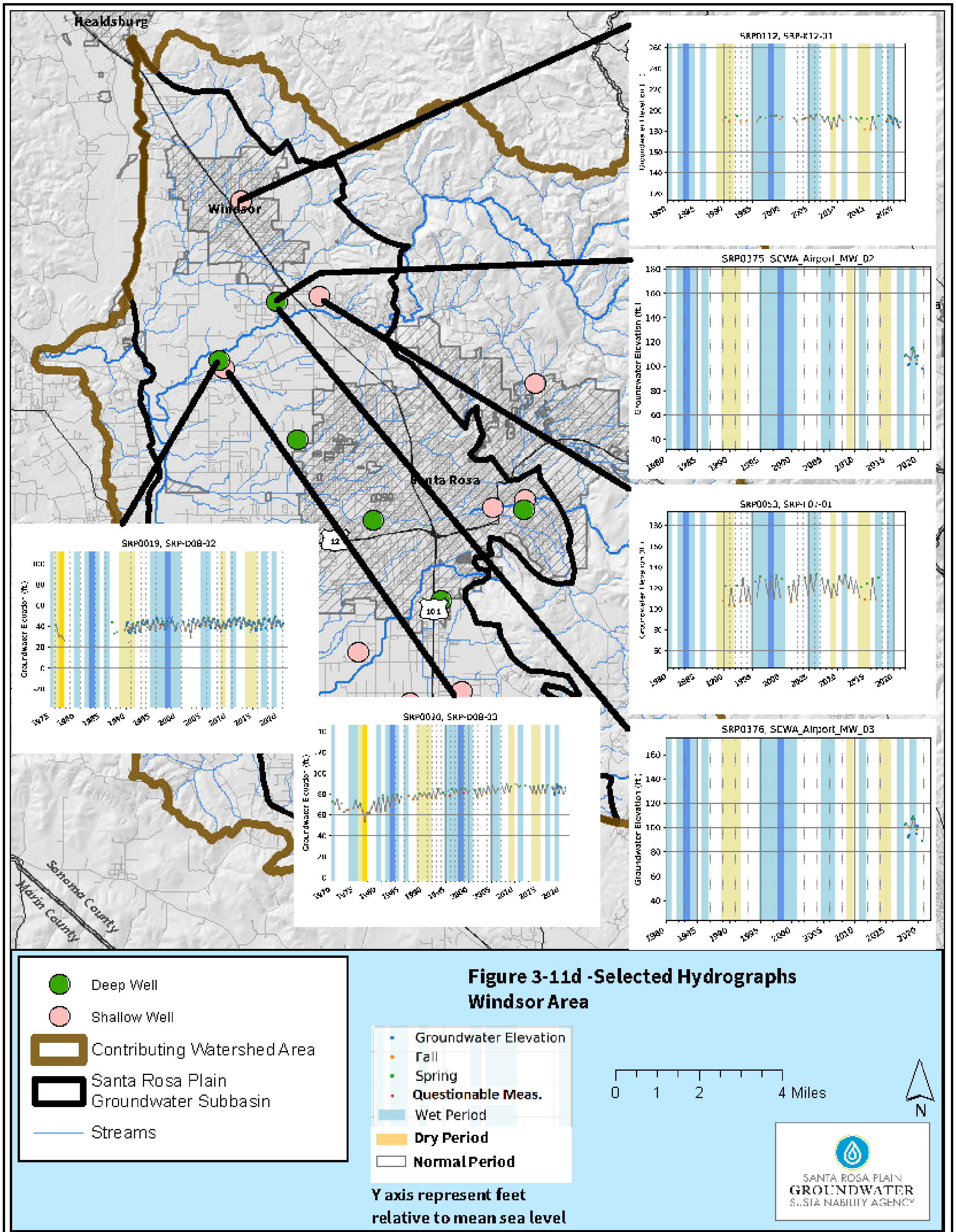

Figure 3-11d. Selected Hydrographs Windsor Area

As described previously the historical groundwater declines in this area are primarily associated with increases in municipal groundwater pumping related to population growth through the 1990s coupled with droughts in 1976-77 and 1987-92, and the recovered groundwater levels coincide with the aforementioned reduced pumping in this area since the early 2000s.

To further evaluate trends for wells that have a minimum of 10 years of recent groundwater-level data, 10-year trend lines (based on the span of available data between 2010 and 2020) were applied to spring groundwater levels on the hydrographs to depict overall trends for these time periods. The slope of the trend lines was computed using the method of ordinary least squares linear regression to estimate the change in groundwater level in feet per year (ft/yr). These computed groundwater-level changes are provided on **Figures 3-12a** and **3-12b** for the shallow and deep aquifer systems, respectively, to display the average groundwater-level change per year at all wells with data spanning the most recent 10 years.

As illustrated on **Figure 3-12a**, most of the shallow aquifer zone wells (31 of 37 wells) exhibit relatively stable groundwater-level trends (change of less than +/- 1 ft/yr) and six wells exhibit increasing trends with the majority of those wells located along the western Subbasin boundary.

Figure 3-12b shows that groundwater-level trend data are more limited in the deeper zone wells (a total of 24 wells are included in the trend analysis). Seven of the 24 wells exhibit relatively stable groundwater-level trends (change of less than +/- 1 ft/yr) and 15 wells located in the southern portions of the Subbasin and along the western boundary exhibit increasing trends with several exhibiting increases of more than 3 ft/yr. The only wells exhibiting decreasing trends are located east and outside of the Subbasin within the contributing watershed area.

Seasonal and Short-term Trends

A number of production and monitoring wells within the Subbasin have been outfitted with pressure transducer dataloggers to assess short-term groundwater-level trends. These include monitoring wells in the vicinity of Sonoma Water production wells along the western edge of the Subbasin, a series of shallow monitoring wells along Copeland Creek in the southeastern corner of the Subbasin, City of Santa Rosa production wells (active and inactive), test wells and monitoring wells located throughout and adjacent to the Subbasin, and several inactive City of Rohnert Park production wells (**Figure 3-13a**).

City of Rohnert Park Wells

Four City of Rohnert Park inactive deep aquifer system production wells (Wells 17, 24, 26, and 38) are currently monitored using pressure transducer dataloggers (**Figure 3-13b**). Prior to 2006, groundwater-level elevations measured in the Rohnert Park wells were significantly lower than they are today.

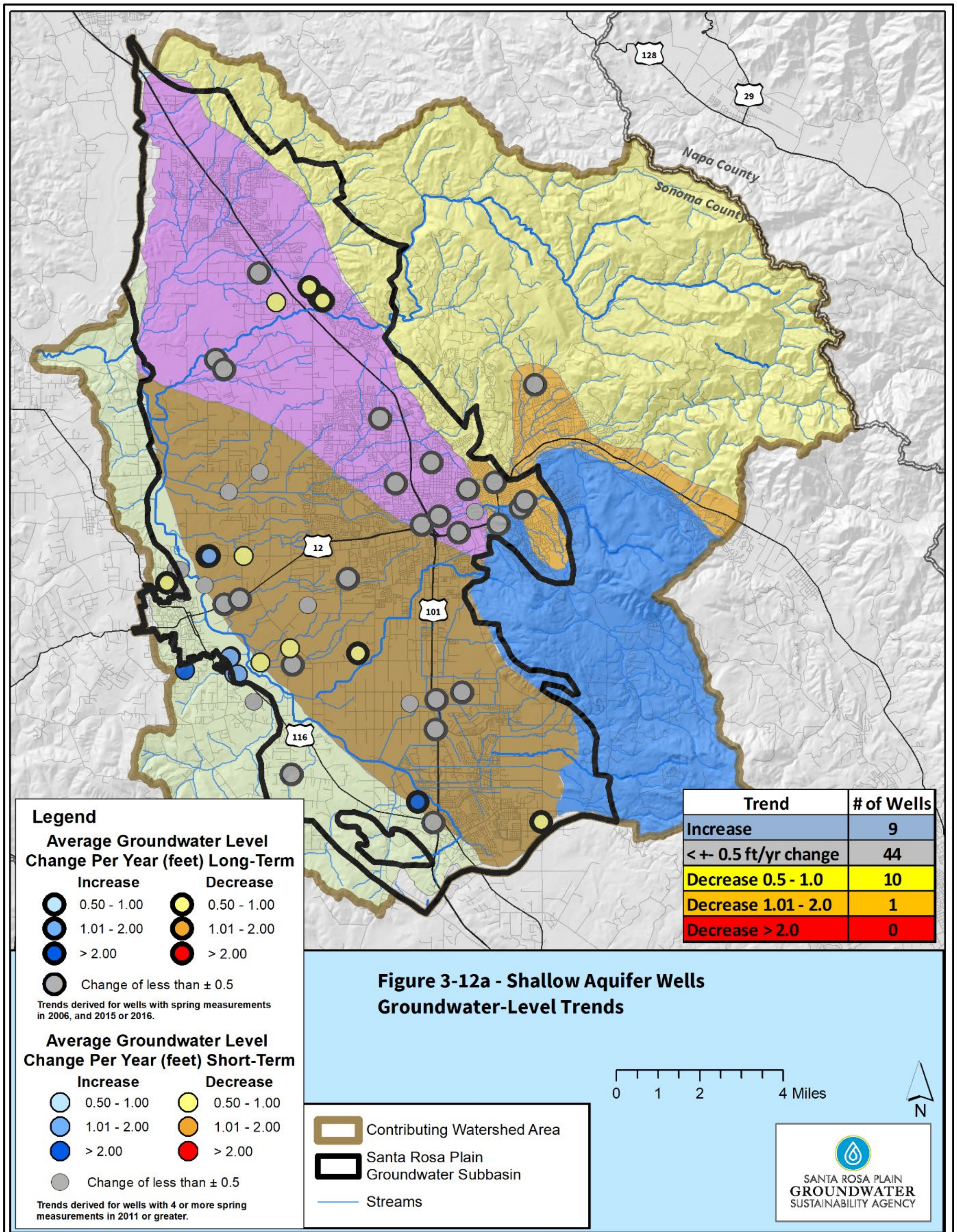

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Figure 3-12a. Shallow Aquifer Wells Groundwater-level Trends

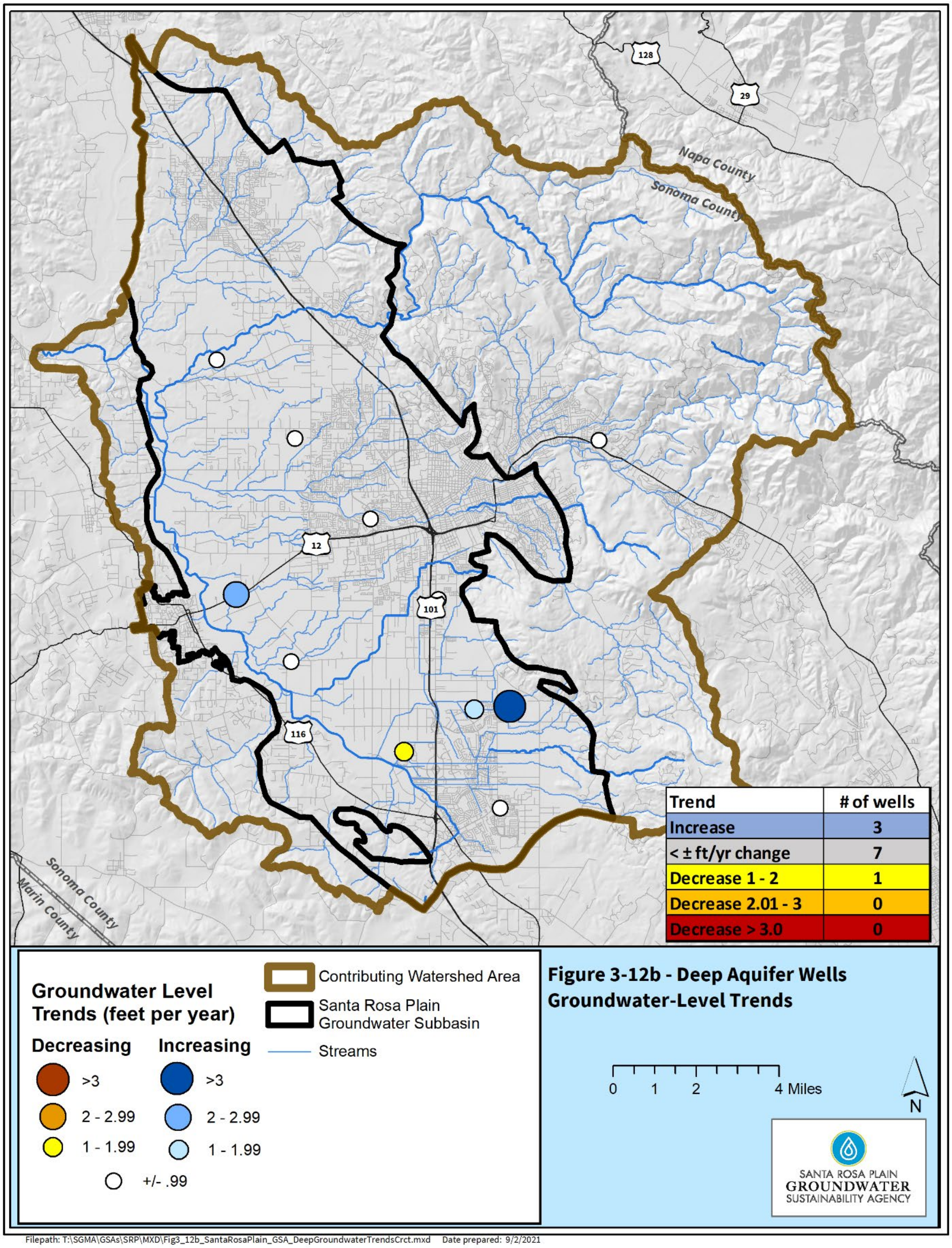

Figure 3-12b. Deep Aquifer Wells Groundwater-level Trends

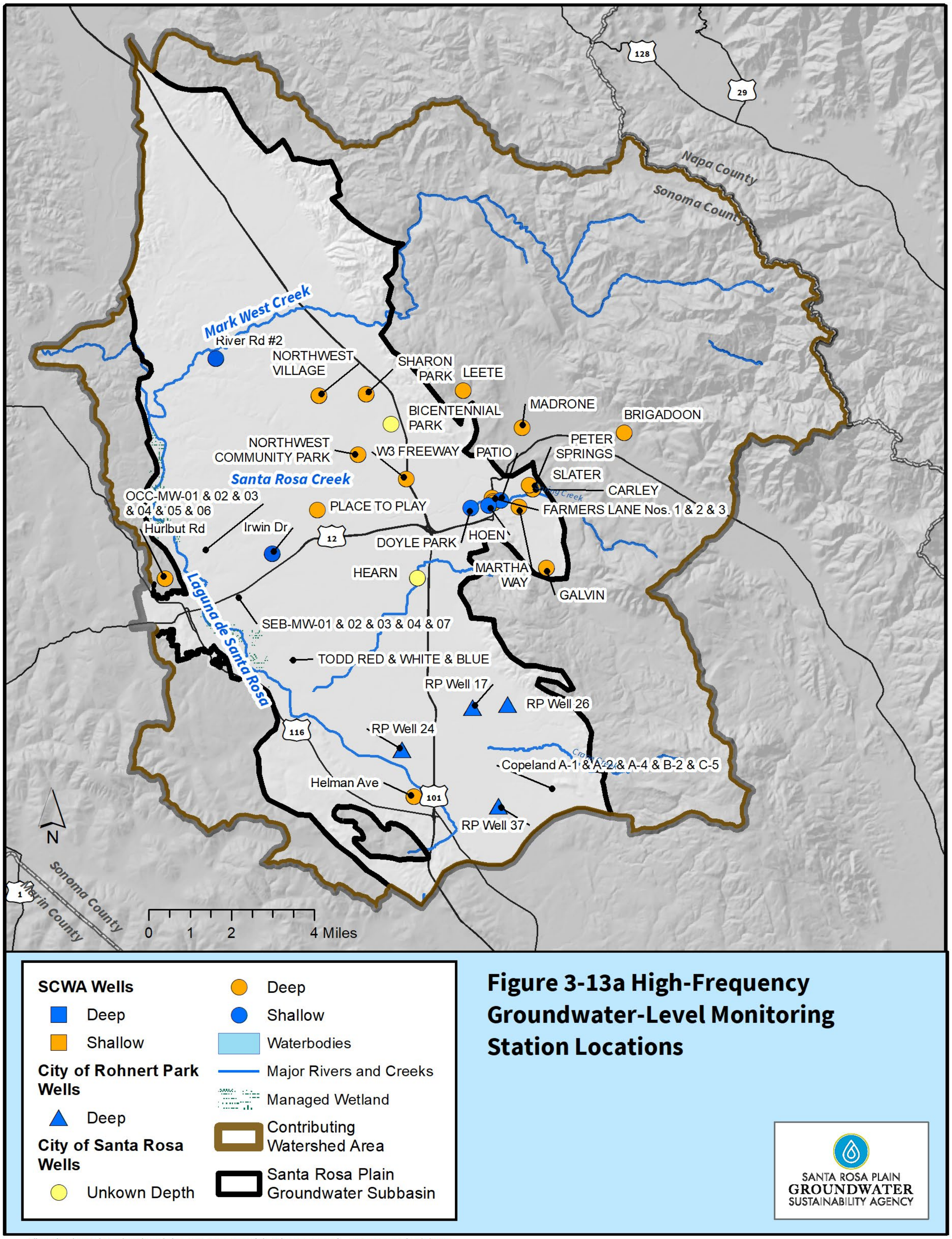

Figure 3-13a. High-frequency Groundwater-level Monitoring Station Locations

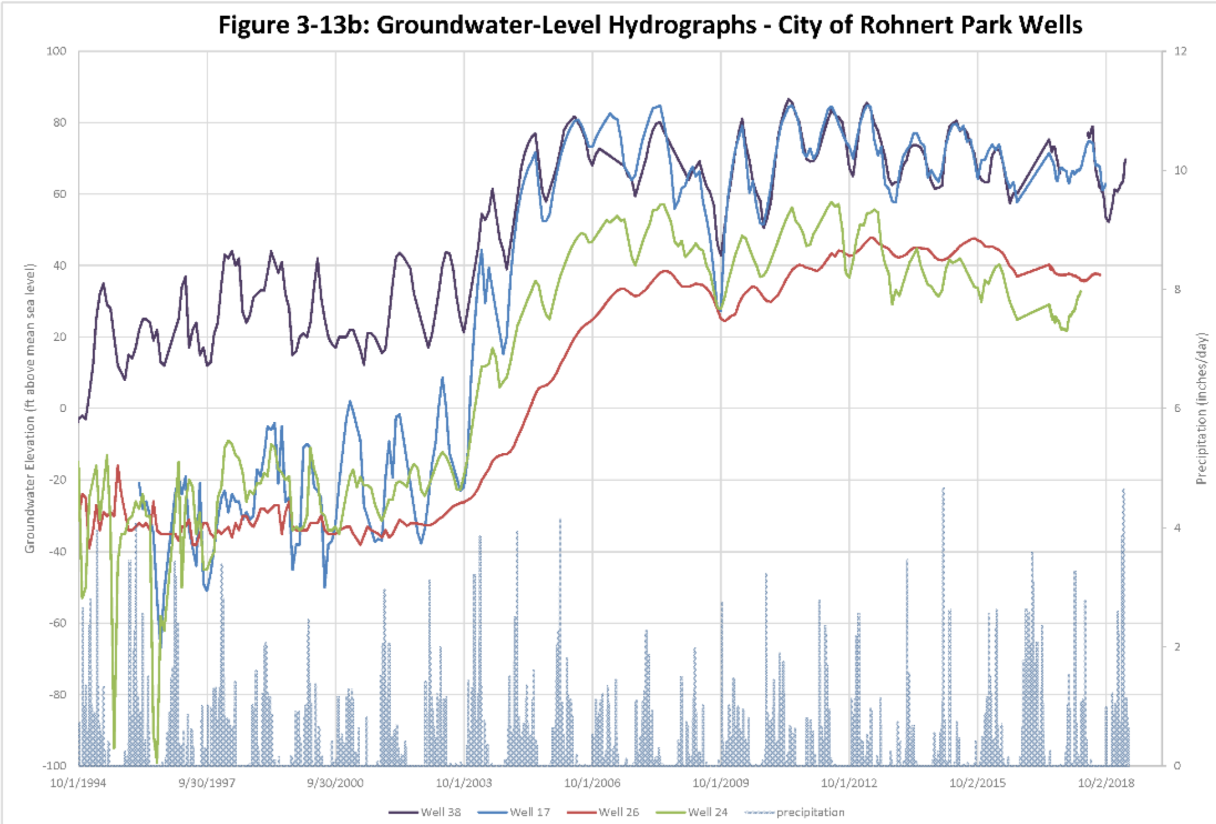

Figure 3-13b. Groundwater-level Hydrographs – City of Rohnert Park Wells

From 2006 to present, groundwater-level elevations have been relatively stable in the Rohnert Park wells, with exception of a decline of approximately 20 feet in Well 24 since approximately 2013. Since WY 2006, seasonal groundwater-level fluctuations range from approximately 5 to 30 feet and are most pronounced in Wells 17 and 38, and least pronounced in Well 26. Seasonal high groundwater levels are typically observed in March to June and seasonal low groundwater levels are typically observed in September to November in these wells.

City of Santa Rosa Wells

The City of Santa Rosa has monitored 23 high-frequency groundwater-level monitoring points with the frequency of water-level data collection ranging from monthly to once every 6 hours. This network includes the following:

- Six active or emergency/standby municipal production wells (five of these are completed within the deep aquifer system and one is completed within the shallow aquifer system)
- Five shallow aquifer system private wells monitored by the city
- Twelve deep aquifer system test wells and inactive former production wells that have been converted to monitoring wells (for data presentation and discussion purposes these deep

aquifer system wells are grouped into wells between 200 and 500 feet deep and wells that are deeper than 500 feet)

Groundwater-level hydrographs for the six active or emergency/standby municipal production wells (Farmers Lane No. 1, Farmers Lane No. 2, Farmers Lane No. 3, Leete Well, Carley Well, and Peter Springs Well) are shown on **Figure 3-13c**. All of these wells are more than 200 feet deep with the exception of the Peter Springs Well, which is 160 feet deep. Farmers Lane No. 1 and Farmers Lane No. 2 are both more than 1,000 feet deep. As shown on **Figure 3-13a**, these wells are all located along the eastern edge of the Subbasin (east of the Rodgers Creek Fault Zone), with the Leete Well located outside of the Subbasin, but within the contributing watershed area. In general, nonpumping groundwater levels are very stable in these wells with artesian conditions present in the Farmers Lane No. 1, Farmers Lane No. 2, and Leete wells. Seasonal groundwater-level fluctuations range from approximately 20 to 30 feet in the Farmers Lane No. 3, Carley, and Peter Springs Wells. Drawdown related to seasonal pumping of Farmers Lane Nos. 1 and 2 are also evident in the hydrographs for those two wells, in addition to the nearby Farmers Lane No. 3.

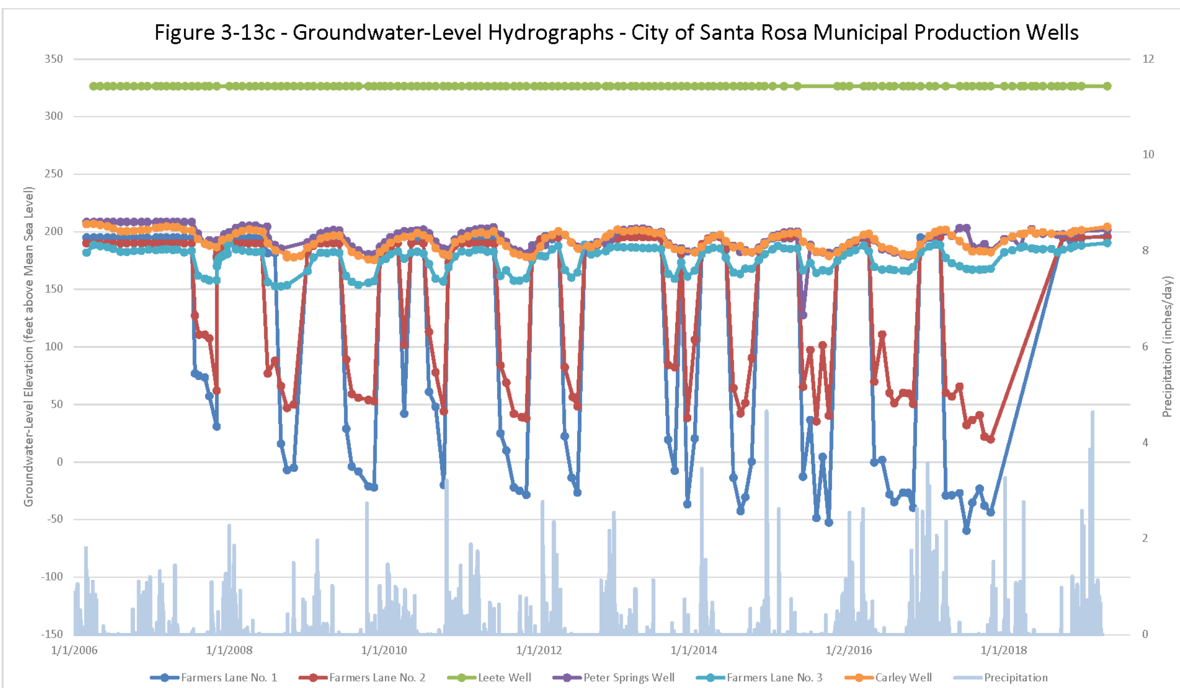

Figure 3-13c. Groundwater-level Hydrographs – City of Santa Rosa Municipal Production Wells

Groundwater-level hydrographs for five City of Santa Rosa shallow aquifer system (total depths ranging from 82 to 200 feet) high-frequency groundwater-level monitoring points are shown on **Figure 3-13d**. The locations of these wells are shown on **Figure 3-13a**. The Patio, Doyle, and Hoen Wells are all in the vicinity of the Farmers Lane production wells on the eastern edge of the Subbasin. These wells exhibit seasonal groundwater-level fluctuations ranging from approximately 5 to 25 feet, which are most pronounced in the Patio Well and least pronounced in the Doyle Well. Two of the wells (Helman Avenue Well and Hurlbut Road Well), which have subsequently been discontinued from monitoring, are located outside of the City of Santa Rosa (**Figure 3-13a**). Groundwater-level data from these wells do not exhibit pronounced seasonal fluctuations or responses to precipitation events. Occasional short-term declines, likely associated with local groundwater pumping, followed by subsequent recovery to relatively stable conditions are observed in both of these wells.

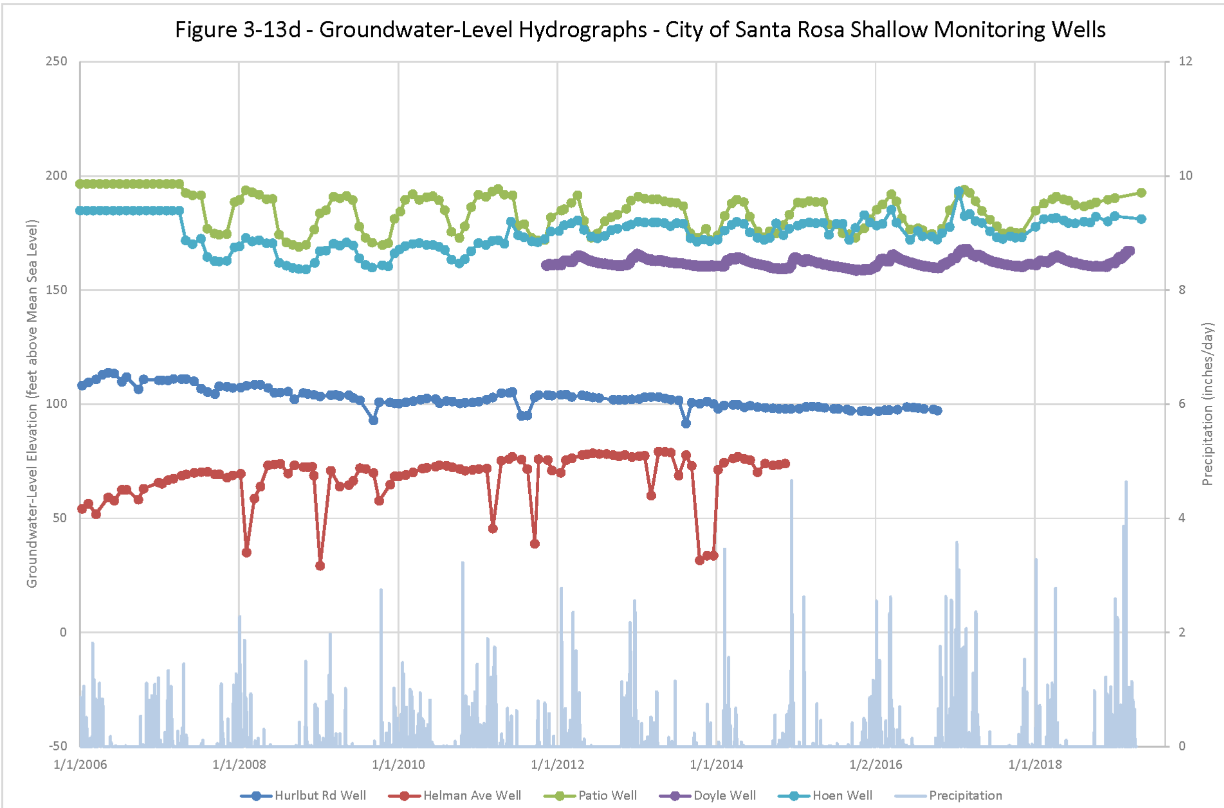

Figure 3-13d. Groundwater-level Hydrographs – City of Santa Rosa Shallow Monitoring Wells

Groundwater-level hydrographs for six City of Santa Rosa deep aquifer system (between 200 and 500 feet deep) high-frequency groundwater-level monitoring points are shown on **Figure 3-13e**. The locations of these wells are shown on **Figure 3-13a**. The Northwest Village and Sharon Park test wells exhibit similar hydrographs with stable groundwater-level elevations and seasonal fluctuations of approximately 10 feet. The Madrone and Brigadoon test wells are located outside of the Subbasin and within the contributing watershed area, in eastern Santa Rosa and exhibit similar hydrographs with seasonal groundwater-level fluctuations ranging from approximately 5 to 20 feet. The Galvin test well exhibits larger seasonal groundwater-level fluctuations up to approximately 50 feet. The Irwin Drive well exhibits seasonal groundwater-level declines, possibly related to local groundwater pumping, of up to 45 feet. The overall groundwater-level elevation trends for all of these wells during their respective observation periods appear to be very stable or increasing.

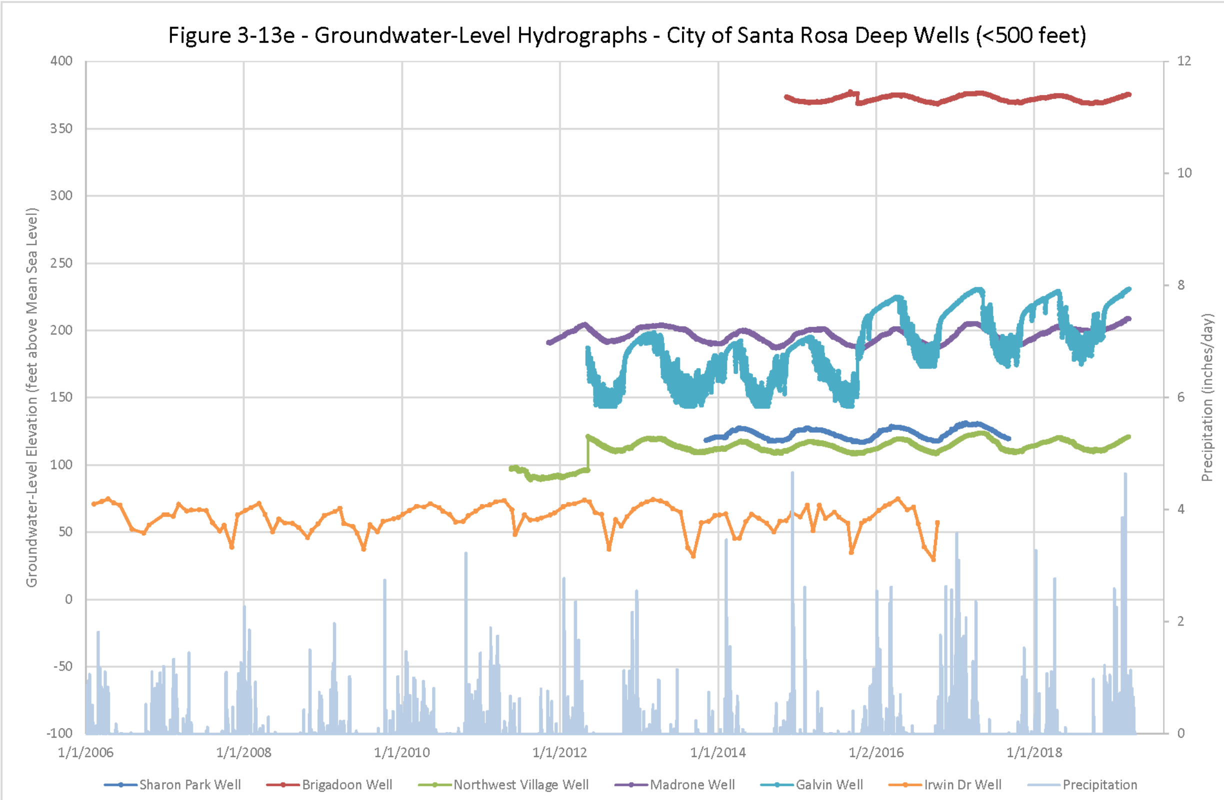

Figure 3-13e. Groundwater-level Hydrographs – City of Santa Rosa Deep Wells (<500 feet)

Groundwater-level hydrographs for six City of Santa Rosa deep aquifer system (greater than 500 feet deep) high-frequency groundwater-level monitoring points are shown on **Figure 3-13f**. The locations of these wells are shown on **Figure 3-13a**. The hydrographs for the Slater and Martha Way wells are nearly identical and depict seasonal groundwater-level fluctuations of approximately 20 to 25 feet. Seasonal groundwater-level fluctuations in the Freeway, Northwest Community Park, and Place 2 Play wells range from approximately 5 to 15 feet, and are most pronounced in the Freeway and Northwest Community Park wells and least pronounced in the Place 2 Play well. The hydrographs for these wells illustrate how seasonal fluctuations in the deep aquifer system are likely less pronounced and occur later (seasonal high groundwater levels are typically observed in April in the Freeway Well and in May in the Place 2 Play Well) toward the center of the Subbasin versus toward the eastern edge. The groundwater-level hydrograph for the River Road No. 2 well exhibits seasonal fluctuations ranging from approximately 5 to 10 feet with seasonal high elevations typically observed in April to June and seasonal low elevations typically observed in August to September. The overall groundwater-level elevation trends for all of these wells during their respective observation periods appear to be very stable.

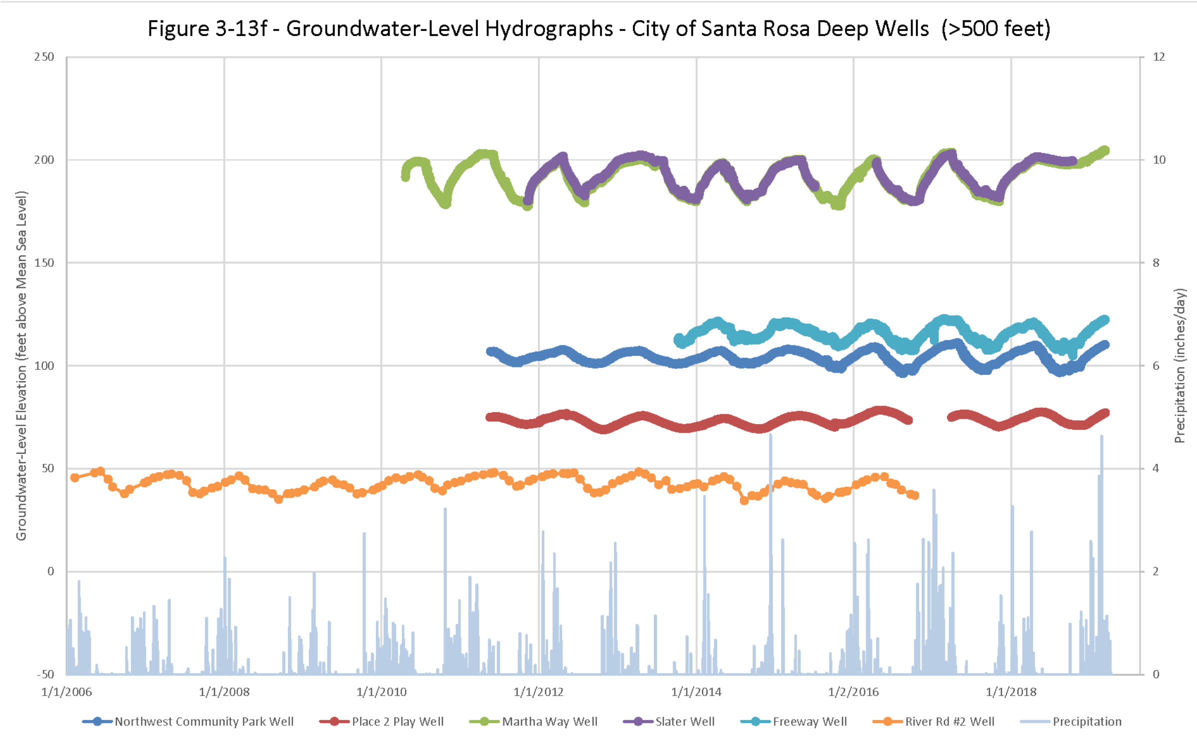

Figure 3-13f. Groundwater-level Hydrographs – City of Santa Rosa Deep Wells (>500 feet)

Sonoma Water Monitoring Wells

Sonoma Water conducts a high-frequency groundwater-level monitoring program in 14 dedicated monitoring wells in the vicinity of its Occidental Road, Todd Road, and Sebastopol water-supply wells (**Figure 3-13a**). Groundwater-level hydrographs for shallow and deep aquifer system monitoring wells in the vicinity of the Sonoma Water's supply wells are presented on **Figures 3-13g** and **3-13h**, respectively. In general, the data collected as part of the Sonoma Water's groundwater-level monitoring program indicate the following:

- Seasonal fluctuations in groundwater levels in the shallow aquifer wells on the order of 5 to 15 feet
- No discernable short-term responses to pumping cycles within shallower monitoring wells
- General stability of shallow zone groundwater levels, with the exception of shallow zone monitoring wells (OCC-MW-2, OCC-MW-3, and OCC-MW-5) located near the Occidental Road supply well, which exhibited declines ranging between 15 to 30 feet between approximately 2000 and 2009 followed by subsequent recovery or stabilization of groundwater levels from 2009 to present (**Figure 3-13g**)
- Rapid drawdown and recovery in response to pumping cycles within the deep aquifer monitoring wells perforated across the same horizon as the groundwater- supply wells (**Figure 3-13h**)

- An overall trend of lowering of deeper zone groundwater levels between approximately 2000 and 2009 when the groundwater-supply wells were operating relatively continuously, followed by subsequent recovery of groundwater levels from 2009 to present

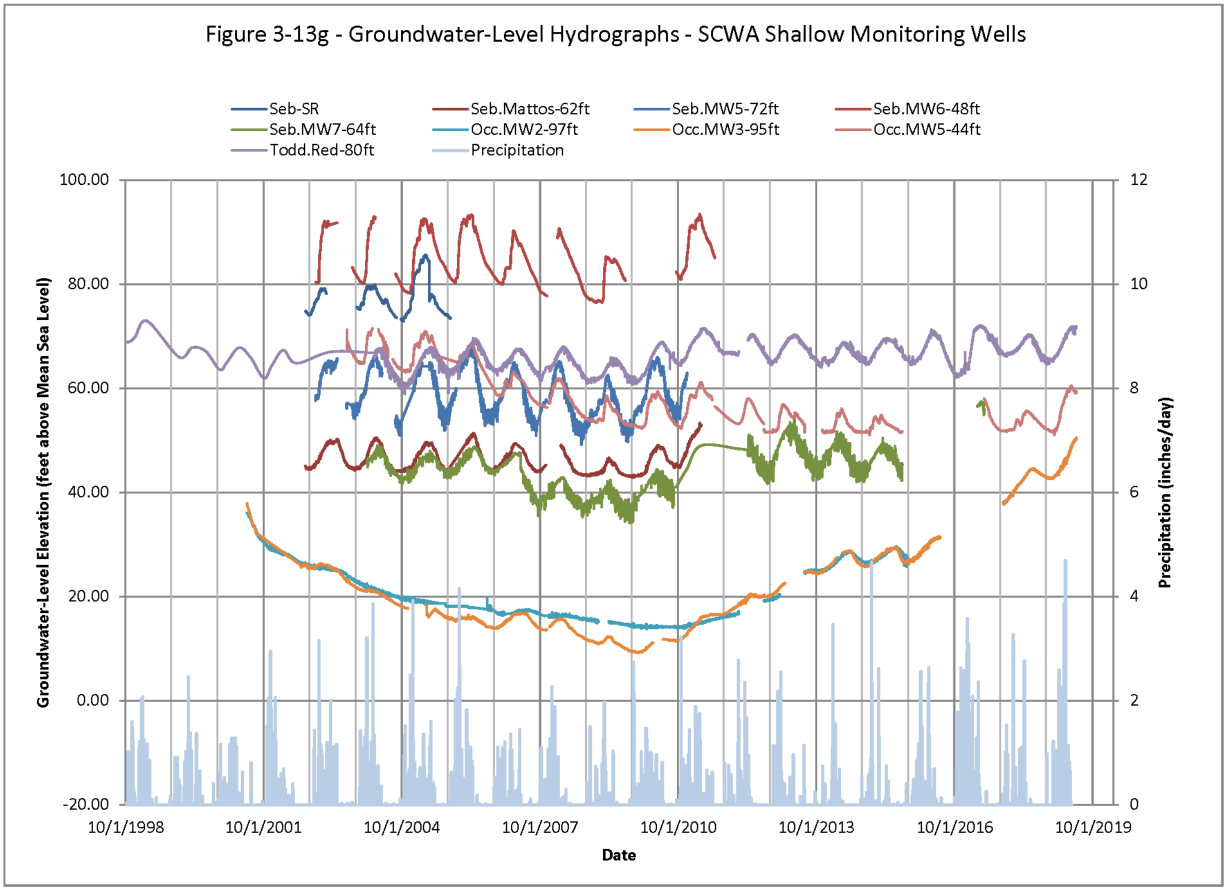

Figure 3-13g. Groundwater-level Hydrographs – SCWA Shallow Monitoring Wells

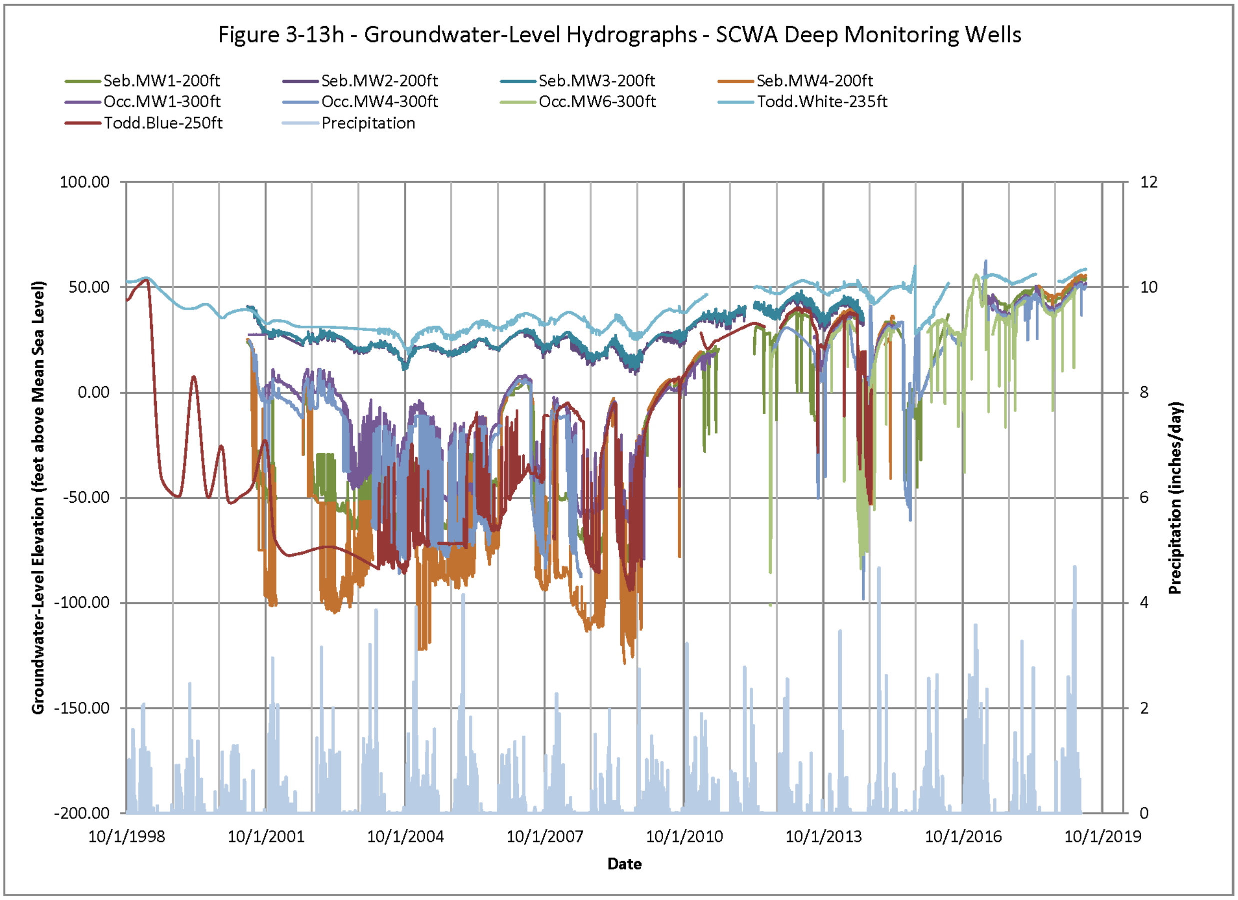

Figure 3-13h. Groundwater-level Hydrographs – SCWA Deep Monitoring Wells

Copeland Creek Monitoring Wells

Sonoma Water conducts a high-frequency groundwater-level monitoring program in a series of shallow monitoring wells in the vicinity of Copeland Creek, in the southeast corner of the Subbasin (**Figure 3-13a**). Groundwater-level hydrographs for select monitoring wells in this area are shown on **Figure 3-13i**. Monitoring wells A-1, A-2, A-4, B-2, and C-5 range in total depth from 24 to 35 feet. Data collected from these wells from 2014 to present indicate the following:

- Seasonal fluctuations in the Copeland Creek shallow monitoring wells range from approximately 10 to 25 feet.
- Groundwater levels in the monitoring wells respond rapidly to precipitation events.
- Timing of seasonal high and seasonal low groundwater levels is highly variable with seasonal high levels observed from December to April, and seasonal low levels observed from August to December.

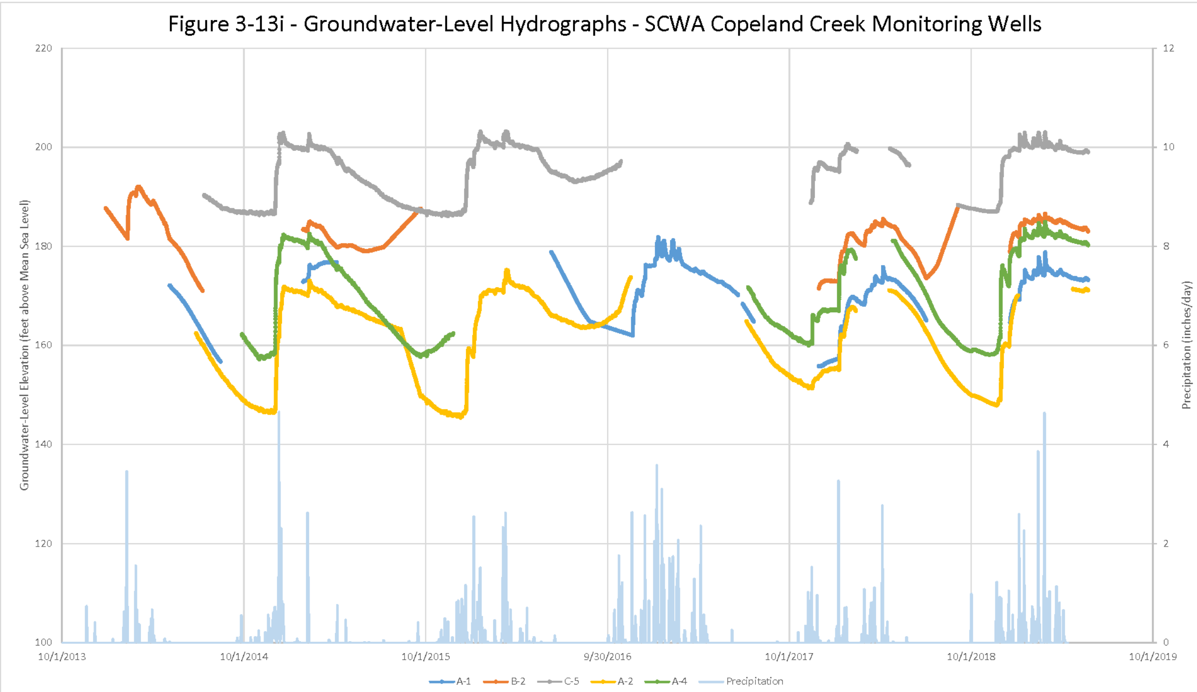

Figure 3-13i. Groundwater-level Hydrographs – SCWA Copeland Creek Monitoring Wells

3.2.3 Estimated Changes in Groundwater Storage

The change in groundwater estimated to be stored in the basin is equal to the total inflow into the Subbasin minus the total outflow. A negative change in groundwater storage indicates groundwater-storage depletion while a positive value indicates groundwater-storage accretion. The groundwater budget finds that storage declined during the historical (1976-2018) and current (2012-2018) budget periods, with a larger magnitude negative change in groundwater storage during the current period, which includes the recent drought. **Table 3-11** (**Section 3.3.3.2**) shows on average, that groundwater storage in the historical period declined by 600 AFY, while it declined by 2,100 AFY in the current period. The average annual results indicate that about 3 percent of pumpage in the basin is supplied by groundwater-storage depletion.

The increased rate of groundwater-storage depletion during the recent period appears to be more a result of a drier climate than increased groundwater pumping during that period. **Section 3.3.3.2** shows groundwater pumpage by water-use sector, along with the 5-year moving average of pumpage for the historical period. The peak of the 5-year moving average of the current period (21,000 AFY) is exceeded during 5 years in the 2000 to 2011 period, indicating that total groundwater pumpage for the current period is not greater than the previous 12-year period.

3.2.4 Land-surface Subsidence

Changes in land-surface elevation may be caused by tectonic processes, hydrologic isostatic-loading, increases in effective stress caused by excessive groundwater pumping, and other processes. In locations where multiple processes impact land-surface elevations, it may be difficult to determine the cause of changes. The North Bay region is located in the tectonically active Pacific margin, characterized by numerous active faults and geologically recent volcanic activity. In addition to the effects of tectonics, water stored on earth's surface and subsurface exerts a downward pull on the earth's crust. Increases in stored water increase this downward force, whereas declines in storage release this downward force. This hydrologic isostatic-loading is important in California, occurs in 100- to 1,000-kilometer (km) scales, and explains much of the land surface changes in areas without significant groundwater pumping or tectonic processes (Borsa et al. 2014). In areas of intensive water use, groundwater pumping can cause subsidence by reducing hydrostatic pressure. When water is removed, hydrostatic pressure decreases, which in turn increases the weight that the skeletal structure of the aquifer must support (effective stress). Aquifer materials rich in clays may collapse under this weight thus causing a lowering of the ground surface and a potentially unrecoverable loss in aquifer storage.

Existing data related to the potential for land subsidence in the Santa Rosa Plain is limited to GPS data collected as part of a plate boundary study and a focused study of the Rodgers Creek Fault zone. GPS data are being collected as part of a PBO network to monitor tectonic earth movements in North America. The project is led and managed by University Navigation Signal Timing and Ranging Global Positioning System Consortium, a university-governed consortium. PBO's network of 1,100 permanent continually operating GPS stations spans the Pacific/North American plate boundary in the western United States and Alaska, with additional stations on the stable continental interior. One PBO GPS station is located within the Santa Rosa Plain Subbasin (**Figure 3-14a**). This station (SRP0496; P197) has been actively monitored since 2006 and results are shown on **Figure 3-14b**.

From late 2005 to 2019 the GPS station in the Santa Rosa Plain has shown a total vertical change of +0.1 inch (**Figure 3-14b**). From 2015 to 2019 the total vertical change for the station is 0.01 inch, with annual changes of +0.003 inch. The positive ground height changes observed in Santa Rosa stand in contrast to other nearby stations. The other stations in Bodega Bay, Marin, Napa, and in the Russian River areas exhibit long-term declines in ground height. Regional interannual variation in hydrologic isostatic-loading is likely the best explanation for the observed regional trends. As described in **Section 3.2.2**, reductions in municipal groundwater pumping beginning in 2002 have resulted in significant recovery of groundwater levels in the Rohnert Park-Cotati area and is likely the cause of the rebound in ground-heights observed in SRP0496 GPS data.

Two focused studies conducted to assess the Rodgers Creek Fault for evidence of creep have revealed potential evidence of land-surface subsidence and subsequent uplift in the southern portions of the Subbasin related to groundwater pumping patterns (Funning et al. 2007; Jin and Funning 2017). The studies used Permanent Scattering Interferometric Synthetic Aperture Radar (PS-InSAR) technique from satellite data from 1992 to 2001 and from 2003 to 2010 to analyze the area for land-surface deformation related to fault movements (**Figures 3-14c** and **3-13d**, respectively).

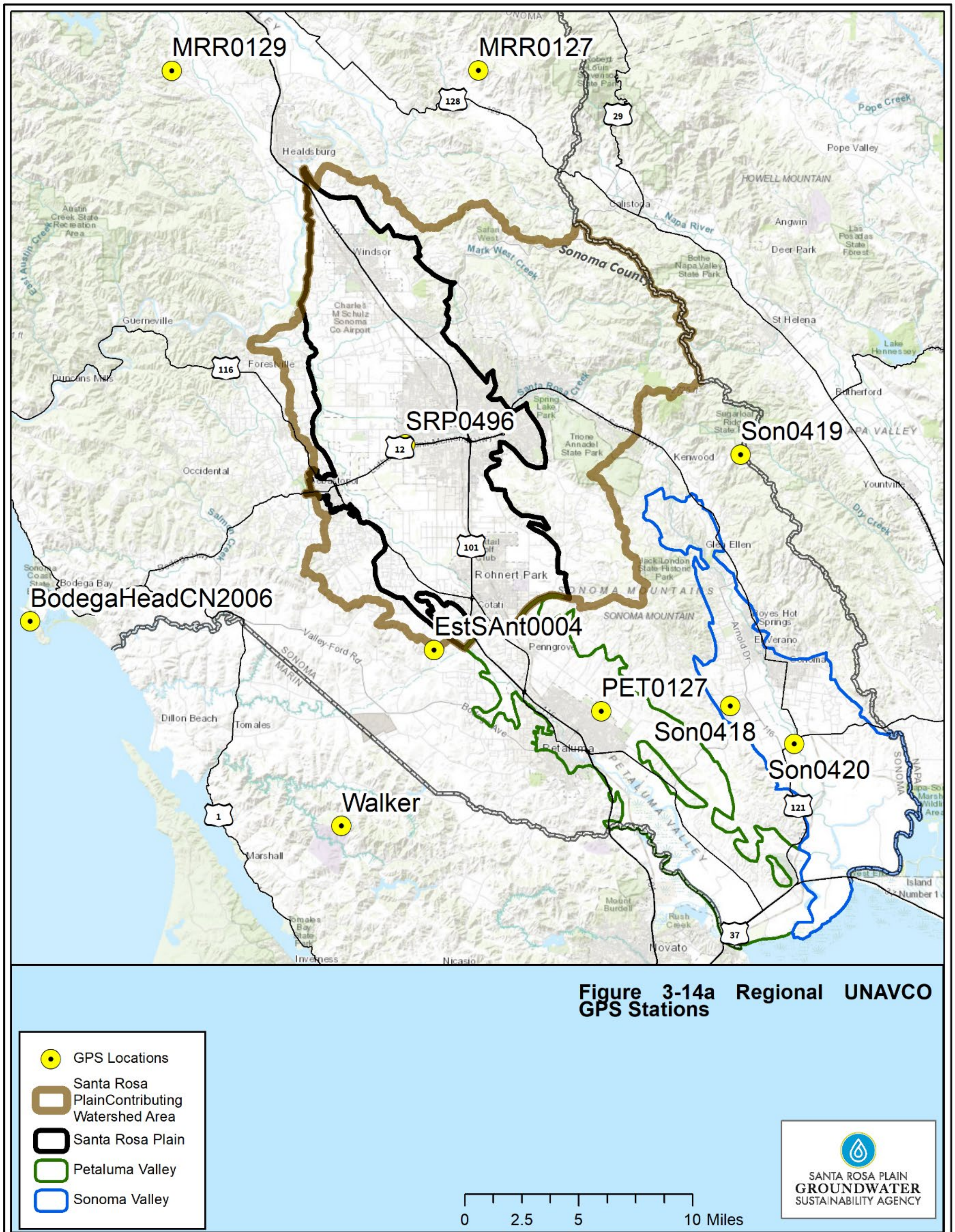

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Figure 3-14a. Regional UNAVCO GPS Stations

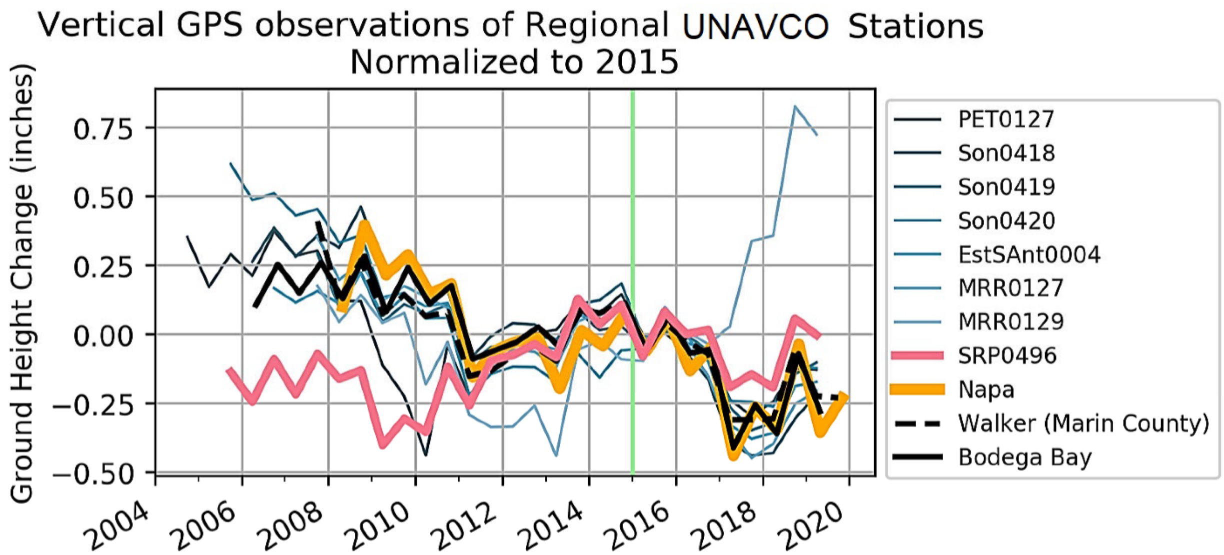

Figure 3.14b. Vertical GPS Observations of Regional UNAVCO Stations Normalized to 2015

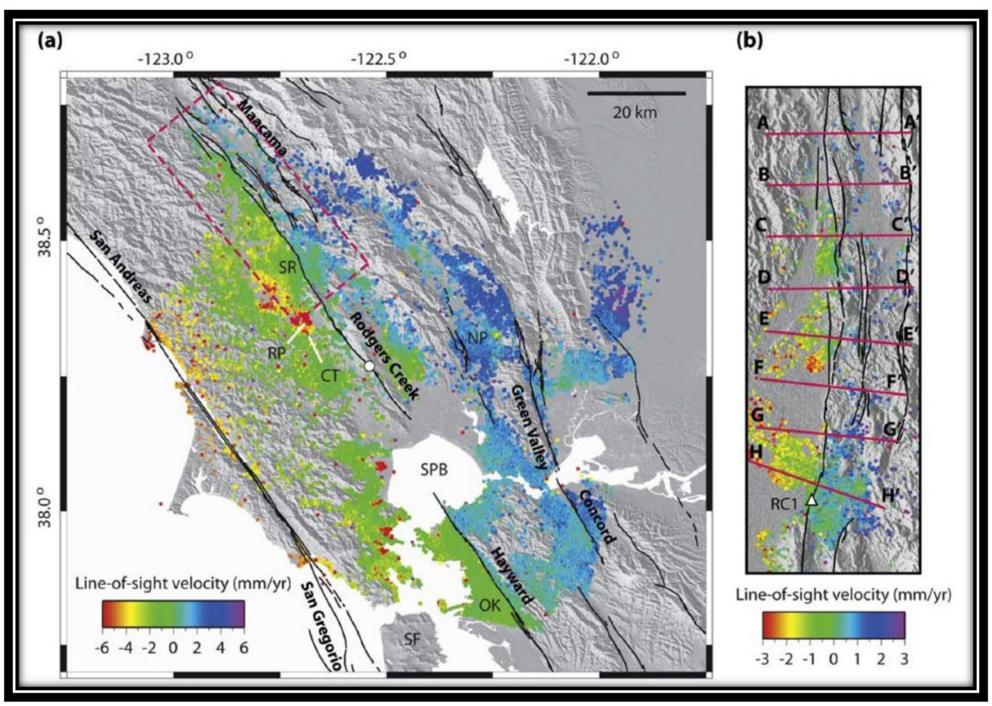

Figure 3-14c. PS-InSAR Data Interpretation for 1992-2001

While not specifically designed to investigate potential land-surface subsidence due to groundwater pumping, the fault studies identified an area in the southern portions of the Subbasin where the land surface subsided and subsequently rebounded coinciding with an area of groundwater-level declines and subsequent recovery. As shown on **Figure 3-14c**, during the 1992 to 2001 timeframe, land-surface elevations declined at a rate of about 6 millimeters

(0.2 inch) per year over the 10-year study period in the vicinity of Rohnert Park and Cotati (Funning et al. 2007). This timeframe coincides with the previously described period of increased municipal groundwater pumping and groundwater-level declines in the same area (**Figures 3-9b** and **3-11a**). During the subsequent study period of 2003 to 2010, the land-surface elevations in the same area exhibited an uplift (or rebound) of approximately 6 millimeters (0.2 inch) per year over the 8 years, as shown on **Figure 3-14d** (Jin and Funning 2017), coinciding with the period of reduced municipal groundwater pumping and increasing groundwater levels. The subsequent rebound of the land surface following the reduction in groundwater pumping and recovery of groundwater levels provides evidence that the relatively minor historical land-surface subsidence in this area represents elastic land-surface subsidence, which has not caused permanent (or inelastic) collapse of fine-grained units within the aquifer system.

Figure 3-14d

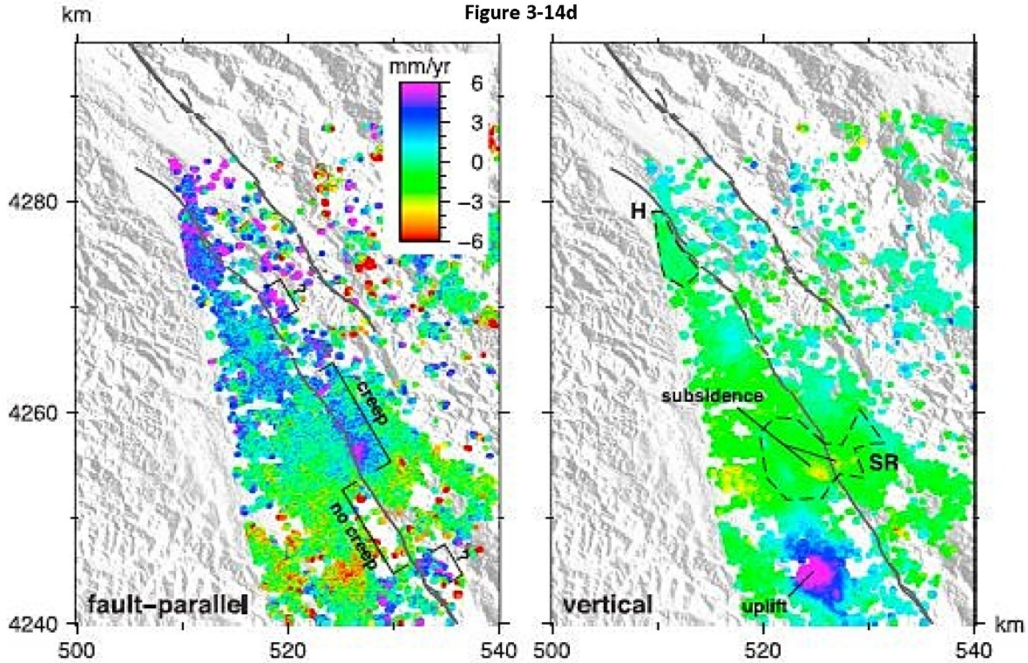

Figure 6. Map pattern of surface deformation velocities, decomposed into (left) fault-parallel and (right) vertical components. Fault-parallel velocities are horizontal velocities with an azimuth of 135°, i.e., positive fault-parallel velocities indicate movement to the southeast. An abrupt increase in velocity from west to east across the Rodgers Creek fault is consistent with right-lateral creep, such as a ~10 km zone extending northwest along strike from Santa Rosa, and also possibly in two other localized zones (indicated by question marks). In contrast, there is no evidence for creep immediately southeast of Santa Rosa. In the vertical deformation map, positive deformation rates indicate uplift; the most prominent feature is an uplift feature with an amplitude of 6 mm/yr in the southern part of the image, which we interpret as a recharging aquifer. We can also identify localized subsidence features across the area, such as a pair of subsiding areas either side of the Rodgers Creek fault in Santa Rosa. (Black dashed lines indicate locations of cities. SR: Santa Rosa, H: Healdsburg.)

Figure 3-14d. Map Pattern of Surface Deformation Velocities

Recent spatial variation of ground surface change (albeit with a lower level of vertical resolution) within the Subbasin is shown on **Figure 3-14e**. This dataset has been provided by DWR and represents changes from June 2015 to 2018 measured by InSAR. The maximum vertical changes are within the +0.25- to -0.25-foot range for the entire basin, with a majority of the basin within the 0.0- to -0.25-foot range over the 3-year period.

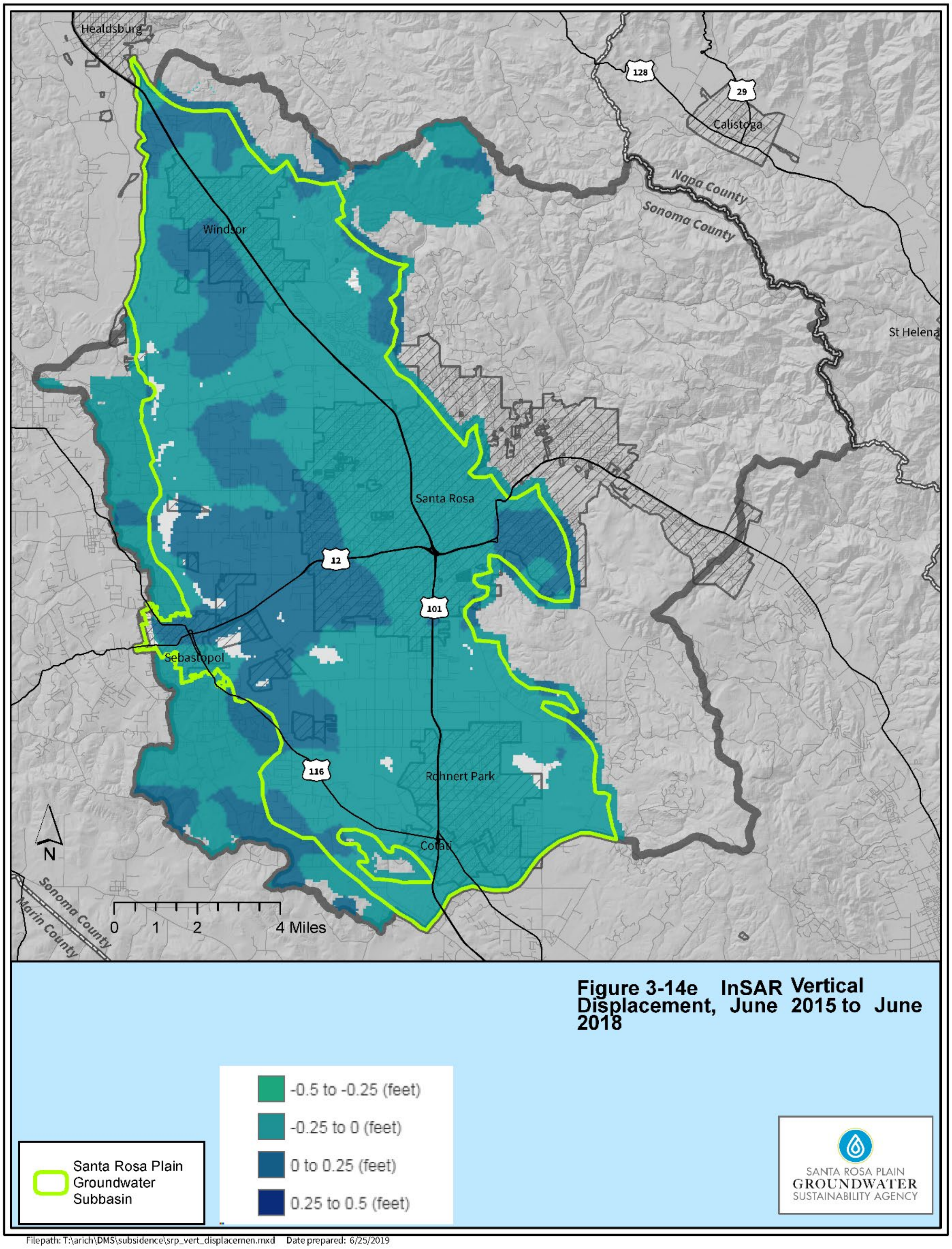

Figure 3-14e. InSAR Vertical Displacement, June 2015 to June 2018

3.2.5 Groundwater Quality Conditions and Trends

Groundwater quality sampling has been performed throughout the Subbasin for a number of different studies and regulatory programs. This section provides a summary of groundwater quality conditions and trends from these various studies and regulatory programs, which include the following:

- DWR periodic sampling of private wells (1950s to 2010)
- GAMA studies of public water-supply wells (Kulongoski et al. 2006) and private domestic wells (Bennett et al. 2014)
- USGS 2013 study (Martin et al. 2013)
- 2013 SNMP (City of Santa Rosa 2013a)
- Data from regulated public water-supply system sampling
- Regulated contaminant sites

Groundwater quality is highly variable throughout the Subbasin and contributing watershed area and is generally acceptable for beneficial uses, although some constituents pose challenges on a localized basis within the study area. Localized areas of poor groundwater quality within the Subbasin and contributing watershed areas are primarily related to the following potential sources of impairment: (1) anthropogenic inputs associated with certain land use activities (for example industrial, agricultural, or urban land uses), (2) deep connate waters associated with ancient seawater entrapped during deposition of Tertiary Era sedimentary units, and (3) hydrothermal fluids associated with portions of the Sonoma Volcanics and/or fault zones.

The following sections describe general groundwater quality characteristics and the occurrence and distribution of naturally occurring and anthropogenic constituents of interest. This section also includes a discussion of special focus parameters, including stable isotopes and trace elements used for age-dating and tracers to provide insights on groundwater movement. Summary results are provided for general minerals major-ion data, TDS, and specific conductance, and arsenic, nitrate, and chloride, which are constituents that have been identified as constituents of interest in previous studies within the Subbasin and/or serve as indicators for thermal or deep connate groundwater. All these constituents of interest occur naturally in groundwater systems, although nitrate also tends to be strongly associated with land use practices. Other anthropogenic constituents associated with land use practices, such as releases of fuel hydrocarbons and solvents, also occur in localized areas.

Much of the data summarized in **Section 3.2.5.1** are from public drinking water systems that provide treatment to remove these and other constituents of potential concern to levels below applicable regulatory standards. The concentrations presented for these wells are prior to such treatment, so as to allow for a characterization of native (or ambient) groundwater quality conditions. Additionally, since much of the data come from public supply wells that typically are completed in deeper aquifer zones, the data largely represent deeper aquifer zones. Therefore, the data may not adequately represent the water quality of the shallower aquifers being accessed by most domestic wells.

3.2.5.1 General Groundwater Quality Characteristics

Major-ion concentrations and stable isotopes were used to help classify and characterize the groundwater quality within the Subbasin and contributing watershed areas.

Major-ion Concentrations

Major-ion concentrations are assessed by evaluating relative proportions of common ions and anions and are used to group and classify by a water type. These data can help indicate groundwater flow paths and interconnection with surface water. The major-ion composition of groundwater is controlled by the natural chemistry of the recharge water, geochemical reactions in the subsurface, and anthropogenic factors. As groundwater flows through the subsurface, it assumes a characteristic chemical composition as a result of interaction with the aquifer matrix (solid) materials and length of time in the subsurface. Typically, the longer the groundwater flows along a pathway following the hydraulic gradient (groundwater flow path) in contact with and flowing through the aquifer matric materials, the higher the dissolved solids concentrations and major constituent concentrations. This helps explain why it is common to find higher dissolved solids concentrations in groundwater with depth. Most groundwater in the Subbasin is bicarbonate-type water and ranges from sodium-potassium-type water to calcium-magnesium-type water.

General groundwater characteristics have been classified on the basis of groundwater quality data analyses by groundwater storage units (Sweetkind et al. 2013; Martin et al. 2013). The following summarizes the general groundwater classification of the five groundwater storage units as defined by Sweetkind et al. (2013):

Subbasin storage units:

Windsor Basin (north of Trenton Fault and between Mayacamas Mountain foothills and Sebastopol Fault)

- Dominantly a mixed cation-bicarbonate- and sodium-bicarbonate-type water
- Median dissolved solids concentration of 321 mg/L

Cotati Basin (south of the Trenton Fault)

- Mixed cation-bicarbonate- or sodium-bicarbonate-type water
- Median dissolved solids concentration of 362 mg/L

Contributing watershed areas storage units:

Uplands (generally upland areas east of the Rodgers Creek Fault)

- Mixed cation-bicarbonate- or calcium/magnesium bicarbonate-type water

- Median dissolved solids concentration of 330 mg/L

Valley (Rincon/Bennett Valley areas east of the Rodgers Creek Fault)

- Mixed cation-bicarbonate-type water with relatively higher sodium
- Median dissolved solids concentration of 392 mg/L

Wilson Grove (generally areas west of the Sebastopol Fault)

- Calcium-bicarbonate- or mixed cation-bicarbonate-type water
- Median dissolved solids concentration of 233 mg/L

Additionally, water samples from wells completed within the shallow aquifer system generally exhibit greater proportions of calcium and magnesium, while deep aquifer samples exhibit greater proportions of sodium and potassium, which is consistent with increasing mineralization and ion exchange between clays and groundwater with increasing distance and depth from recharge sources (Martin et al. 2013).

Stable Isotopes and Age-dating

Stable environmental isotopes are measured as the ratio of the two most abundant isotope types of a given element, and in hydrologic studies, oxygen and hydrogen are commonly used. For oxygen, it is the ratio of Oxygen-18 (^{18}O) to Oxygen-16 (^{16}O), and for hydrogen, it is the ratio of deuterium (^{2}H or D) to hydrogen (^{1}H). These data provide information on the potential source, evaporative history, and movement of water. Water that condensed at cooler temperatures (precipitation that condenses at higher altitudes, cooler climatic regimes, or higher latitudes) tends to be isotopically lighter than precipitation that condenses at higher temperatures (precipitation that condenses at lower altitudes, warmer climatic regimes, and lower latitudes) (Muir and Coplen 1981). Because the source of much of the precipitation globally is derived from the evaporation of seawater, the ^{18}O and D compositions of precipitation near coasts throughout the globe cluster along a line known as the global meteoric water line (GMWL) (Craig 1961). Water that has been partially evaporated is enriched in the heavier (less negative) isotopes; these values plot to the right of the GMWL, along a line known as the evaporative-trend line. Results from the stable isotope analyses suggest that groundwater recharge in the Subbasin is primarily from infiltration of precipitation and the infiltration of seepage from water courses (Martin et al. 2013).

Isotopic values of groundwater samples collected within the Subbasin generally plotted slightly below the GMWL, indicating that the samples could have been subject to some evaporation, been mixed with evaporated surface water, or been derived from recharge source areas with somewhat different meteoric water lines because of differing altitudes. Within the Subbasin, the heavier isotopic values, which only deviated slightly from the GMWL, indicated that at least some of the recharge to the Subbasin originates as precipitation directly falling on the lower elevations of the Subbasin. In general, the isotopic values of samples east of the Rodgers Creek Fault grouped together and were in the lighter range of all measured isotopic values. The isotopic values for well samples from the western margins of the SRP watershed also grouped together but fell within the heavier range of all isotopic values from wells in the study area (Martin et al. 2013).

Measured carbon-14 ages in groundwater samples collected from the SRP watershed indicate groundwater ages of 1,000 to 34,000 years before present (Martin et al. 2013). As determined by carbon-14 dating or the presence of tritium, the shallow and deep aquifers exhibit different groundwater ages, with the deep well samples all exhibiting water ages of 4,000 years or older and the shallow aquifer generally containing waters recharged within the last 50 years (Martin et al. 2013). The tritium and carbon-14 data indicate that the vertical migration of recharge in the Santa Rosa Plain is probably retarded by the presence of low-permeability clay deposits in the Glen Ellen and Petaluma Formations (Martin et al. 2013).

3.2.5.2 Naturally Occurring Constituents of Interest

Arsenic, boron, TDS, and chloride have been identified as naturally occurring constituents of interest through previous studies within the Subbasin.

Arsenic

Arsenic is a relatively common element that occurs naturally in the environment. Arsenic is considered a carcinogen, and the maximum contaminant level (MCL) for arsenic has been set at 10 micrograms per liter (µg/L). Arsenic solubility increases with increasing water temperature, and also tends to desorb from aquifer matrix materials under alkaline conditions (pH greater than 8.0) (USGS 2014). Due to its increased solubility with increased temperature, arsenic is commonly elevated in groundwater that is affected by hydrothermal fluids.

Water-sample analyses for arsenic were available from 89 wells within the SRP watershed between 2010 and 2019. The occurrence and distribution of arsenic in groundwater is displayed on **Figure 3-15a**. Groundwater samples from 15 of the 89 wells (17 percent) exceeded the MCL of 10 µg/L for arsenic. Areas of elevated arsenic concentrations are most notable in the northeastern portions of the Subbasin, immediately south of the City of Santa Rosa, in the vicinity of the City of Sebastopol and along the Trenton Fault near Mark West Creek. Many areas of higher arsenic concentrations appear to be associated with known or inferred faults.

Chloride and Total Dissolved Solids

Chlorides are widely distributed in nature as salts of sodium, potassium, and calcium. Chlorides are leached from various rocks into soil and water by weathering and can also be an indicator for seawater intrusion or the presence of older connate water. Anthropogenic sources of chloride commonly include manufacturing, power generation, landfill leachate, and wastewater. Chloride has a secondary MCL of 250 mg/L based on taste (salty).

TDS refers to the amount of minerals, salts, metals, cations, and anions dissolved in water. Pure water such as distilled water will have a very low TDS and sea water, brackish water, older connate water, and mineralized thermal waters exhibit high TDS concentrations.

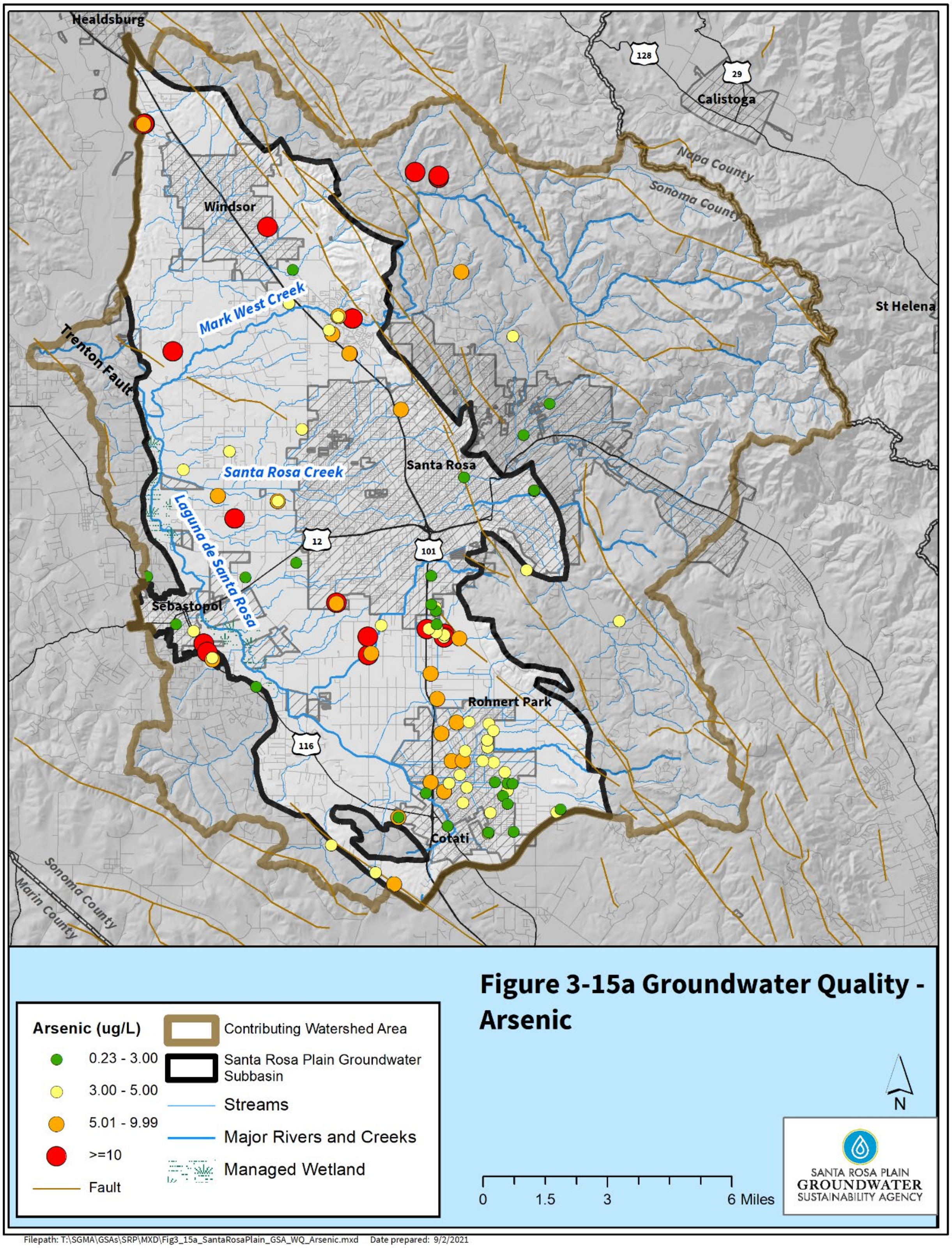

Figure 3-15a. Groundwater Quality – Arsenic

TDS has a secondary MCL of 500 mg/L based on hardness deposits, colored water, staining, and salty taste. Specific conductance (SC - also called electrical conductivity [EC]) is the measure of the liquid capacity to conduct an electrical charge, which is dependent on the amount of dissolved minerals, salts, metals, cations, anions, and temperature of water, and correlates with TDS measurements. SC is easily and inexpensively measured via portable water-quality sensor in the well or in water samples on site from a well, whereas TDS is generally analyzed in the laboratory at a greater expense.

Water-sample analyses for chloride were available from 95 wells within the SRP watershed between 2010 and 2019. The occurrence and distribution of chloride in groundwater is displayed on **Figure 3-15b**. No groundwater samples exceeded 100 mg/L chloride.

Water-sample analyses for TDS (and SC as a surrogate for TDS) were available from 97 wells within the Subbasin and contributing watershed areas between 2010 and 2019 (18 within the shallow aquifer system and 121 within the deep aquifer system). The occurrence and distribution of TDS in groundwater is displayed on **Figure 3-15c**. Groundwater samples from three of the wells exceeded the secondary MCL.

Martin et al. (2013) reported that while concentrations of chloride and SC are predominantly well below secondary drinking water standards, concentrations of these two constituents appear to be increasing with time in the Subbasin. Chloride concentrations increased similarly in about two-thirds of the wells, and just more than half increased by more than 10 percent. Not all wells had increases; a more than 10 percent decrease in concentration was measured in 15 percent of the wells for SC and 30 percent for chloride. The greatest increases in concentrations of SC, chloride or both were in wells located in the vicinity of the Cities of Rohnert Park and Cotati. Possible causes of the increased SC and chloride include groundwater underflow of high dissolved solids concentration groundwater present along the Rodgers Creek Fault zone, historic irrigation return flow, septic tank effluent, or leaky sewer pipes (Martin et al. 2013). Depth-dependent hydrologic, chemical, and isotopic data are needed to better understand the cause of the increased SC and chloride concentrations.

Figures 3-15d through **3-15g** display more recent time-concentration plots of chloride and TDS, respectively, for wells with the longest periods of records based on available historical data. As indicated on the time-concentration plots, the majority of wells exhibit relatively stable concentrations of chloride and TDS over time. The absence of increasing trends in this more recent data may be related to samples from different wells than the USGS study or indicate that concentrations have stabilized since the USGS study. It is important to note that many of the time-concentration plots do not include very complete records over time (sampling for several of the wells, which were sampled in the 1950s through 1970s were discontinued and many of the wells with more complete recent data do not have data extending back over time). Additionally, spatial data gaps occur in both the shallow and deep aquifer system.

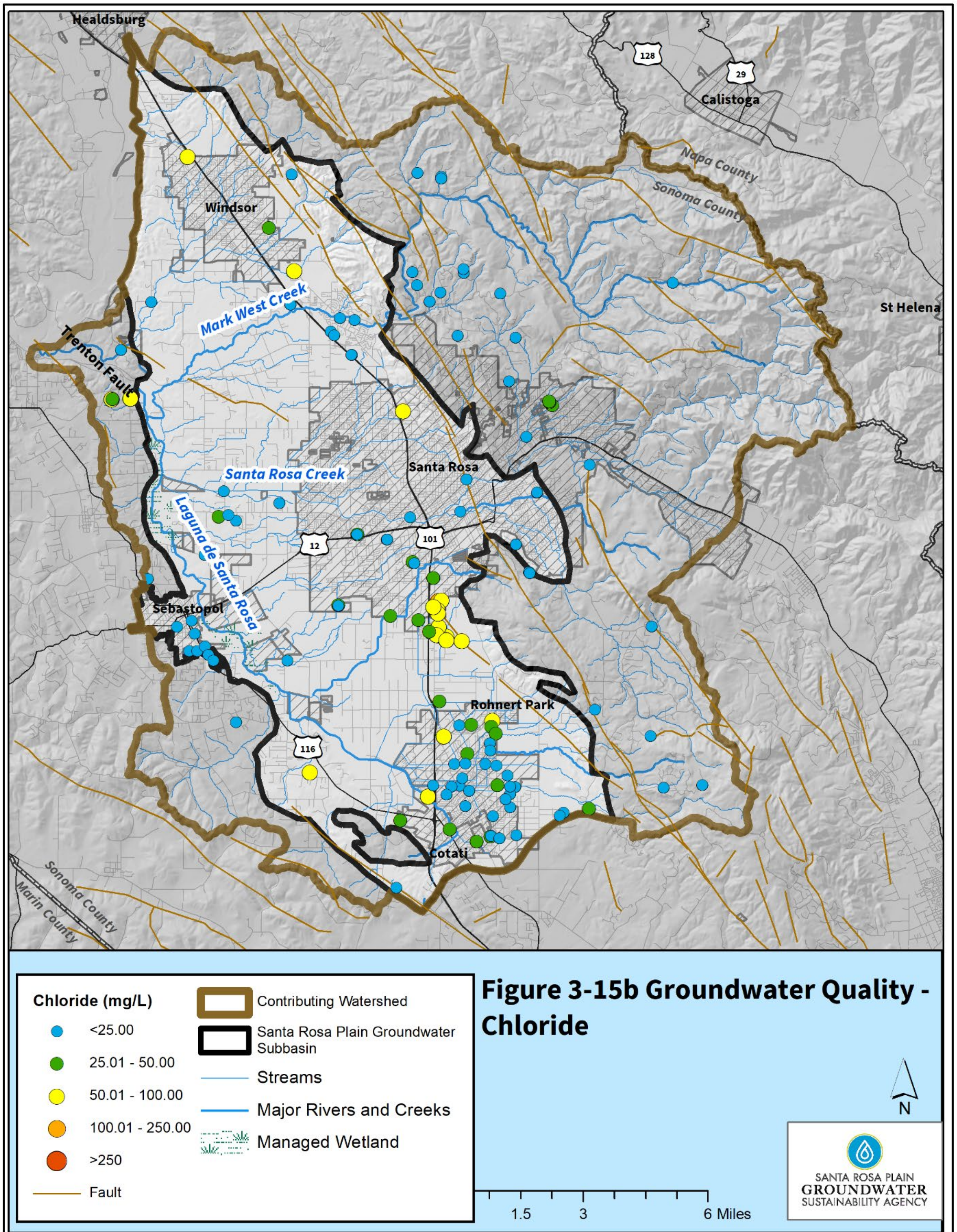

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Figure 3-15b. Groundwater Quality – Chloride

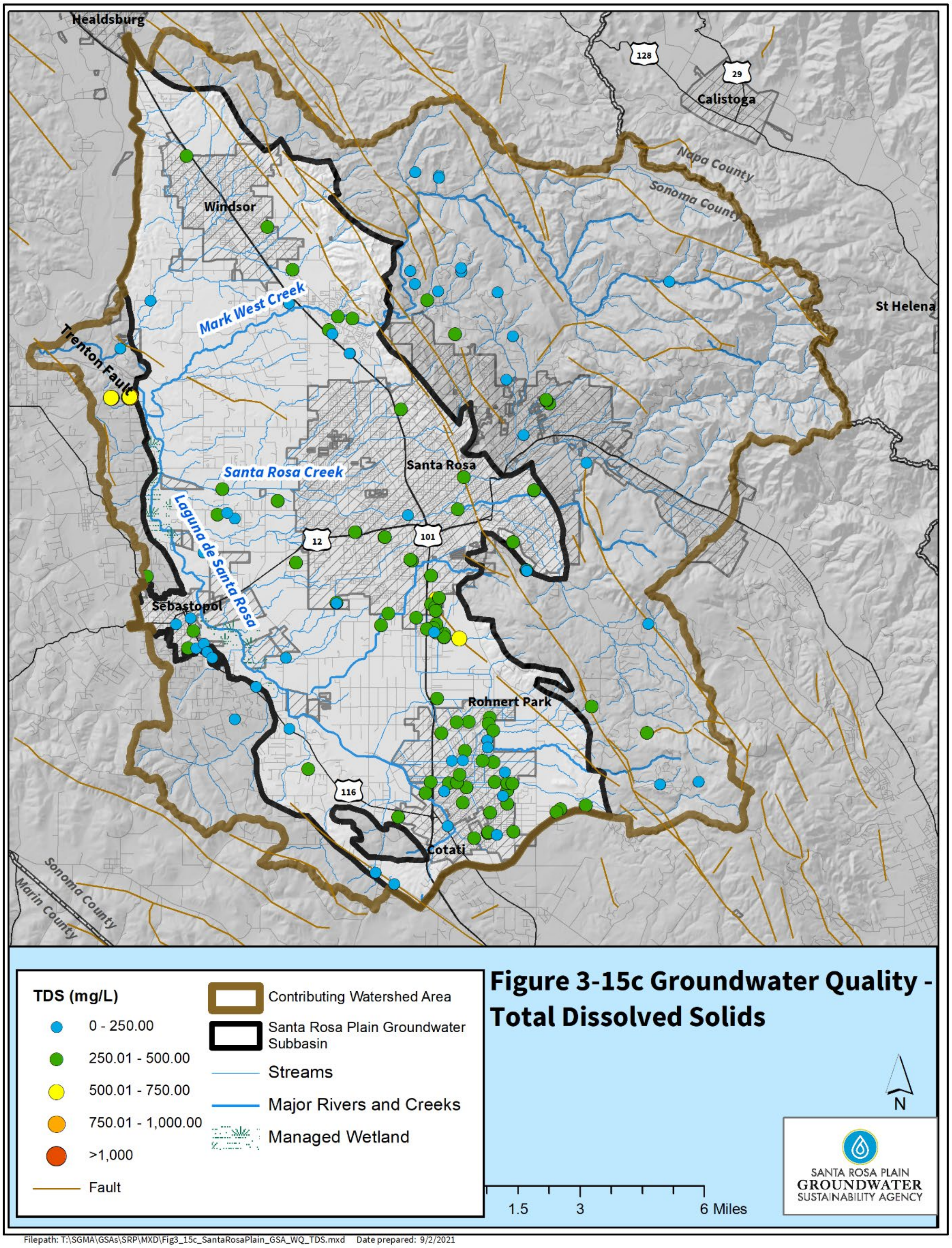

Figure 3-15c. Groundwater Quality – Total Dissolved Solids

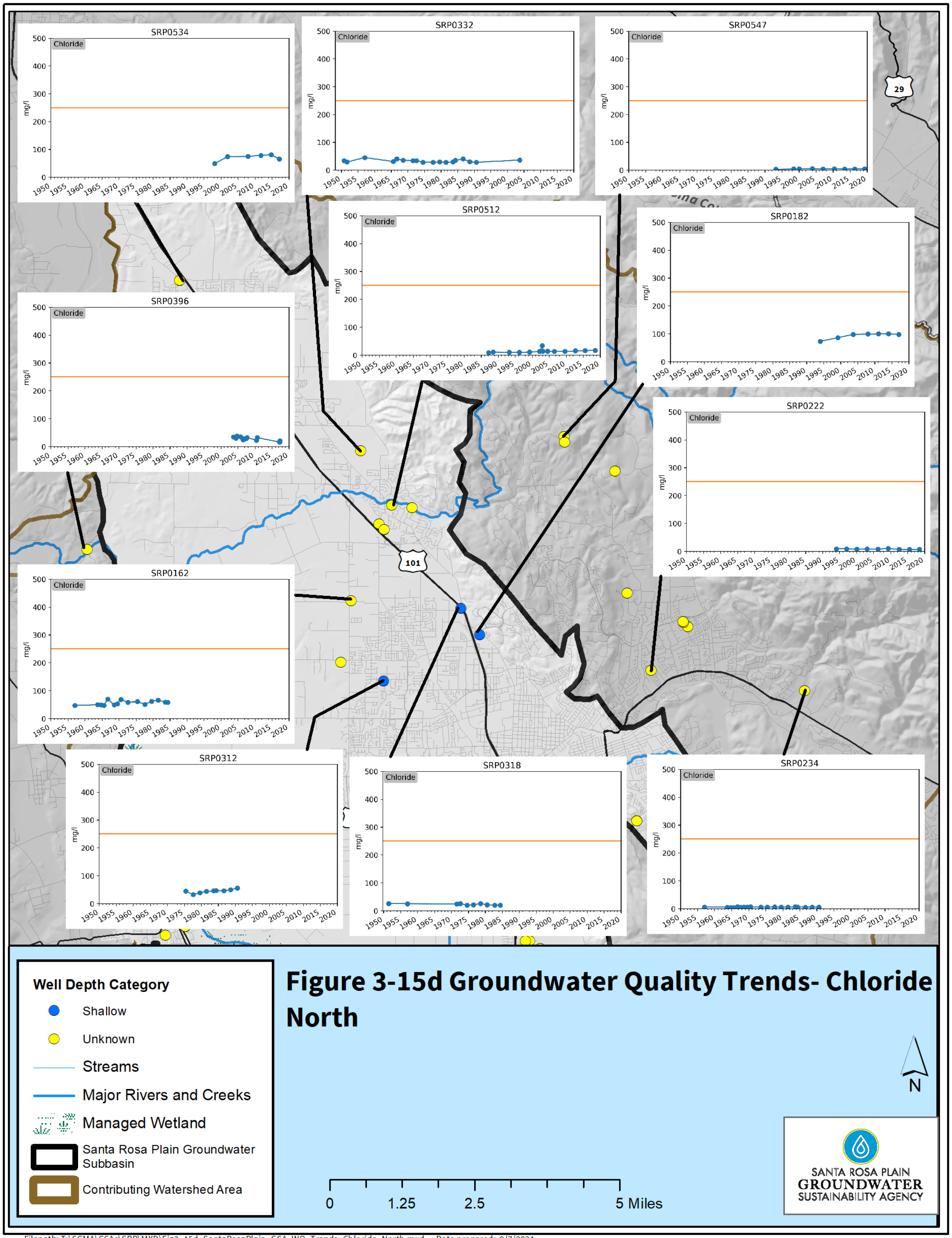

Figure 3-15d. Groundwater Quality Trends – Chloride North

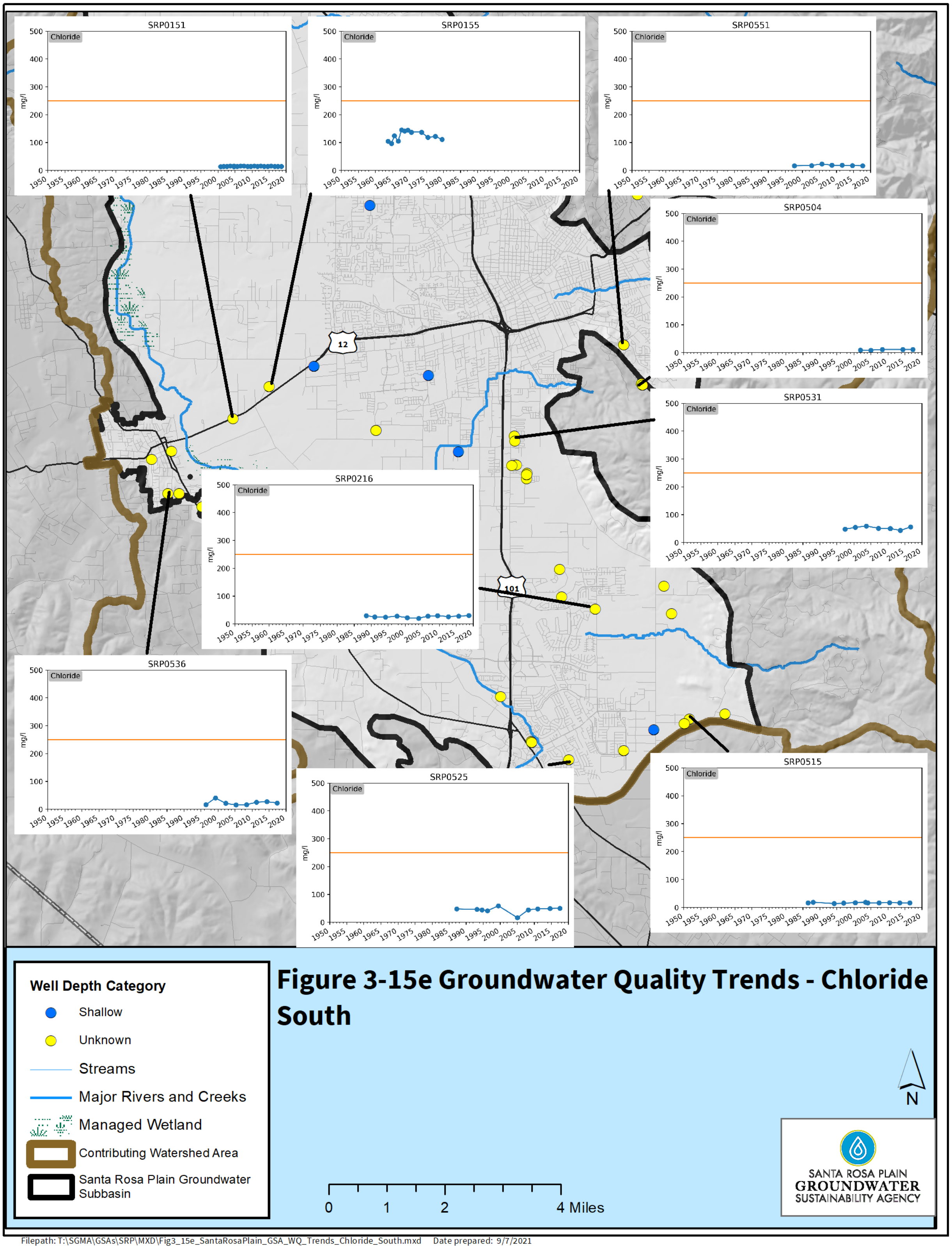

Figure 3-15e. Groundwater Quality Trends – Chloride South

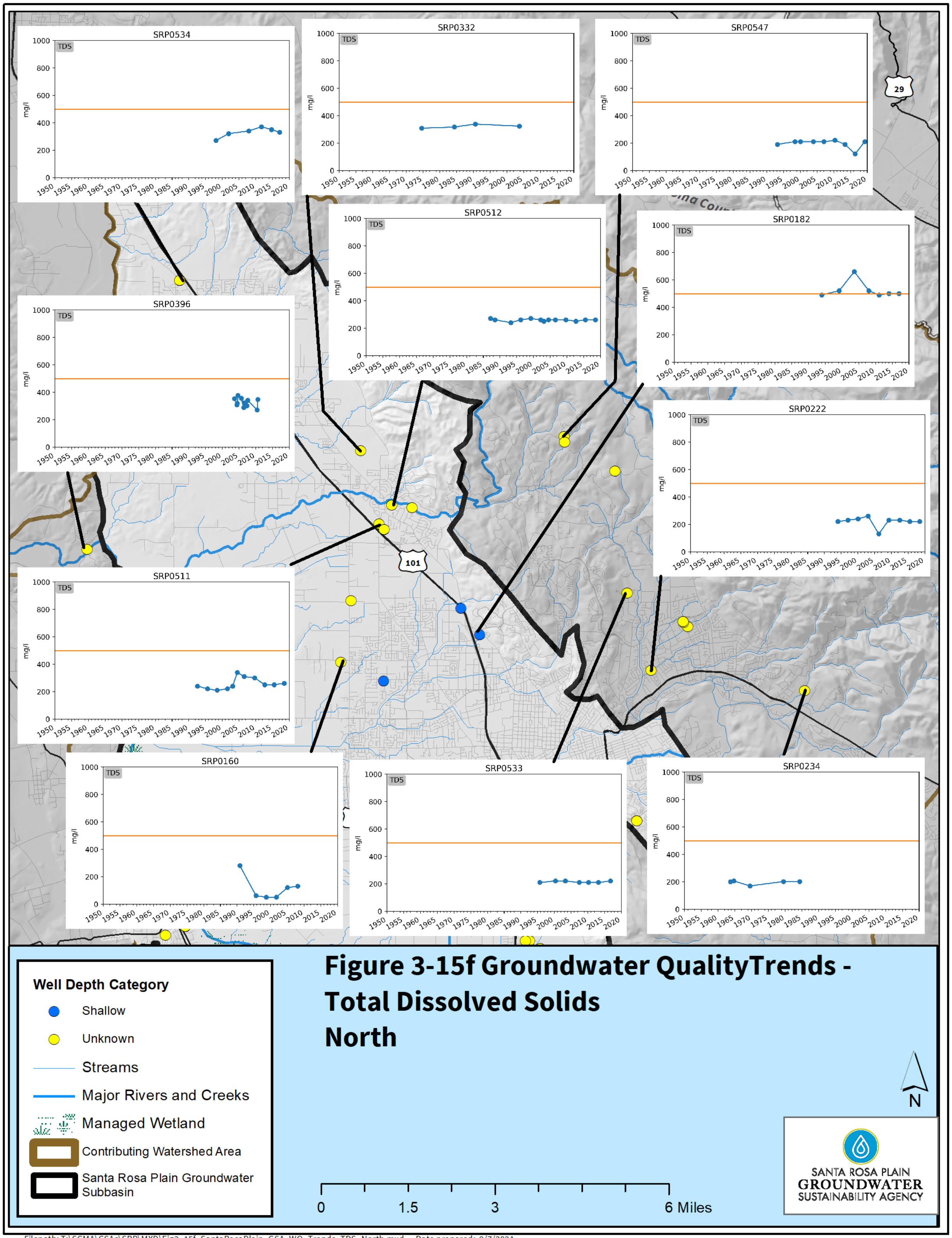

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Figure 3-15f. Groundwater Quality Trends – Total Dissolved Solids North

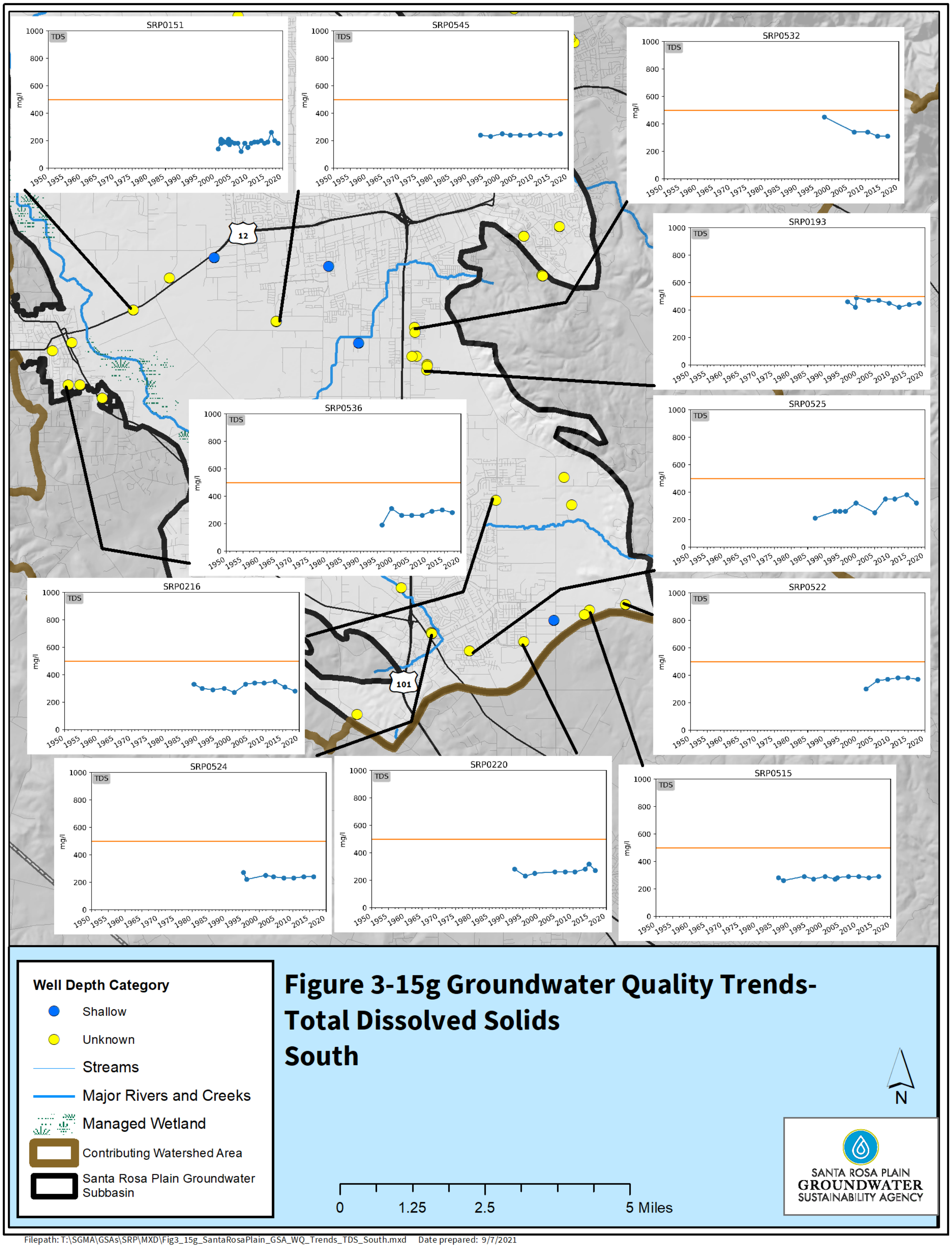

Figure 3-15g. Groundwater Quality Trends – Total Dissolved Solids South

3.2.5.3 Anthropogenic Constituents of Interest

Nitrate

Nitrate is a widespread contaminant and its occurrence in groundwater systems is commonly associated with agricultural activities, septic systems, confined animal facilities, landscape fertilization, and wastewater treatment facility discharges. Elevated levels of nitrate in drinking water are considered to be especially unhealthy for infants and pregnant women (SWRCB 2012) and the MCL for nitrate as N is 10 mg/L.

Only 2 of the 92 groundwater samples analyzed for nitrate as nitrogen exceeded or equaled the nitrate MCL of 10 mg/L, as shown on **Figure 3-15h**. The median concentration of nitrate in shallow wells was 0.9 mg/L in the Windsor structural trough and 4.4 mg/L in the Cotati structural trough (Martin et al. 2013). Median concentrations for deeper wells were 0.2 mg/L in the Windsor structural trough and 1.0 mg/L in the Cotati structural trough (Martin et al. 2013).

Regulated Groundwater Contamination Sites

The SRP watershed contains a number of currently regulated contaminant release sites (**Figure 3-16**), many of which are under an active cleanup order by the SWRCB (SWRCB 2021). These include leaking underground tanks from gasoline and solvent storage, land disposal, and military facilities. These releases, which include petroleum and chlorinated solvent contaminants and metals, are generally of limited areal extent, although impacts to water-supply wells from a number of sites have occurred within the study area. These releases and sites are regulated through programs administered by other agencies, including the North Coast Regional Water Quality Control Board, DTSC, and County of Sonoma Environmental Health.

The SWRCB GAMA Priority Basin Project study of the North San Francisco Bay Groundwater Basins has included two studies by the USGS, which evaluated inorganic and organic constituents in groundwater, and which includes constituents associated with regulated contaminant release sites. The first study conducted in 2004 included samples from 18 public water-supply wells in the Subbasin and contributing watershed areas. The second study conducted in 2012 included samples from seven private domestic wells in the Subbasin and contributing watershed areas. These samples were analyzed for up to 270 constituents and water-quality indicators including volatile organic compounds, pesticides, nutrients, major and minor ions, trace elements, radioactivity, microbial indicators, dissolved noble gases, and naturally occurring isotopes (Kulongoski et al. 2010; Bennett et al. 2014). A small number of the public and private wells sampled as part of the GAMA program had very low-level detections of volatile organic compounds and/or pesticides, but all detections were significantly below the contaminant’s respective MCLs (Kulongoski et al. 2010; Bennett et al. 2014).

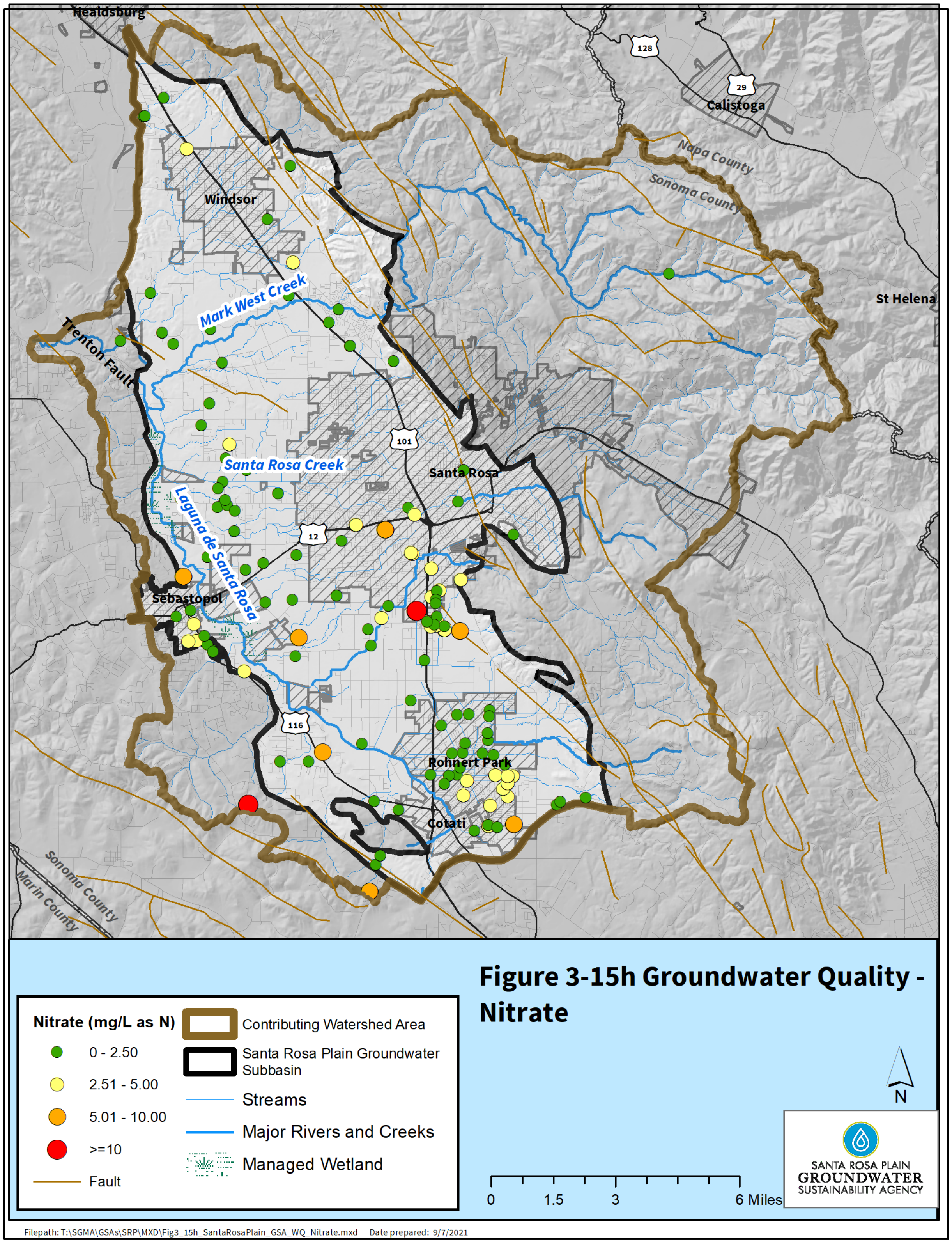

Figure 3-15h. Groundwater Quality – Nitrate

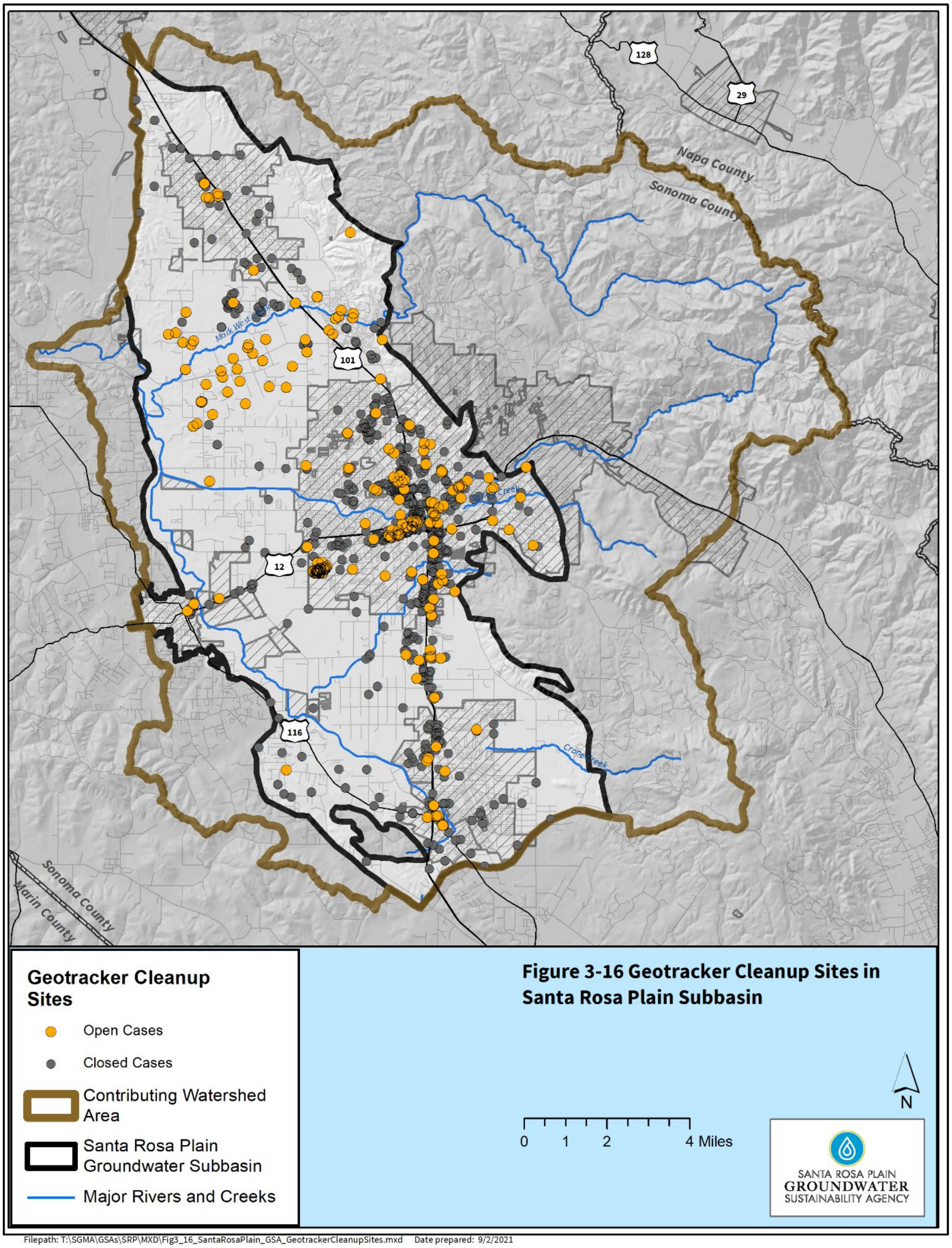

Figure 3-16. GeoTracker Cleanup Sites in Santa Rosa Plain Subbasin

3.2.6 Surface Water Conditions and Surface Water and Groundwater Connectivity

SGMA requires the GSP include a HCM that provides a qualitative and quantitative understanding of the Subbasin's physical characteristics and how the aquifers react to hydrologic stresses over time, and interaction of the surface water and groundwater systems in the basin, to include quantitative information on surface water inflows and outflows in the water budget. Also required are the development of sustainable management criteria for surface water depletion from groundwater pumping.

3.2.6.1 Surface Water Conditions

Streamflow information in the Subbasin and contributing watershed is based on data gathered from stream gages and previous studies. Historical streamflow records are available at 15 USGS gaging stations and at the time of GSP preparation, 9 stream gaging stations were operated by the USGS, 7 gages were operated by Sonoma Water, and 1 stream gage was operated by the Pepperwood Preserve (**Figure 2-7d**). Most streamflow records within the Subbasin are relatively recent and date to WY 1998 or more recent. **Figure 3-17** shows total annual gaged surface water flow at the nine active USGS gages for WY 2000 through 2020 and historical data for one inactive USGS stream gage (Brush Creek).

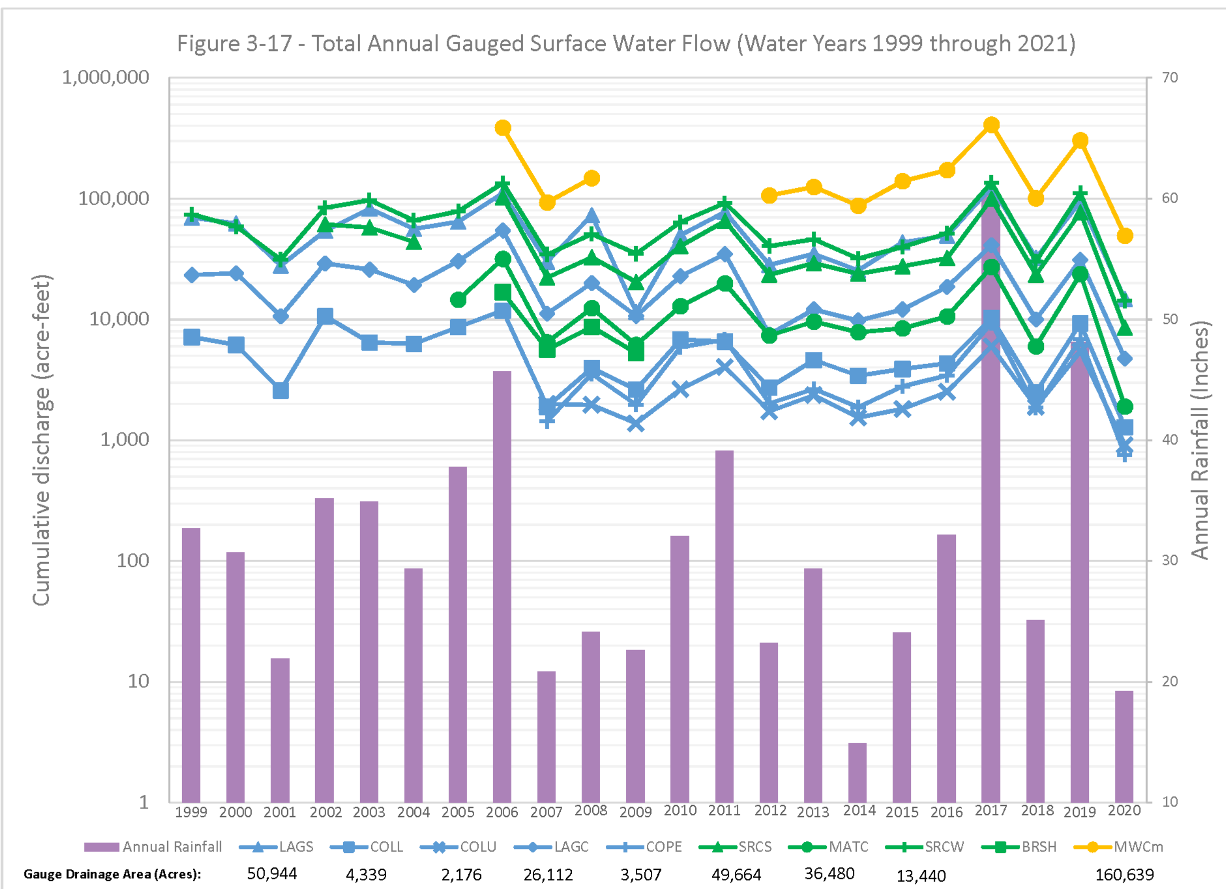

Figure 3-17. Total Annual Gaged Surface Water Flow (Water Years 1999 through 2021)

The Subbasin and contributing watershed experience extremes, from very high flows and flooding during wetter than normal winters, to periods of much lower flows during drought years. High Russian River flows, and rapid, high-volume inflow to the Laguna de Santa Rosa from tributary drainages, can slow and even reverse streamflow in the Laguna de Santa Rosa drainage channel, and in the lower channels of Mark West Creek and Santa Rosa Creek due to backwater effects in the Laguna de Santa Rosa floodplain. These conditions arise only from larger storms, during wetter than normal winters. The largest floods within the Subbasin are caused by the combined effects of runoff from within the Subbasin and contributing watershed areas and inflows from the Russian River into the Laguna de Santa Rosa floodplain. When the Russian River rises above flood stage, the Laguna de Santa Rosa Plain acts as a natural flood retention basin for the Russian River by capturing and storing flood water, thus dampening the peak flows in the Russian River downstream of the Mark West Creek tributary.

During summer, low-flow conditions occur throughout the Subbasin and contributing watershed, with most of the streamflow consisting of baseflow (the component of the streamflow that persists without precipitation, generally spring-fed or groundwater-fed), and in some cases irrigation runoff. Perennial streamflow may characterize sections of Matanzas Creek, Spring Creek, and upper Santa Rosa Creek.

3.2.6.2 Interconnected Surface Water

Interconnected surface waters are defined in the GSP Regulations as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted." A stream segment is interconnected where (and when) variations in groundwater hydraulic head influence the rate of exchange between the groundwater and surface water systems (Brunner et al 2011; Sophocleous 2002). Below this depth, changes in groundwater elevation do not influence streambed infiltration. The direction and magnitude of the flux between surface waters and the groundwater system depends upon the difference between the surface water level or stage and adjacent groundwater elevations, and the hydraulic conductivity of aquifer and streambed, channel morphology, and other factors. During gaining conditions, the groundwater elevation is above the surface water stage and during losing conditions the groundwater elevation is below the stream stage. Because groundwater elevations and stream stage are not constant, this interaction may change in magnitude and direction seasonally or year-to-year, and along the length of a stream reach. The degree of interaction can be impacted by changes in climate and groundwater pumping, upstream diversions, and land use, amongst other factors (Winters et al. 1999).

Direct measurements of the flux between surface water and groundwater are difficult to make. As such, indicators of interconnected surface waters were assimilated with direct measurements to assess where interconnected surface waters in the Subbasin likely exist. The types of evidence used are the following:

1. Measured groundwater-level and streambed elevation differences
    a. Depth-to-groundwater along stream channels, spring 2015

2. Modeled output derived from Woolfenden and Nishikawa (2014)
    b. Percent of time stream is gaining, from 2000 to 2010
    c. Median stream flow, from 2000 to 2010
    d. Surface leakage, 2006

The two types of data are combined into a scoring system to determine where interconnected surface waters likely occur. The points are aggregated for model cells that were used in the GSFLOW model for the Santa Rosa Plain. The rationale for this approach is that it allows for direct use of output from model simulation and size of the cells are appropriate (660 feet by 660 feet) for assessing local variability.

The first data source used in the scoring system is the estimated depth-to-groundwater derived from a groundwater-level contour map derived for the shallow aquifer system of the Subbasin. This map was derived by interpolation between groundwater levels measured in shallow aquifer system wells from spring 2015 and converting these to elevations. These elevations were intersected with the stream bottom elevation for each grid cell. Where the shallow groundwater elevation is greater than the stream bottom elevation interconnected surface, water conditions are inferred to occur. Stream bottom elevations were extracted from 2013 Vegmap LiDAR (Sonoma Vegmap 2013). Where shallow groundwater elevations are lower than the stream bottom, then the stream is inferred to be disconnected from the groundwater system. This analysis does not consider the impact of varying stream stage and assumes that the stream bottom is a reasonable surrogate for stream stage. Points for this category were assigned to give the full 5 points for reaches inferred to be interconnected using this method (negative values) and decreasing to 0 points where groundwater elevations are 10 feet below the stream bottom. To provide a conservative approach and account for the inherent uncertainties within the datasets, reaches where the groundwater elevation is estimated to be within 10 feet of the streambed were assigned either one or two points depending upon the depth. If the substrates below the streams were understood to be homogenous and had high hydraulic conductivities, a deeper value would be selected. However, with the likely existence of a heterogeneous alluvium beneath the streams, the low-permeability lenses characteristic of these deposits inhibit hydraulic connections at greater depths (Peterson and Wilson, 1988). **Figure 3-18a** shows the depth-to-water for all of the stream reaches.

The second data source used for the scoring system relates to the amount of time there is a direct groundwater connection with the stream cell and the stream is simulated as gaining. This data was derived from the GSFLOW simulation. The values represent the amount of time from 2000 to 2010 that simulated hydraulic head in stream flow cells were greater than the simulated stream stage. The values range from 0 to 100 percent, where 0 percent indicates that the stream stage is always greater than the groundwater elevation, whereas 30 percent value indicates that a reach is gaining 30 percent of the time. The points awarded for the different percent time gaining range from 0 points for stream reaches that are never gaining to 5 points for stream reaches that are gaining more than 60 percent of the time. The simulated percent time that streams are gaining is shown on **Figure 3-18b**.

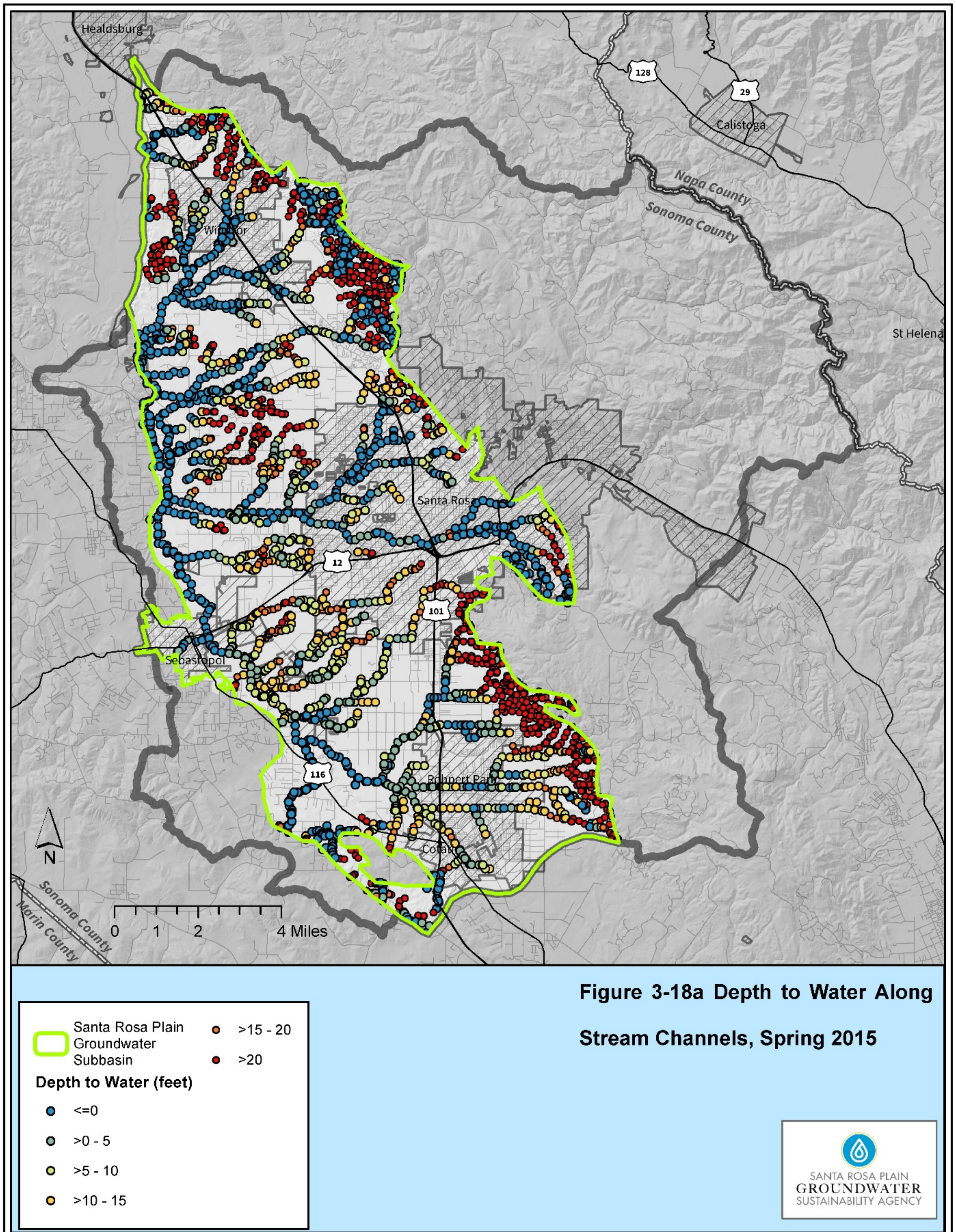

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Figure 3-18a. Depth-to-Water Along Stream Channels, Spring 2015

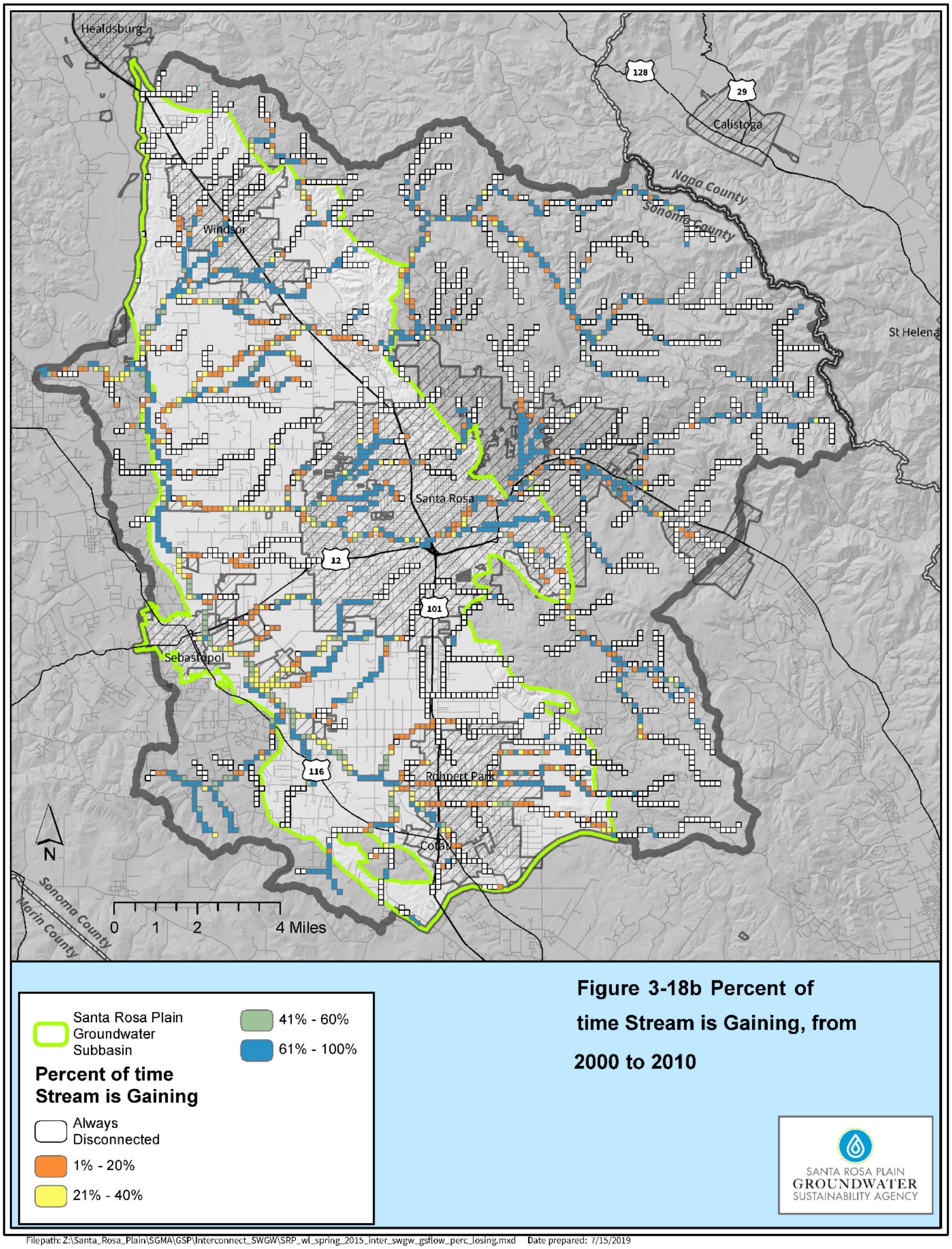

Figure 3-18b. Percent of Time Stream is Gaining, from 2000 to 2010

The simulated median stream flow was extracted from the GSFLOW output as the third criteria for the scoring system. The purpose of including this dataset was to account for stream reaches that are frequently dry. For stream reaches that are dry more than 50 percent of the time 0 points were assigned, whereas reaches with median nonzero discharges receive 2 points. A large majority of stream reaches are not frequently dry and receive 2 points, as shown on **Figure 3-18c**).

The simulated surface leakage was included as the fourth criteria to account for areas outside of stream reaches where interconnected surface water conditions might occur. Surface leakage occurs in GSFLOW where simulated groundwater heads are greater than the altitude of cell top. When surface leakage occurs, it would indicate wetland-like conditions. Model cells with simulated surface leakage are shown on **Figure 3-18d** and receive 2 points. Many of these cells are located in areas of the Subbasin that receive recycled water from the City of Santa Rosa.

Classifying Reaches as Interconnected Surface Waters

The point values from **Figures 3-18b** through **Figure 3-18d** were summed for each cell. The resulting values range from 1 to 14. A cutoff value is chosen to select stream reaches classified as interconnected surface waters based on a multiple lines of evidence approach. A value of 7 points was chosen based on the following reasoning. Stream reaches below a value of seven have either only one high-scoring metric (for example, 5 points) and a low-scoring metric (2 points or fewer), or multiple low-scoring metrics. These reaches therefore do not have multiple lines of strong evidence indicating they are interconnected. On the other hand, reaches with 7 or more points have at least one high-scoring and one medium-scoring metric, or multiple medium-scoring metrics. These reaches are therefore characterized by multiple lines of evidence as having interconnections to the groundwater system. The second line of reasoning that supports the chosen point value cutoff is its distinction between small and large streams. It is expected that small streams go dry during summer months and during drier periods. As presented on **Figure 3-18e**, some smaller streams are included in the interconnected reaches, but the interconnected reaches are predominantly the higher order stream reaches. Groundwater elevations from 10 recently constructed shallow monitoring wells equipped with dedicated pressure transducers, at 9 locations near streams in the Santa Rosa Plain, were used to further assess and corroborate the mapping of interconnected surface water in the Subbasin. The nine locations are all along streams mapped as interconnected using the scoring methodology. Streambed elevations near each monitoring well were obtained from LiDAR datasets to compare with groundwater elevations and assess interconnectedness, as only a few shallow wells have stream-surface water measurements near enough to assess the presence of gaining or losing conditions. While the period of record from these datasets only begins in November 2019, the limited available data indicate that at eight of the nine locations, groundwater levels occur above the estimated streambed at least part of the time and at the remaining location (SRP 0710 located along the Laguna de Santa Rosa at Stony Point Road), groundwater levels are within 10 feet of the streambed elevation. While limited, this additional dataset supports the mapping of interconnected streams shown on **Figure 3-18e**.

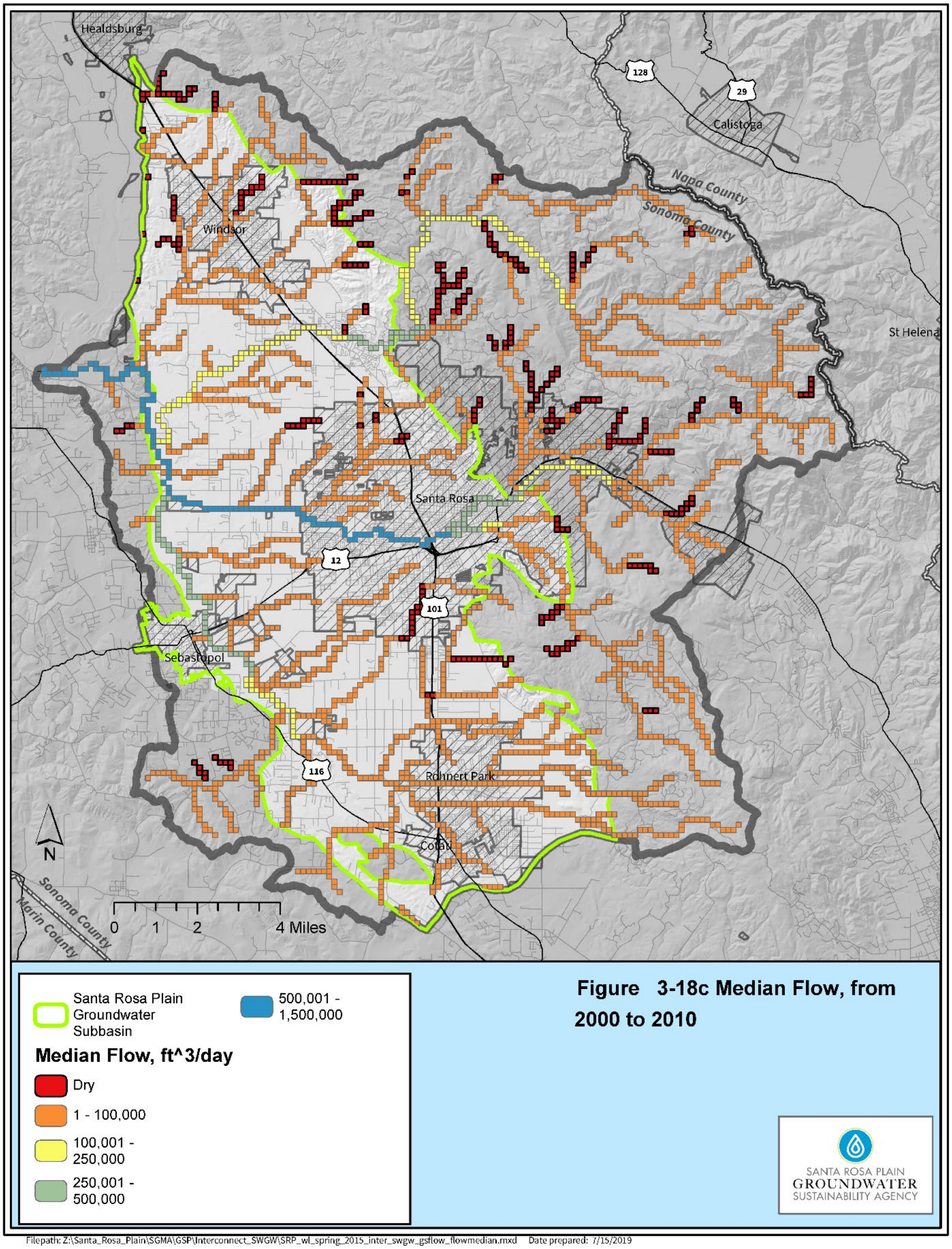

Figure 3-18c. Median Flow, from 2000 to 2010

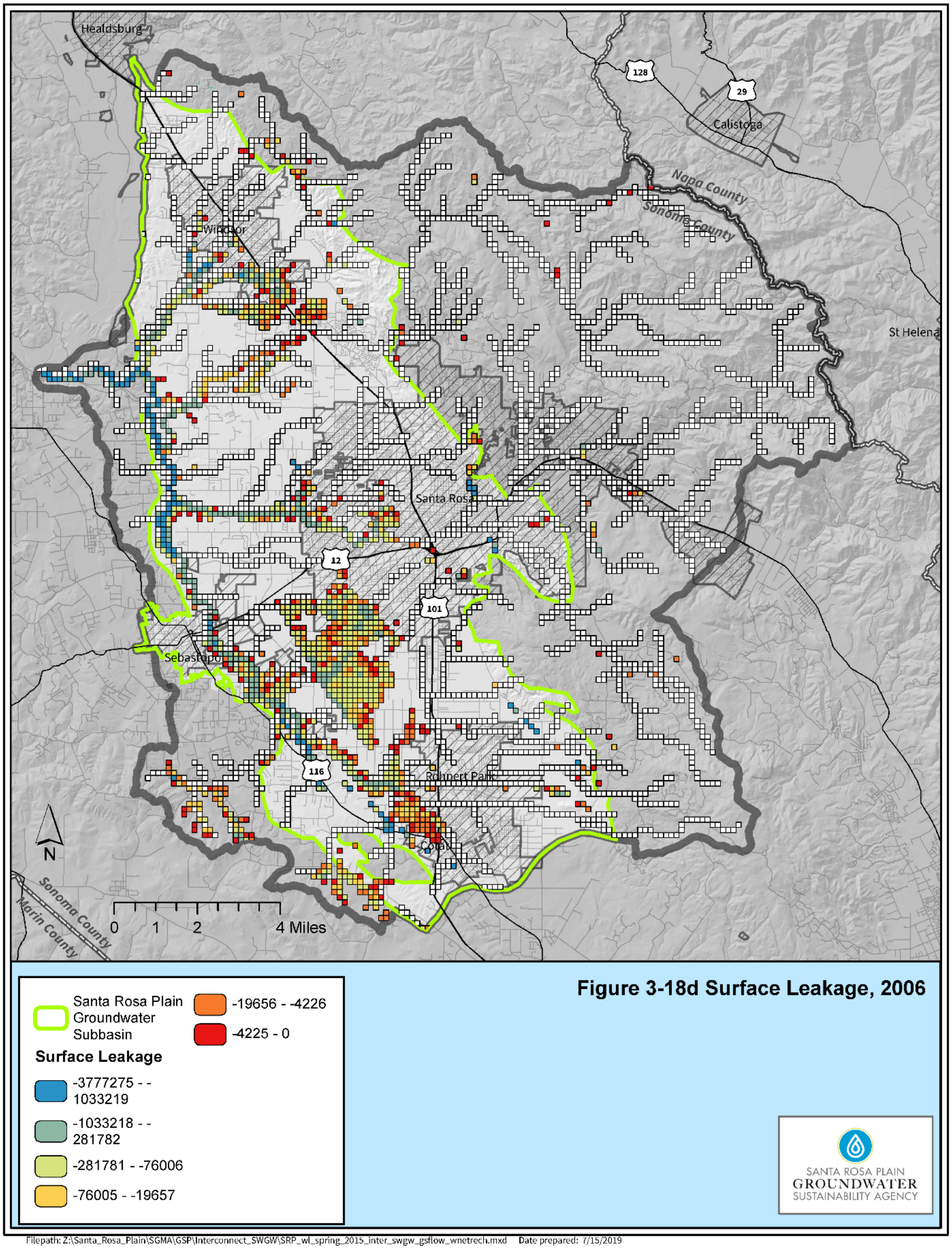

Figure 3-18d. Surface Leakage, 2006

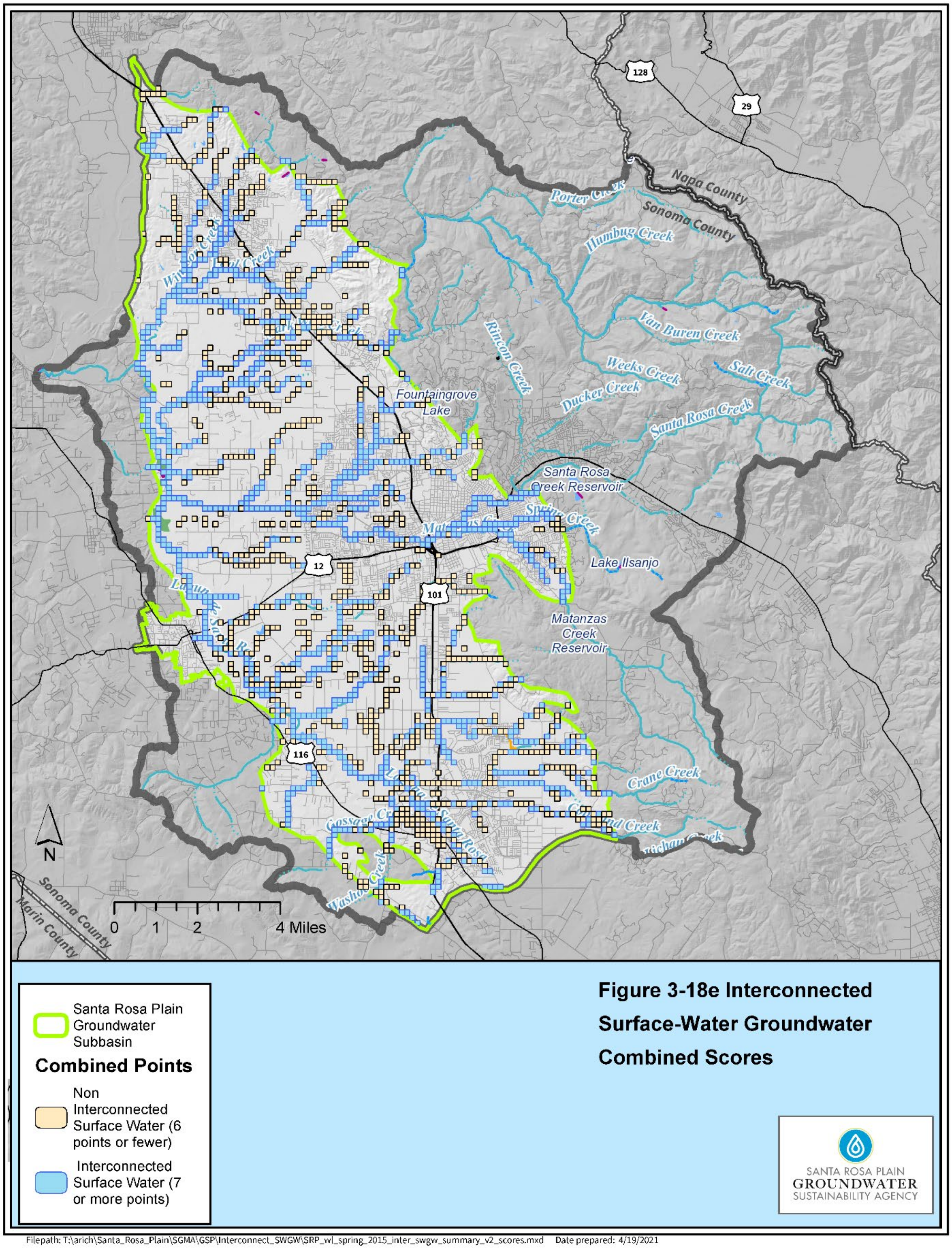

Figure 3-18e. Interconnected Surface Water Groundwater Combined Scores

The characterization of interconnected reaches of streams will continue to be evaluated and refined as additional data and information are gathered during implementation of the GSP. Unfortunately, there is insufficient data to estimate the quantity and timing of the depletion of surface water systems from groundwater pumping, and this data gap will need to be filled in the first five years of GSP implementation

3.2.6.3 Groundwater Dependent Ecosystems

SGMA defines an undesirable result as “depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water” (CA Water Code Section 10721 [w][6]). To help characterize environmental beneficial users, it is necessary to identify the aquatic species and habitats that could be adversely affected by lowered groundwater levels in principle aquifers and interconnected surface water depletion. The GSA partnered with the Petaluma Valley and Sonoma Valley GSAs to form a practitioner’s work group to provide expert advice and perspectives. This group met three times between July and November 2020. Meeting summaries and meeting materials are included in **Appendix 4-C**. The GDE Work Group included staff, expert biologists from Sonoma Water, and representatives from the following groups:

- San Francisco Estuary Institute
- County of Sonoma Ag and Open Space Preservation District
- Sonoma Ecology Center
- California Department of Fish and Wildlife
- Permit Sonoma
- The Nature Conservancy
- National Marine Fisheries Service
- Laguna Foundation

SGMA defines GDEs as “ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface,” which generally includes plant and animal communities that rely on shallow groundwater levels or interconnected surface water to meet all or some of their needs. The GDE Work Group focused on mapping aquatic species GDEs and vegetation GDEs that can be affected by groundwater conditions and management and are within the jurisdiction of the GSA. The methodology for mapping potential GDEs used information and guidance developed by The Nature Conservancy (TNC 2018) and the Groundwater Resource Hub (https://groundwaterresourcehub.org/).

3.2.6.4 Aquatic Species Groundwater Dependent Ecosystems

For mapping aquatic species GDEs, species listed in Critical Species LookBook (Rohde et al. 2019) were identified and include steelhead, Chinook salmon, coho salmon, California red-legged frog, and California tiger salamander. The Critical Species LookBook is a compendium of 84 state- and federally listed species that are likely to be affected by groundwater management and merit consideration by GSAs under the SGMA. Also, the federal- and state-endangered California freshwater shrimp was added at the request of resource agency staff. California tiger salamander was excluded because this species has “no known reliance on groundwater” (Rohde et al. 2019). The distribution of target species (species or groups of species specifically chosen for long-term monitoring) is based on frameworks developed for evaluating historically suitable coho salmon habitat (Leidy et al. 2005) and the salmonid sample frame developed for coastal monitoring plan in the Russian River watershed (Sonoma Water and University of California Cooperative Extension/California Sea Grant 2014).

In the Santa Rosa Plain, a total of eight streams were identified as habitat for at least one target species. Steelhead was the most widespread species occurring in each of the eight streams. The distribution of Chinook salmon and coho salmon within Mark West Creek coincides with the distribution of steelhead. For this reason, steelhead are essentially used as a priority indicator species to cover all aquatic GDEs in the Subbasin. To provide a conservative assessment whether any segment of a stream has been identified as habitat for steelhead (priority indicator species for sensitive aquatic species), the entire stream reach downstream of any interconnected reaches is included as sensitive aquatic species GDE.

Vegetation Groundwater Dependent Ecosystems

For mapping vegetation GDEs high-resolution local mapping available from the Sonoma County Veg Map was used (Sonoma Veg Map 2013). Classifications considered to have a potential reliance on groundwater included the following general classifications:

- Riparian Woodland
- Oak Woodland
- Freshwater Marsh and Aquatic

To identify where these vegetation classes are likely to have some connection with groundwater conditions within the Subbasin, the rooting depths of common tree species were compared to available depth-to-groundwater (DTW) mapping.

Following guidance from TNC, potential vegetation GDEs were mapped for areas with DTW of 30 feet or less to incorporate the potential rooting depths of oak trees (TNC 2018). The DTW mapping utilized available contoured springtime datasets for the shallow aquifer system (from 2015 and 2016) and high-resolution LiDAR data. The resulting high-resolution DTW maps used to assess potential rooting depths are included with other GDE Work Group meeting materials and meeting summaries in **Appendix 4-C**. To address Work Group member concerns that groundwater levels were generally at lower levels in 2015 and 2016 due to dry conditions, minor adjustments in some areas were made to incorporate the shallowest depth-to-water on record for each well based on review of all available data from 2005 to 2020. Additionally, all riparian woodland and oak woodland habitat within 100 feet of mapped interconnected surface waters were included as potential vegetation GDEs.

Integrated Potential Groundwater Dependent Ecosystem Map

The potential aquatic species GDEs and the potential vegetation GDEs were then integrated into a single potential GDE map presented on **Figure 3-19**.

As further described in **Section 4** and **Section 7**, additional studies and data gathering are recommended during the implementation of the GSP to better define the mapping and relationship of GDEs to groundwater conditions within the Subbasin.

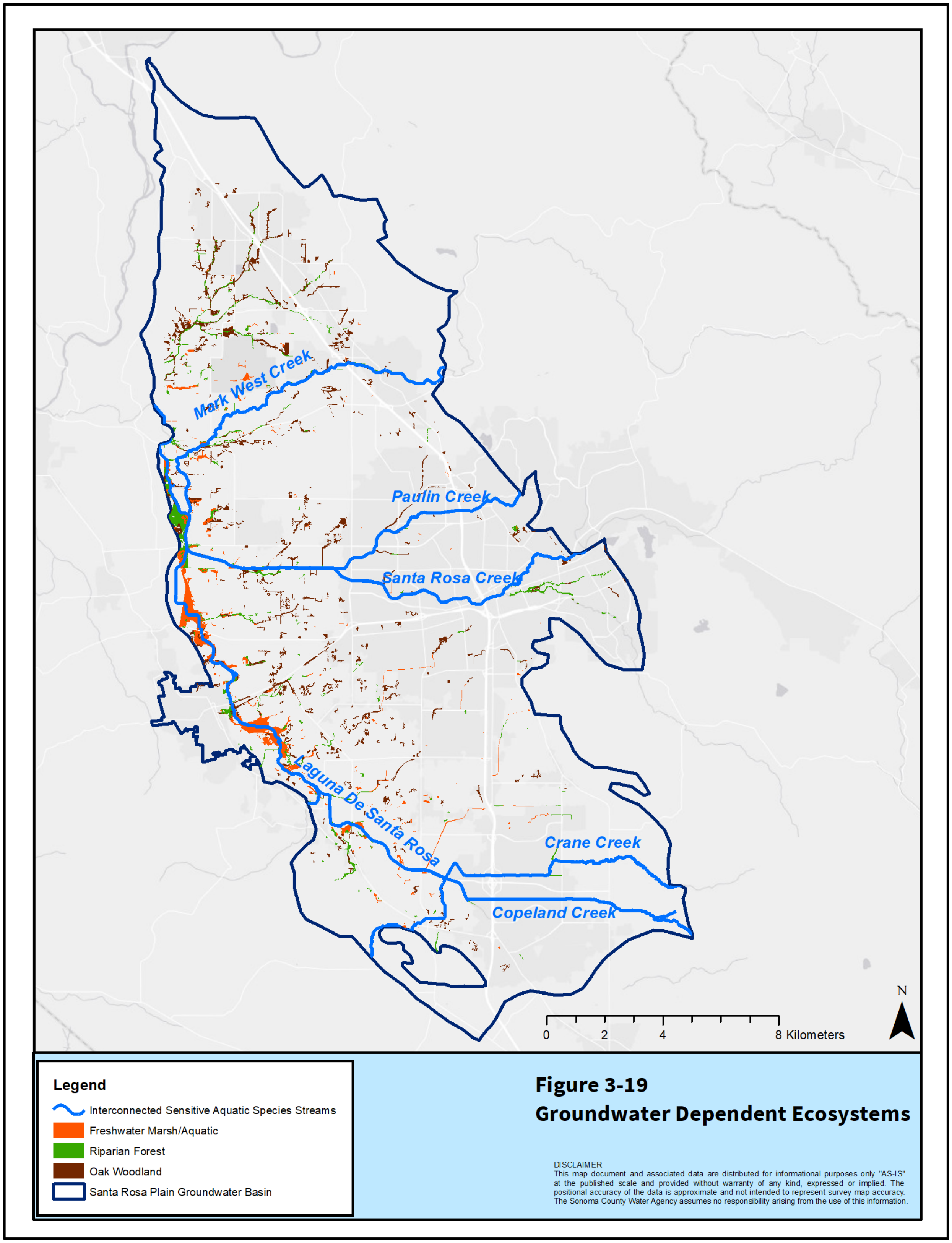

Figure 3-19. Groundwater Dependent Ecosystems

3.3 Water Budget

This section summarizes the estimated water budgets for the Subbasin, including information required by the SGMA Regulations and information that is important for developing an effective plan to achieve sustainability. In accordance with the GSP Regulations Section 354.18, this water budget provides an accounting and assessment of the total annual volume of surface water and groundwater entering and leaving the basin, including historical, current, and projected water budget conditions, and the change in the volume of groundwater in storage. Water budgets are reported in graphical and tabular formats, where applicable.

3.3.1 Overview of Water Budget Development

This section is subdivided into three subsections: (1) historical water budgets, (2) current water budgets, and (3) future water budgets. Within each of these subsections, a surface water budget and groundwater budget are presented. Water budgets were developed using the Santa Rosa Plain Hydrologic Model (SRPHM), originally developed by the USGS (Woolfenden and Nishikawa 2014), and revised by Sonoma Water for purposes of developing more accurate water budgets in the Subbasin. An overview of the model constructions and revisions made for this GSP are provided in **Appendix 3-C**. A detailed description of the construction and calibration of the original SRPHM can be found in the report by Woolfenden and Nishikawa (2014).

Before presenting the water budgets, a brief overview of the inflows and outflows pertaining to the Santa Rosa Plain Subbasin is provided.

In accordance with Section 354.18 of the GSP Regulations, one integrated groundwater budget was developed for the combined inflows and outflows for the two principal aquifers for each water budget period. Groundwater is pumped from both principal aquifers for beneficial use.

3.3.1.1 Water Budget Components

The water budget is an inventory of surface water and groundwater inflows and outflows from the Subbasin. A few components of the water budget can be measured, such as groundwater pumping from a metered well. Other components of the water budget are estimated, such as septic return flows and unmetered domestic groundwater pumping. Additional components of the water budget are simulated by SRPHM, such as unmetered agricultural pumping, recharge from precipitation and irrigation return flows, and change of groundwater in storage.

Figure 3-20 presents the general schematic diagram of the hydrologic cycle (DWR 2016d).

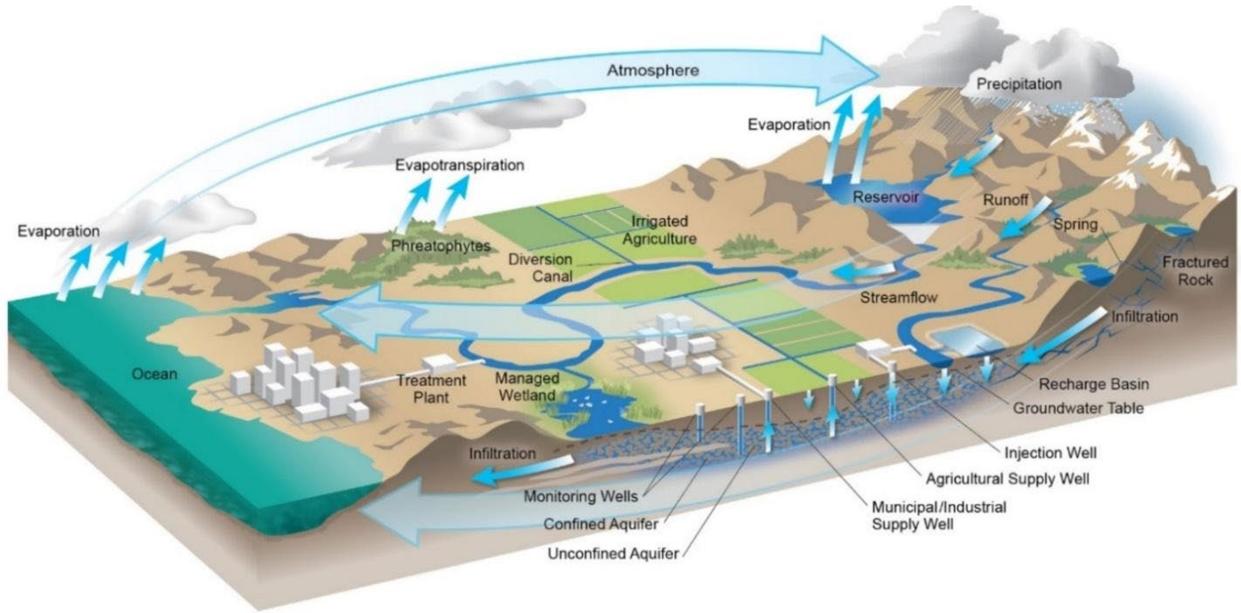

Figure 3-20. Schematic Hydrologic Cycle
Source: DWR 2016d

The water budgets for the Subbasin are calculated within the following boundaries:

- Lateral boundaries: The perimeter of the Santa Rosa Plain Subbasin as shown on **Figure 3-21.**
- Bottom: Base of the groundwater subbasin is approximately 2,000 feet, which is the depth below which groundwater is generally not considered usable. The water budget is not sensitive to the exact definition of this base elevation because it is defined as a depth below where there is not significant inflow, outflow, or change in storage.
- Top: Above the ground surface, such that surface water is included in the water budget.

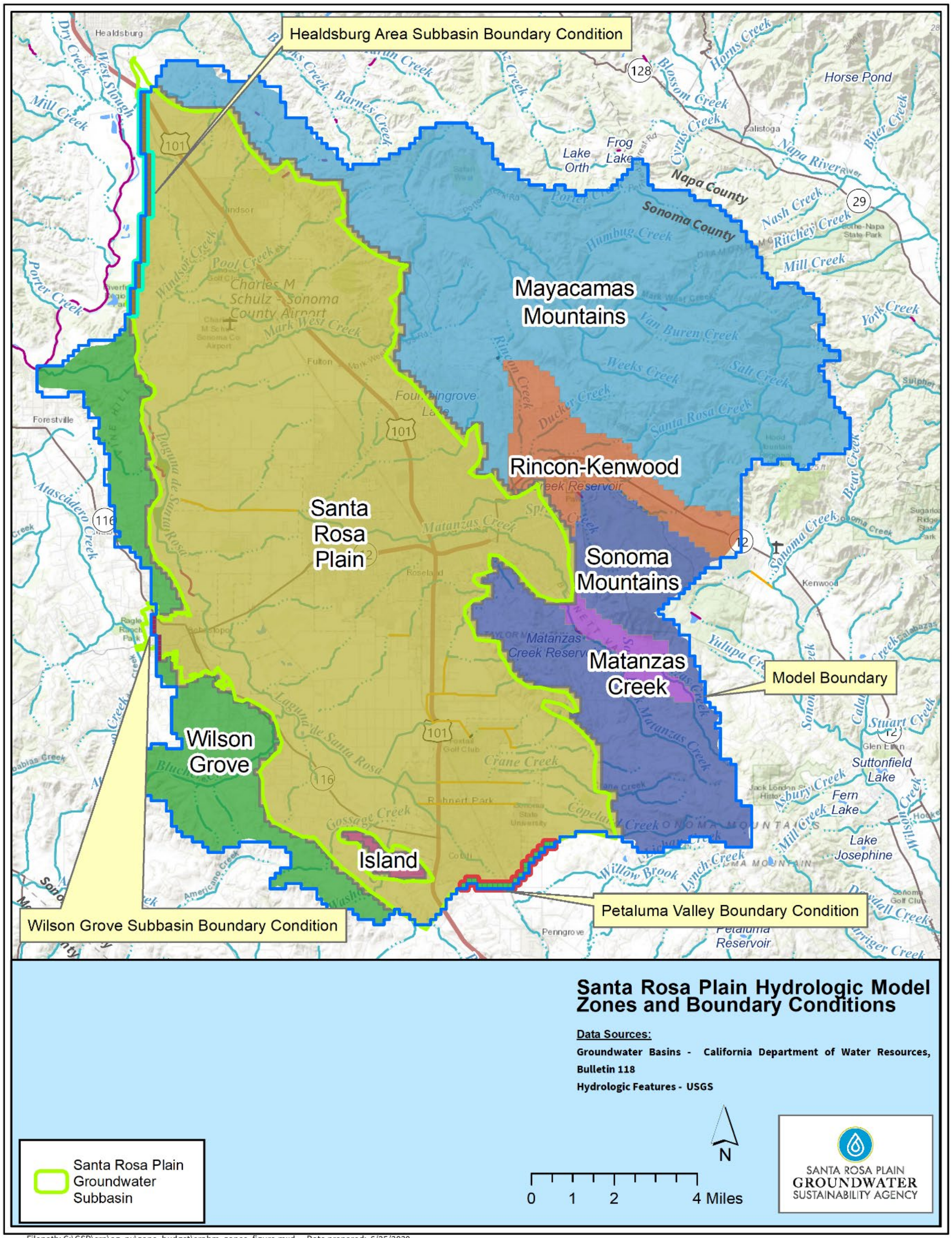

Figure 3-21. Zones and Boundary Conditions for the Santa Rosa Plain Hydrologic Model

The Santa Rosa Plain Subbasin includes the following inflows and outflows:

Surface Water Inflows:

- Runoff of precipitation (overland flow)
- Surface water inflows from creeks that enter the Subbasin: Mark West Creek, Santa Rosa Creek, Laguna de Santa Rosa, Blucher Creek, Windsor Creek, Copeland Creek, and other smaller streams
- Groundwater discharge to streams

Surface Water Outflows:

- Streambed recharge to groundwater
- Outflow to neighboring subbasins
    - Outflow of Mark West Creek and Windsor Creek
    - Outflow to Petaluma River and Estero de Santa Antonio to the Petaluma Valley Basin
    - Outflow of combination of other smaller streams
- Evaporation (assumed to be negligible compared to other surface water outflows)
- Direct diversions are not currently simulated in the model for lack of data accuracy; however, estimates are provided through summaries of eWRIMS data

The inflow and outflow locations are shown on **Figure 3-22**, along with the Hydrologic Unit Code (HUC) 12 (USGS 2006) boundaries that define the subregions used to aggregate inflows and outflows into the Subbasin.

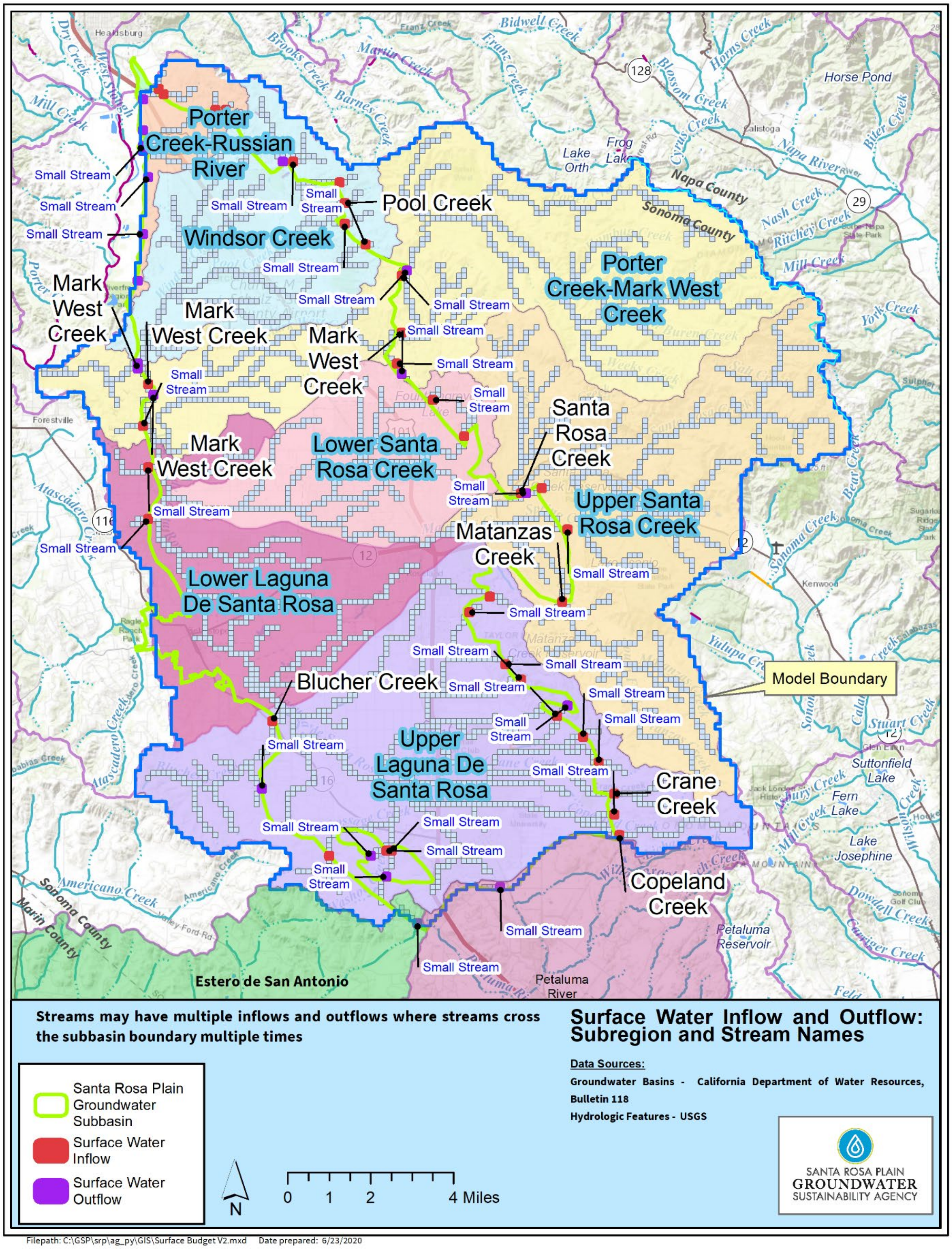

Figure 3-22. Surface Water inflow and Outflow: Subregion and Stream Names

Groundwater Inflows:

- Deep percolation from precipitation and applied irrigation water
- Septic return flows
- Streambed recharge to groundwater
- Subsurface inflows:
  - Inflow from Wilson Grove Formation Highlands Subbasin (Wilson Grove Subbasin and Wilson Grove Subbasin Boundary Condition on **Figure 3-22**)
  - Inflow from Healdsburg Area Subbasin (Healdsburg Area Subbasin Boundary Condition on **Figure 3-22**)
  - Inflow from Petaluma Valley Basin (Petaluma Valley Subbasin Boundary Condition on **Figure 3-22**)
  - Inflow from Rincon-Kenwood Subbasin
- Subsurface inflow from the surrounding watershed that are not other DWR subbasins, or mountain-front recharge (including the "island" just west of Cotati [**Figure 3-22**])

Groundwater Outflows:

- Crop, native vegetation and riparian ET
- Groundwater pumping (including municipal and industrial, rural domestic, and agricultural)
- Groundwater discharge to streams
- Subsurface outflows:
  - Outflow to Wilson Grove Formation Highlands Subbasin (Wilson Grove Subbasin and Wilson Grove Subbasin Boundary Condition on **Figure 3-22**)
  - Outflow to Healdsburg Area Subbasin (Healdsburg Area Subbasin Boundary Condition on **Figure 3-22**)
  - Outflow to Petaluma Valley Subbasin (Petaluma Valley Basin Boundary Condition on **Figure 3-22**)
  - Outflow to Rincon-Kenwood Subbasin
- Surface leakage, which is groundwater discharge to soil zone (rejected recharge to the surface in shallow groundwater areas)

Water infiltrates into the soil zone through a few processes, including infiltration of precipitation and applied agricultural irrigation water. Once in the soil storage reservoirs, it may end up as recharge but there is no way to distinguish different fates between the two. Because of this, deep percolation from precipitation and applied irrigation water are combined as one groundwater inflow term. However, precipitation is a far greater source of recharge than applied irrigation water over a yearly time period.

The difference between groundwater inflows and outflows is equal to the change of groundwater in storage.

3.3.1.2 Water Budget Time Frames

In estimating the Subbasin water budget, a time period for the budget needs to be specified. The GSP Regulations require water budgets for three different timeframes, representing historical conditions, current conditions, and projected conditions, as follows:

- The historical water budget is intended to evaluate how past water supply availability has affected aquifer conditions and the ability of groundwater users to operate within the sustainable yield. GSP Regulations require that the historical water budget includes at least the most recent 10 years of water budget information. DWR's Water Budget BMP document (DWR 2016d) further states that the historical water budget should help develop an understanding of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability to operate the basin within the sustainable yield. Accordingly, historical conditions should go back to the most reliable historical data that are available for GSP development and water budgets calculations.

- The current water budget is intended to allow the GSA and DWR to understand the existing supply, demand, and change in storage under the most recent population, land use, and hydrologic conditions. Current conditions are generally the "most recent conditions" for which adequate data are available and that represent recent climatic and hydrologic conditions. Current conditions are not well-defined by DWR but can include an average over a few recent years with various climatic and hydrologic conditions (for example, centered around the most recent drought in 2015, which is also the effective date of SGMA).

- The projected water budget is intended to quantify the estimated future baseline conditions both with and without implementation of potential GSP projects and management actions. The projected water budget is based on information from the historical budget and includes an assessment of uncertainty. The projected water budget estimates the future baseline conditions concerning hydrology, water demand, and surface water supply over a 50-year planning and implementation horizon. It is based on historical trends in hydrologic conditions, which are used to project forward 50 years while considering projected climate change and sea level rise (if applicable).

Although there is a significant seasonal variation between wet and dry seasons, the GSP does not consider seasonal water budgets for the groundwater budget. All water budgets are developed for complete WY(s). Though not required, a monthly water budget is shown for the surface water budget because of the importance of seasonal flow regimes for GDEs. Selected time periods for the historical and current water budgets are summarized in **Table 3-2** and on **Figure 3-23,** and described in **Sections 3.3.3.1** and **3.3.3.2**.