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DRAFT Basin Setting Section

**Groundwater Sustainability Plan for
Sonoma Valley Groundwater Subbasin**

****Note to Reader: Text in Red indicates information that has not yet been developed and/or will be modified or further described in subsequent sections of the GSP****

Contents

3. Basin Setting

This section provides information about the physical setting, characteristics and current conditions of the Sonoma Valley Groundwater Subbasin, 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. The Basin Setting 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)

The Basin Setting draws upon previously published studies and reports including the following primary data sources that document the conditions of the Sonoma Valley Subbasin and contributing watershed areas:

- 2014, Sonoma Valley Groundwater Management Program. Five-Year Review and Update Report.
- http://sonomavalleygroundwater.org/wp-content/uploads/5-year-Review-and-Update-2014.pdf2007, Sonoma County Water Agency. Sonoma Valley Groundwater Management Plan.
- http://sonomavalleygroundwater.org/wp-content/uploads/Sonoma-Valley-Groundwater-Management-Plan-2007.pdf2006, U. S. Geological Survey. Geohydrological Characterization, Water-Chemistry, and Ground-Water Flow Simulation Model of the Sonoma Valley Area, Sonoma County, California. https://pubs.usgs.gov/sir/2006/5092/

For additional details, the reader should refer to these documents and studies.

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:

- An understanding of the general physical characteristics related to regional hydrology, geology, geologic structure, water quality, principal aquifers, and principal aquitards of the basin setting;
- The context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks, and
- A tool for stakeholder outreach and communication.

As such, the 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 5.0 (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 Sonoma Valley Subbasin is located in the North Coast Ranges geomorphic province of California. The North Coast Ranges are characterized by predominantly northwest trending mountains and valleys formed in response to regional tectonic stresses that produced northwest-trending faults related to the San Andreas Fault system. The Subbasin is adjacent to and north of San Pablo Bay and is approximately 20 miles in length, encompassing the majority of Sonoma Valley between the Sonoma Mountains to the west and the Mayacamas Mountains to the east, as shown on **Figure 3-1**.

The Sonoma Mountains separate the Subbasin from the Petaluma Valley and Santa Rosa Plain to the west and are of moderate relief sloping gently from a few hundred feet in the southern part to greater than 2,000 feet southwest of Glen Ellen and reaching a maximum elevation of about 2,295 feet on Sonoma Mountain. The Subbasin is bounded on the east by the Mayacamas Mountains that range from less than 100 feet elevation in the Carneros area increasing from south to north to a maximum elevation of 2,730 feet at Hood Mountain northeast of the Subbasin.

The Subbasin between the two ranges is not uniform in width or slope, and can be subdivided into two portions on the basis of topography. The upper portion of the Subbasin is much narrower than the lower portion and has a hilly topography. This portion of the valley is sometimes referred to as the Valley of the Moon and includes the Glen Ellen area and extends southward to near Boyes Hot Springs. In this part of the valley, elevations drop from about 400 feet to about 100 feet over an approximately 5-mile distance, from north to south. The remainder of the valley southward to San Pablo Bay has a flat topography and ranges as much as 5 miles in width and includes the City of Sonoma, El Verano and Schellville areas. In this area, the elevation of the Subbasin floor gradually slopes from about 100 feet to sea level over a distance of about 12 miles.

3.1.2 Surface Water and Drainage Features

The Subbasin and contributing watershed area are drained by Sonoma Creek and its tributaries, which discharge into San Pablo Bay in the northern part of San Francisco Bay, as shown on **Figure 3-1**. Sonoma Creek flows for approximately 33 miles and begins in the Mayacamas Mountains outside of the Subbasin in the northeastern portions of the Sonoma Creek watershed, at an elevation of about 1,600 ft within Sugarloaf Ridge State Park. The creek flows generally westward through a narrow canyon with a steep gradient from the headwaters to the edge of the Kenwood Valley Basin near the community of Kenwood. In this 3-mile reach, the creek drops about 1,100 ft to an elevation of about 500 ft. The course of the creek turns to the south near Kenwood and then turns to the southeast where it enters the Sonoma Valley Subbasin near Glen Ellen. The gradient is much less steep in the 6.5-mile reach between the mountain front and Glen Ellen, dropping in elevation by about 280 ft. The gradient flattens further between Glen Ellen and San Pablo Bay. As it passes through the city of Sonoma, it is an urban creek that emerges into agricultural areas to the south. South of State Route 121 where Sonoma Creek flows through tidal marshland to San Pablo Bay, the stream drops only about 10 feet in 9 miles (USGS, 2006). Primary tributaries to Sonoma Creek within the Subbasin include Calabazas Creek, Yulupa Creek, Carriger Creek, Fowler Creek, Nathanson Creek, Arroyo Seco, Schell Creek, Tolay Creek and Fryer Creek.

3.1.3 Soil Characteristics

Soil types and characteristics in Sonoma Valley have been mapped by the U.S. Department of Agriculture (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 NRCS, 2007). The SSURGO database defines 17 different soil textures (excluding variable and unknown textures) present in the study area (USDA, 1997), which are shown on **Figure 3-2a**. The majority of the valley floor is characterized by clayey soils and loams with gravelly and cobbly loams and more prevalent along alluvial fans and hilly areas. Gravelly and sandy soils are primarily limited to narrow stream channels within the Subbasin.

The SSURGO database also assigns saturated hydraulic conductivity values to soil groups, which are shown on **Figure 3-2b**. 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 3-2b**, 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. 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 northwest of Glen Ellen and west of El Verano (Carriger Creek alluvial fan area). The highest saturated hydraulic conductivities (rapid to very rapid) on the order of 12 to 40 feet per day primarily occur within streambed channels.

3.1.4 Regional Geologic Setting

Sonoma Valley is located within a region of geologic complexity caused by long periods of active tectonic deformation, volcanic activity and sea level changes. Geologic formations within the Subbasin are grouped into two broad categories (Mesozoic Era basement rocks and younger Cenezoic 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. **Figure 3-3a** presents a geologic map of the Subbasin and contributing watershed areas showing the surficial distribution of these geologic units, with the legend and relative ages for the units shown on **Figure 3-3b**. The inferred subsurface distribution of the geologic units is displayed on the hydrogeologic cross-sections shown on **Figures 3-4a-d**. **Note to Reader**: The hydrogeologic cross-sections are in development and will be included in subsequent draft of Section 3.1, along with a written description and discussion of the cross-sections in the following sections.

3.1.4.1 Geologic Structure

In Sonoma Valley, these geologic formations have undergone several episodes of folding and faulting that have resulted in a general synform (or U-shaped) structure to the valley with unit layering tilted towards the valley axis. This general structure is not uniform and is disrupted by many minor folds and faults (Farrar et al, 2006). As shown on **Figure 3-3a**, both inactive and active faults are prevalent in the region and numerous faults and fault systems have been mapped within the hills surrounding Sonoma Valley particularly within the southwestern hills and northwestern hills associated with the Rodgers Creek/Tolay Faults and the Bennett Valley Fault, respectively. Faults are generally not evident on the valley floor where they are concealed by younger sediments. However, along the east side of the valley, a fault termed the Eastside Fault has been mapped based on geophysical studies and the outcrop pattern of Tertiary sediments of the Huichica Formation. Available information on the effects of faults on groundwater movement and groundwater quality is described in Section 3.1.6 below.

3.1.4.2 Mesozoic Era Basement Rocks

Mesozoic Era basement rocks generally yield very little water, as their porosity is primarily attributed to fractures, which are commonly limited in extent and water transmitting capacity. The Mesozoic basement rocks are only exposed outside of the Subbasin within the northeast portions of the contributing watershed where rocks of the Franciscan Complex and Coast Range Ophiolite occur around Hood Mountain. The depth to the Mesozoic basement rocks is inferred to range from approximately 1,000 feet in the northern portions of the Subbasin near Glen Ellen to greater than 10,000 feet adjacent to San Pablo Bay based on gravity data modelled by the USGS, as indicated on **Figure 3-5**. Beneath the majority of the Subbasin, the modeling indicates that the depth to the Mesozoic basement rocks generally ranges from 3,000 to 6,000 feet (Langenheim, 2006).

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. Geologic units that are of greatest importance for groundwater resources within Sonoma Valley

(Farrar et al, 2006) are described below in general order of decreasing age (older to younger) and include both Tertiary-aged (between 66 to 2.5 million years old) and Quaternary-aged (younger than 2.5 million years old) units.

Tertiary Volcanic Units

Sonoma Volcanics

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, 2011). The western age group consists of five volcanic-sedimentary assemblages within Sonoma Valley: the Sonoma Mountain, Sonoma Creek, Arrowhead Mountain, Bismarck Knob, and Sugar Loaf assemblages. The majority of the volcanic materials associated with these assemblages appear to have been sourced predominantly from local volcanic vents and domes located within the Mayacamas Mountains east of the Subbasin (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. **Figure 3-6** displays the inferred top of the Sonoma Volcanics based on lithologic data obtained from well completion reports for approximately 2,000 water wells in Sonoma Valley. As shown on **Figure 3-6**, the depth to the top of the volcanics ranges from less than 50 feet to at least 750 feet and is generally shallowest along the margins and northern portions of the Subbasin and is deepest in the southern portions of the Subbasin and within and north of the El Verano area. The Sonoma Volcanics are highly variable in lithology and their subsurface distribution is often difficult to discern from well drillers logs in the Sonoma Valley. Additionally, the upper part of the Sonoma Volcanics interfingers with the sedimentary units of the Glen Ellen and Huichica Formations in places further complicating the 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 near Sonoma Mountain (Farrar et al, 2006).

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. 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 Sonoma Valley. Estimated specific-yield values for the Sonoma Volcanics vary from 0 to 15 percent and well production yields generally range between 10 and 50 gallons per minute (gpm) and occasionally as much as several hundred gpm.

Specific yield is defined as the ratio of the volume of water that a saturated rock or soil will yield by gravity and is usually expressed as a percentage.

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. The occurrence of the Petaluma Formation in the Subbasin is limited to the upper member which is exposed in fault-bounded blocks along the western hills south of Sonoma Mountain.

The vertical extent of the Petaluma Formation is unknown owing to its limited distribution in Sonoma Valley. Due to the large amount of silt- and clay-sized particles, the specific yields of wells completed in the Petaluma Formation are generally low, varying from 3 to 7 percent. Domestic wells drilled into the Petaluma Formation yield on average about 20 gpm and vary from 10 to 50 gpm.

Huichica Formation

The Huichica Formation is a Pliocene- to Pleistocene-aged (approximately 3.5 to 4 million years old) fluvial sedimentary unit deposited by small streams into alluvial fans, lakes and lagoons. The unit consists of massive yellow silt and yellow and blue clay with interbedded lenses of sands, gravels, and tuff beds. The Huichica Formation crops out primarily in the hills along the southeastern part of Sonoma Valley in the Carneros region and underlies younger deposits beneath much of the southern valley floor. The unit overlies and is partly interbedded with the Sonoma Volcanics and may interfinger with the Glen Ellen Formation beneath the central portions of the Subbasin and may be indistinguishable in well logs and in outcrops.

The total thickness of the Huichica Formation is likely greater than 1,000 feet beneath parts of the valley floor (USGS, 2006). Well yields of the formation are low, typically 2 to 20 gpm, however, in some areas, the lower part of this formation can be higher yielding. The specific yield range for the Huichica is between 3 and 7 percent.

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 along 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 a few hundreds of feet, both laterally and vertically. This unit interfingers with the Huichica Formation and lies on top of the Sonoma Volcanics in some regions and on the Franciscan Complex in other regions. The Glen Ellen Formation is primarily exposed along the northern margins of the Subbasin and within the Kenwood Valley north of the Subbasin.

The Glen Ellen Formation is estimated to be about 600 feet thick near Glen Ellen, but the thickness may be greater beneath some portions of the Subbasin. The relatively high content of clay-sized material, degree of compaction, and cementation tend to limit the permeability of the Glen Ellen. 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. Glen Ellen Formation wells typically produce a few tens to hundreds of gpm, with well yields generally less than 20 gpm. The specific yield range for the Glen Ellen is between 3 and 7 percent.

Quaternary Sedimentary Deposits

<u>Quaternary Alluvial Deposits</u>

Quaternary alluvial deposits cover much of the valley floor and include Holocene (younger than 100,000 years) 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. These deposits form a broad blanket in the lower valley, a narrower band and discontinuous patches through the hilly middle valley, and a wide blanket in the Kenwood Valley outside the Subbasin. In general, the alluvial materials nearest the valley margins and directly along major stream courses contain the greatest proportions of coarse-grained sediments.

The Quaternary alluvial units are inferred to range in thickness from near zero at the valley margins to as much as 300 feet near the center of the valley. Where these deposits are thick and saturated, they are the highest yielding aquifers in the valley, with well yields of more than 100 gpm. The specific yield range for the Quaternary alluvial units is 3 to 15 percent.

<u>Quaternary Bay Muds</u>

Quaternary bay mud deposits of Holocene age cover the southern tidal marshlands of the Subbasin. These deposits are primarily composed of organic rich muds and silts with small amounts of sand. The bay muds were deposited during a higher stand of sea level and, as such, contain entrapped brackish and saline water.

The thickness of the bay muds ranges from near zero at its margins to an estimated 200 feet along the shore of San Pablo Bay (USGS, 2006). Due to the low permeability and poor water quality associated with the bay muds, they are generally not tapped for groundwater supply and their specific yield is estimated to be less than 3 percent.

3.1.4.4 Lateral and Vertical Extent of Subbasin

The structural setting and distribution of geologic units described above influence the Subbasin extents, which are defined by DWR, as documented in Bulletin 118. In general, the lateral extent of the Subbasin is defined based on the surficial distribution of the Tertiary sedimentary units and their contact with the Tertiary Sonoma Volcanics based on the 1982 Geologic Map of the Santa Rosa Quadrangle (CDMG, 1982). The boundary does not precisely match up with these contacts on the more recent geologic map shown on Figure 3-3a, which is more detailed and refined than the 1982 map (California Geologic Survey, 2017). Additionally, the southeastern portions of the Subbasin are defined based on the county boundary between Sonoma and Napa counties. The lateral extent and boundaries of the Subbasin are defined as follows:

- The southernmost corner of the basin is aligned with Tolay Creek for 5 miles, from the mouth of Tolay Valley to Tubbs Point. The shoreline of San Pablo Bay is the boundary from Tubbs Point to the outlet of Sonoma Creek. From Sonoma Creek to near Highway 121, the boundary is the Sonoma and Napa county boundary.

- The depositional contact between the topographically higher Sonoma Volcanics and the Tertiary sedimentary units (Glen Ellen, Huichica, and Petaluma Formations) and overlying Quaternary alluvial deposits defines the remaining eastern, western and northern boundaries, with portions of the boundary also coinciding with the Eastside and Bennett Valley faults.

The vertical extent 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 1,200 feet and no existing known water wells extending deeper than 1,500 feet. At depths exceeding approximately 1,500 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 geothermal fluids.

3.1.5 Principal Aquifer Systems and Aquitards

The GSP Regulations require the identification of principal aquifers and aquitards within groundwater basins. Principal aquifers, which are defined by DWR as "*aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems*", have unique and important requirements defined in the GSP Regulations, which require the following for <u>each</u> 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

In order to characterize the aquifer systems within the Subbasin 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. While previous investigators have evaluated and described hydraulic properties associated with the geologic formations discussed above, insufficient information and data is available to correlate distinct aquifer systems based solely on geologic information. The limitations on available information and data with which to draw correlations is due, in part, to the high degree of heterogeneity associated with the geologic units, deformation related to folding and faulting of Tertiary-aged units which are difficult to discern in the subsurface, similarities in texture and composition of many of the sedimentary units, and related lack of high quality lithologic descriptions for the subsurface.

A fairly high degree of correlation and distinctions can be made based on aquifer depth. As described below, the shallow and deep aquifer systems exhibit properties and features that allow for their grouping into separate aquifer systems, including 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 is developed during implementation of the GSP regarding the lateral and vertical characteristics and hydraulic connections between the different aquifer units.

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 aquitards that predominantly occur within the sedimentary units of the Glen Ellen and Huichica Formations.
- The shallow aquifer system is generally present under unconfined to semi-confined conditions, while the deep aquifer system is nearly always present under confined or semi-confined conditions.
- The shallow aquifer system generally exhibits stable long-term groundwater levels, while in southern Sonoma Valley many wells completed within the deep aquifer system have exhibited long-term declining groundwater levels (some important exceptions to this attribute are further described in Section 3.2.2)
- Wells completed in the shallow aquifer system near streams exhibit sharpseasonal increases in groundwater-levels highly correlative with precipitation and runoff

events, while sharp increases and decreases in groundwater levels within the deep aquifer system appear to correlate more closely with groundwater pumping events.

- In many areas the shallow aquifer system is locally and seasonally connected to Sonoma Creek and other tributaries within Subbasin, 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. Water samples from wells within the shallow aquifer system are typically isotopically heavier in comparison with the deep zone and anthropogenic 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 vastly different groundwater ages, with the deep aquifer containing water that was recharged up to 50,000 years before present, and the shallow aquifer generally containing waters recharged within the last 50 years.

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 below.

3.1.5.1 Shallow Aquifer System

The shallow aquifer system is generally present under unconfined or semi-confined conditions from the water table to depths ranging from 100 to 220 feet. The shallow aquifer system is present over the entire lateral extent of the Subbasin and primarily occurs within Quaternary alluvial deposits. However, in areas where these units are absent or thin, the shallow aquifer system locally occurs within sedimentary units of the Glen Ellen and Huichica Formations and in some areas, most notably in the northernmost portions of the Subbasin, occurs within the Sonoma Volcanics. In some localized and limited areas, very shallow and seasonal perched aquifers are present where infiltrating water can perch on very shallow lenses of clay; these are not considered to be part of the shallow aquifer system, as they are not continuous, not tapped for water supply, and likely do not contribute to the baseflow of streams.

<u>Shallow Aquifer System Materials and Properties</u>

The materials of the shallow aquifer system are primarily heterogeneous deposits of sand, silt, clay and gravel deposited along alluvial fans, stream channels and floodplains, with sand and gravel sequences forming the more permeable and transmissive portions. The heterogeneity and variability associated with these materials is displayed on **Figure 3-7a**, which was created from a lithologic textural model developed by Sonoma Water using lithologic data from well completion reports for approximately 2,000 water wells in Sonoma Valley. The distribution of primary lithologic textural components (clays, coarse sands or gravels, volcanic, and mixtures) are shown for the shallow aquifer system and provide an indication of where higher and lower aquifer storage and transmission values can be expected. In general, higher values are expected where the primary textures are either coarse sands and gravels or mixtures in comparison with clays. Areas with volcanic lithologic textures are expected to exhibit a high variability in aquifer storage and transmission values. As shown on **Figure 3-7a**, the coarser-grained materials within the shallow aquifer system primarily occur west and south of the El Verano area (Rodgers Creek, Felder Creek and Carriger Creek drainages and alluvial fans) and in the Agua Caliente area. Clays make up the primary lithologic texture in the vicinity of and southeast of the City of Sonoma and east of El Verano. Volcanic lithologic textures primarily occur along the margins of the Subbasin in some areas, such as near the Rodgers Creek drainage and most significantly in the northernmost areas of the Subbasin, north of Glen Ellen, and within the Kenwood Valley outside of the Subbasin.

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 driller 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. Very few aquifer tests have been conducted and reported within the Subbasin and none have been documented within the shallow aquifer system; therefore estimates for the shallow aquifer system are primarily based on lithologic texture data and numerical model calibration.

The specific yield of the shallow aquifer system is estimated to vary from approximately 3 to 15 percent based on the estimates for the Quaternary sedimentary deposits and Huichica and Glen Ellen Formation described above (DWR, 1981). An estimate of 10% for specific yield for the shallow aquifer system has been derived through numerical modeling (Farrar, et al 2006 and Bauer, 2008). Estimates of hydraulic conductivity for the shallow aquifer system derived through numerical modeling range from 1 to 60 feet per day (Farrar, et al 2006 and Bauer, 2008).

Shallow Aquifer System General Water Quality Characteristics

Groundwater samples collected from wells within the shallow aquifer system are most commonly characterized as a mixed-bicarbonate type water with relatively low dissolved solid concentrations (Farrar et al, 2006). Additionally, water samples from wells completed within the shallow aquifer system typically exhibit fairly young ages based on carbon 14 dating or the presence of tritium. Anthropogenic constituents, such as nitrate, are more commonly found in the shallow aquifer system in comparison to the deep aquifer system. These characteristics are typical of shallow aquifer systems in general and consistent with water derived either directly from precipitation or indirectly from precipitation through infiltration from streams (Farrar et al, 2006).

Additional details on data and groundwater quality conditions and trends are included in Section 3.2.

Shallow Aquifer System Primary Uses

The shallow aquifer system serves numerous 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 also provides a significant amount of baseflow to Sonoma Creek and some of its tributaries, which contributes to streamflow and provides benefits to ecosystems in the Subbasin. Additionally, in some areas where groundwater levels are close to the ground surface, such as near streams and in the tidal marshland areas, the shallow aquifer system provides water for vegetation communities in the Subbasin.

3.1.5.2 Deep Aquifer System

Aquifer zones beneath the shallow aquifer system are characterized collectively as the deep aquifer system and are generally separated from the shallow aquifer by thick sequences of clay aquitards, as described below. The deep aquifer is generally present beneath approximately 400 feet below ground surface (i.e., below the shallow aquifer system and clay aquitard described below) 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. In areas where multiple permeable zones occur within the deep aquifer system, these different zones can sometimes exhibit distinct features (e.g., distinct water quality signature or appreciable differences in piezometric heads), although 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. In areas where data is available, distinctions between the upper and lower portions of the deep aquifer system are discussed in this GSP.

Deep Aquifer System Materials and Properties

The deep aquifer system is primarily composed of relatively thin sand and gravel sequences interspersed within variable amounts of clay. The deep aquifer system generally occurs under confined conditions within sedimentary deposits of the Glen Ellen, Huichica and, to a lesser degree, Petaluma Formations. Locally, the deep aquifer system also occurs within volcaniclastic sediments, tuffs, and fractured volcanic rocks of the Sonoma Volcanics where the volcanic units present within the hills extend beneath the alluvial fill of the valley floor. The heterogeneity and variability associated with these materials is displayed on **Figure 3-7b**, which was created from a lithologic textural model described in Section 3.1.5.1, above. As shown on **Figure 3-7b**, in comparison with the shallow aquifer system, the deep aquifer system exhibits a much higher percentage of volcanic materials which nearly entirely make up the deep aquifer system from near Boyes Hot Springs to the northern Subbasin boundary. Clay and mixtures of gravelly and sandy clays are pervasive throughout the southern portions of the Subbasin and coarser-grained materials occur either as a predominant texture or mixed with clay in the central portions of the Subbasin.

There have been a limited number of aquifer tests conducted within the Subbasin's deep aquifer system to estimate aquifer properties. Transmissivity estimates from these tests have ranged from approximately 3,000 to 30,000 gallons per day per foot (gpd/ft) for tests on wells within the Sonoma Volcanics and from approximately 1,000 to 10,000 gpd/ft for wells in the Glen Ellen and Huichica Formations (GHD, 2012 and LSCE, 1999). Estimates for storativity (a dimensionless parameter defined as the volume of water released from storage per unit decline in aquifer) from the tests were 0.0007 within the Sonoma Volcanics and ranged from 0.001 to 0.008 within the Glen Ellen Formation (GHD, 2012 and LSCE, 1999). These values are generally reflective of confined aquifer conditions. Estimates of hydraulic conductivity from these tests is limited to the Sonoma Volcanics within the City of Sonoma, which yielded a range of approximately 5 to 34 feet per day (GEI et al, 2017).

Estimates of specific storage for the deep aquifer system derived through numerical modeling range from 0.0001 to 0.0000015 (Farrar, et al 2006 and Bauer, 2008). Estimates of hydraulic conductivity for the deep aquifer system derived through numerical modeling range from 0.5 to 25 feet per day (Farrar, et al 2006 and Bauer, 2008).

Deep Aquifer System General Water Quality Characteristics
Groundwater samples collected from wells within the deep aquifer system are most commonly characterized as sodium-mixed anion or sodium-bicarbonate type water with relatively higher dissolved solid concentrations in comparison with the shallow aquifer system (Farrar et al, 2006). Additionally, water samples from wells within the deep aquifer system typically exhibit pre-modern ages (older than 50 years) based on carbon 14 dating or the presence of tritium. Additionally, in many areas of the deep aquifer system, particularly areas near the Eastside Fault and Sonoma Volcanics, warm geothermal fluids occur within the deep aquifer system (Youngs et al, 1982). Further data and discussion of groundwater quality conditions and trends are included in Section 3.2.

Deep Aquifer System Primary Uses
The deep aquifer system serves numerous different users and uses with extractions being from a combination of domestic water supply wells that provide water to rural residential properties in the unincorporated areas of the Subbasin, agricultural irrigation wells used for crop irrigation, industrial wells used for businesses, and public water supply wells for municipal and smaller public supply systems.

3.1.5.3 Aquitards

Aquitards composed of clay deposits or volcanic flow rocks typically separate the shallow and deep aquifer systems and serve to locally confine the deeper aquifer system. In the southern portion of the Subbasin, thick sequences of clay generally present between approximately 200 and 400 feet below ground surface (bgs) form an effective aquitard, generally limiting hydraulic communication between shallow and deeper aquifer zones. The confining unit in this area is composed of clay-rich sediments of the Glen Ellen and Huichica Formations with thin interspersed lenses of sand and gravel and generally ranges from 160 to 350 feet thick. In some areas, the clay aquitards are thinner and/or interspersed with lenses of sand and gravel. In such areas, the shallow and deeper aquifer systems may exhibit a stronger degree of hydraulic connection. In the northern portions of the Subbasin (from approximately Boyes Hot Springs to the northern boundary), the aquitard(s) separating the shallow and deep aquifer systems are likely comprised of relatively impermeable volcanic flow rocks.

The heterogeneity and variability associated with materials of these confining aquitards is displayed on **Figure 3-7c**, which was created from a lithologic textural model described in Section 3.1.5.1, above. As shown on **Figure 3-7c**, clays or mixtures of gravelly or sand clays make up much of the aquitard in the central and southern portions of the Subbasin and volcanics are the predominant component north of Boyes Hot Springs and in a small area along the Subbasin margin east of the City of Sonoma. Interspersed coarse-grained units occur within the aquitard primarily within the Felder and Rodgers Creek drainages, which is an area where greater hydraulic communication may occur between the shallow and deep aquifer systems.

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 moved next to each other.

Several faults have been mapped in the Sonoma Volcanics within the uplands surrounding the Subbasin, with the Tolay, Rodgers Creek and Bennett Valley faults being the primary fault zones. One northwest-striking fault has been mapped along the eastside of the valley floor. This fault, referred to as the Eastside Fault, is a high angle fault with vertical offset that has down-dropped geologic units on the west side of the fault. The fault may act as a hydrologic barrier to horizontal groundwater flow and may be a conduit for the upward circulation of deeper thermal waters (Farrar et al, 2006). Alignment of thermal wells and springs located along the fault, mainly on its east side in the Boyes Hot Springs area are indicators that the fault is a conduit for warm water and/or groundwater barrier for warm water (Youngs et al, 1983). While it appears that the fault has offset aquifers, additional groundwater level data is needed to further assess the fault's effect on groundwater flow.

Other faults which border portions of the Subbasin may also serve as groundwater flow barriers and limit the amount of subsurface inflows from aquifer zones of the Sonoma

Volcanics along these Subbasin boundaries, such as along Carriger Creek where groundwater levels west of a splay of the Bennett Valley Fault zone are much higher than groundwater levels east of the fault zone. Groundwater data needed to make this determination in other areas along the Subbasin boundaries is limited.

3.1.7 Natural Groundwater Recharge and Discharge

Groundwater Recharge

Recharge to aquifers in the Subbasin primarily occurs through streambed recharge along portions of Sonoma Creek and its tributaries, as well as through direct infiltration of precipitation and along the margins of the valley areas (mountain front recharge). The shallow aquifer system receives most of this recharge. Recharge that reaches the deeper aquifer zones is more poorly defined and likely comes from a combination of leakage from overlying shallow aquifers and mountain front recharge along the margins of the valley.

Previous estimates of groundwater recharge in Sonoma Valley have primarily included qualitative assessments. Qualitative relative potential groundwater recharge mapping included a desktop study conducted by the Sonoma Ecology Center and the Sonoma County Water Agency based on soil type, slope, vegetation, and underlying geology (Sesser et al, 2011). The potential recharge map developed as part of this study is shown on **Figure 3-8a**. The term recharge potential is used because the actual recharge rate also depends on other factors such as the distribution 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 Quaternary alluvial deposits and volcanic tuffs and sediments. 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.

To further qualitatively assess groundwater recharge potential in the Subbasin, **Figure 3-8b** was developed to show other lines of evidence for recharge potential, including depth to groundwater within the shallow aquifer system, locations of losing stream reaches, lithologic texture of the shallow aquifer system, and groundwater ages. As shown on **Figure 3-8b**, areas identified as having a higher recharge potential based on two or more of these additional lines of evidence include the Carriger Creek, Felder Creek, and Rodgers Creek drainages and alluvial fans (coarser-grained texture of the shallow aquifer system, losing stream reaches and some younger groundwater ages). Areas identified as having a lower or medium potential for recharge include areas east of the Eastside Fault where very old groundwater ages are observed, the northern portions of the Subbasin where shallow volcanic rocks likely impede recharge, and the central portions of the Subbasin in the vicinity of and south of the City of Sonoma where relatively shallow groundwater conditions occur in the shallow aquifer system.

Groundwater Discharge

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

Natural groundwater discharges occur where groundwater levels are higher than either the land surface or water surface in stream channels. Figure 3-9 shows the location of potential natural groundwater discharge areas, including the location of springs and seeps, from the USGS' National Hydrography Dataset or National Water Information System (USGS, 2019), gaining stream reaches based on seepage run datasets collected intermittently from Sonoma Creek and its tributaries between 2003 and 2019 (SEC, 2019), and wetlands mapped by the Sonoma County Vegetation Mapping and LiDAR Program (Tukman Geospatial LLC, 2018).

As shown on **Figure 3-9**, the majority of springs and seeps occur outside of the Subbasin along fault traces within the Sonoma Volcanics. Springs and seeps located inside or along the margins of the Subbasin occur at the northern end of the Subbasin (at and in the vicinity of the Sonoma Developmental Center property) and along the southeastern boundary of the Subbasin. Gaining stream reaches are most prevalent along the mainstem of Sonoma Creek and some of its tributaries including Calabazas Creek, Mill Creek and Nathanson Creek. Gaining stream reaches also occur periodically along Carriger Creek, Felder Creek, Rodgers Creek, and Arroyo Seco. Wetlands that represent potential locations of groundwater discharge are located in small areas throughout the Subbasin and are most prevalent within and around the tidal marshlands at the southern portions of the Subbasin.

3.1.8 Data Gaps and Uncertainty

While the information and data presented in this hydrogeologic conceptual model incorporates the best available information and datasets, it is recognized that all hydrogeologic conceptual models 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 hydrogeologic conceptual model for the Sonoma Valley Subbasin and are considered and prioritized in Section 6 (Projects and Actions) and Section 7 (Implementation Plan).

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 limits 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:

- 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 system, which could be improved through construction of dedicated nested monitoring wells in key areas.

- Improving estimates of aquifer properties, including hydraulic conductivity and storage coefficients through aquifer testing.
- 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 Eastside Fault and Bennett Valley Fault. Potential methods for addressing this data gap could include the performance of aquifer tests and geophysical surveys 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.
- Improving the understanding of groundwater flowpaths near areas of brackish water in southern Sonoma Valley will support the appropriate setting of Sustainable Management Criteria in this area. Potential methods for addressing this data gap could include the construction of dedicated nested monitoring wells and/or and geophysical surveys in this area.

<u>Recharge and Discharge Areas and Mechanisms and Surface Water/Groundwater Interaction</u>

Improved understanding of recharge and discharge mechanisms within the Subbasin for both the shallow and deep aquifer systems, as specified below, will support the appropriate selection of projects and actions needed for the Subbasin.

- 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, stream gages and meteorological stations can help advance this understanding.
- Conducting geochemical or tracer studies. These studies 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

3.2.1 Climatic Conditions and Trends

3.2.2 Groundwater Elevations and Trends

3.2.3 Estimated Changes in Groundwater Storage

3.2.4 Land Surface Subsidence

3.2.5 Groundwater Quality Conditions and Trends

3.2.6 Surface Water and Groundwater Connectivity

3.2.6.1 Interconnected Surface Water

3.2.6.2 Groundwater Dependent Ecosystems

3.3 Water Budget

3.4 Management Areas