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Technical Memorandum

Hydrogeologic Conceptual Model

Santa Clara River Valley Groundwater Basin
East Subbasin
Groundwater Sustainability Plan
Santa Clarita Valley Groundwater Sustainability Agency

Prepared for
GSI Water Solutions, Inc.

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SECTION 1: 1.0 Hydrogeologic Conceptual Model

Provided in this Technical Memorandum (TM) is a description of the hydrogeologic conceptual model of the Santa Clara River Valley Groundwater Basin, East Subbasin (Basin). The purpose of this TM is to describe the physical characteristics of the Basin as they relate to groundwater occurrence in the aquifers. This TM has been prepared as part of the ongoing efforts by the Santa Clarita Valley Water Agency (SCV Water) on behalf of the Santa Clarita Valley Groundwater Sustainability Agency to prepare a Groundwater Sustainability Plan (GSP) for the Basin. Data and interpretations compiled herein are based on the long term experience of Richard C. Slade & Associates LLC (RCS) performing hydrogeologic services for various water agencies and private parties in the Basin, coupled with information from a number of publicly available resources.

1.1 Basin Setting

1.1.1 Topography and Boundaries

Figure 1-1, "Location Map", shows the boundary of the local groundwater basin superimposed on a topographic map of the area, and the locations of select wells that are known to exist or to have existed in the region. Topographically, the area surrounding the groundwater basin is defined by higher elevations on the north, south, and east, and lower elevations on the west. This topography defines the watershed of the Santa Clara River, which has its headwaters in Soledad Canyon, and this watershed has a drainage area of several hundred square miles. The Santa Clara River provides regional drainage in an east to west direction across the groundwater basin and it continues westerly across Ventura County and into the Pacific Ocean. In general, the local groundwater basin is oriented along the Santa Clara River.

Principal tributaries draining the northern side of the groundwater basin include, from east to west, Mint Canyon, Bouquet Canyon, San Francisquito Canyon, and Castaic Creek Canyon. Principal tributaries draining the southern side of the basin include, from east to west, Oak Spring Canyon, Sand Canyon, and Potrero Canyon. The South Fork of the Santa Clara River, which drains in a northerly direction toward its confluence with the main reach of the Santa Clara River (located just west of Bouquet Junction), has Placerita Creek Canyon, Newhall Creek Canyon, and Pico Canyon as its main tributaries.

DWR-defined boundaries of the groundwater basin are based on ground surface exposures of the two main aquifers that comprise the local groundwater basin: the alluvial aquifer, and the Saugus Formation aquifer (Slade, 1988, 2001). Depending on the location of the boundary, the boundary of the Basin is either defined as the geologic contact of the Saugus Formation with other geologically older, nonwater-bearing formations, or the contact of the alluvium of the Santa Clara River and its tributaries with geologically older, nonwater-bearing formations. The same is true for the "bottom" of the Basin in the subsurface: in some instances, the alluvial aquifer is in contact with non-water bearing sediments where no Saugus Formation is present (as in the western portion of the groundwater basin), and in areas where the Saugus Formation is relatively thick, the Basin is defined as its contact with the underlying Pico Formation, or even other older, nonwater-bearing formations. Additional discussions of the nature of these geologic contacts are discussed below.

1.1.2 Soils Infiltration Potential

Soil infiltration is defined as the ability of a soil to allow water movement through the soil profile. The infiltration rate of a soil is the velocity or speed at which water enters and flows into the soil under gravimetric forces. Publicly available databases of soil types and estimated infiltration rates of these soils were reviewed, and are summarized below.

1.1.2.1 *Soil Types in the Basin*

Soils in the region have been mapped and described by the Natural Resources Conservation Service (NRCS, 1999), a division of the United States Department of Agriculture (USDA). Figure 1-2, "NRCS Soil Map," shows the locations of soil groups within the boundaries of the Basin and the surrounding region. Four groups of soil types are shown to exist within the boundaries of the Basin on Figure 1. Below is a description of these four soil groups as adapted from the NRCS (1999), shown in order of relative abundance within the Basin:

- Entisols are the most prevalent soil group within the Basin, and are exposed throughout the Basin. Entisols are comprised of mineral soils that have not yet developed distinct soil horizons. Because entisols have no diagnostic horizons, these soils appear unaltered from their parent material, which can be unconsolidated sediment or rock. Entisols are the most abundant soil order on earth, occupying about 16% of the global ice-free land area.

- Inceptisols are the second most prevalent soil group and are exposed primarily in the western portion of the Basin. These soils are comprised of freely draining soils in which the formation of distinct horizons is not far advanced. By definition, Inceptisols are more developed than Entisols, but have no accumulation of clays or organic matter. Inceptisols develop more rapidly from parent material than do Entisols,
- Alfisols are similar in abundance to inceptisols, but occur primarily in the eastern portion of the Basin. Alfisols consist of a group of leached basic or slightly acidic soils, exhibiting clay-enriched subsoils with a relatively high native fertility. These subsoils are considered mineral soils and contain higher concentrations of aluminum (Al) and iron (Fe) than other soils. Alfisols typically are found to have formed on late-Pleistocene aged geologic deposits.
- Mollisols are the least abundant soil type within the Basin, generally found along the Santa Clara River. These soils are commonly very dark colored, base-rich, mineral soils and contain high concentrations of calcium and magnesium. These soils typically develop under grassland cover.

1.1.2.2 *Soil Infiltration Rates*

To help provide a general understanding of estimated infiltration capacity of the soils within the boundaries of the Basin, infiltration rates for these soils were compiled from the Los Angeles County Department of Public Works (LACDPW) Hydrology Manual (LACDPW, 2006). Infiltration rates throughout Los Angeles County were obtained by LACDWP by performing double ring infiltrometer tests of various soil types (LADPW, 2006). Results of these infiltration tests were reportedly used by LACDPW to produce runoff coefficient curves of the tested soil type, from which infiltration rates were interpreted. Compiled results from the LADPW infiltration tests are presented in Figure 1-3, “Infiltration Rates, LA County.” Reported infiltration rates ranged from 0.1 to 1.0 inch(es) per hour (in/hr). Lower infiltration rates of 0.1 in/hr were observed in individual areas located in the southern portion of the Basin. Spatially, an infiltration of 0.3 in/hr was more prevalent than others.

1.1.3 Regional Geology

The regional geologic conditions in and around the Basin consist predominantly of continental to marine deposits of clay, silt, sand and gravel divided amongst several formations ranging in geologic age from late-Tertiary (approximately 25 million years old) through the present. The oldest of these Formations lies unconformably (a separation of two or more units by a geologic time gap) upon basement complex rock, which consist of undifferentiated crystalline granitic rocks and metamorphic-type rocks of late Mesozoic age (greater than 66 million years old). Figure 1-4, “Geologic Map Showing Cross Sections,” shows the locations and lateral extents of these various earth materials as mapped at ground surface by others. This map, which provides the basis for the following discussion of the geologic conditions of the region, has been adapted from geologic maps published by Slade (Slade, 1986, 1988). Those maps by Slade were created by updating interpretation on various geologic mapping efforts by others combined with subsurface interpretation of geologic materials derived over time during the drilling of deep boreholes. Among the geologic references used by Slade (1986, 1988) were those by Oakeshott (1958), Dibblee (1991), and others. For Figure 1-4, various crystalline rocks have been simplified and grouped into a single unit named “basement complex,” and no distinction is provided between the various rock types of which those crystalline rocks are comprised. Also, alluvial deposits are shown as one unit, although Quaternary mapping efforts by others in the past have separated those into more discrete units based on slight differences in age or location. The legend to the map provides information on the names and basic earth materials of each formation shown on that map. Also shown on Figure 1-4 are the alignments of several geologic cross sections which are discussed later in this text.

1.1.3.1 *Geologic Formations within the Basin*

There are three relatively young geologic formations that comprise the local Basin, namely: Alluvium, Terrace Deposits and the Saugus Formation. These formations, except for the Terrace Deposits, are generally utilized by high-capacity water production wells for municipal-supply purposes by SCV Water and the County Waterworks District and, thus, provide a major portion of the water-supply to valley residents. Privately owned wells that utilize these formations (primarily the Alluvial aquifer) are owned by Fivepoint (formerly Newhall Land and Farming Company), the Disney Company, multiple golf courses, and others for agricultural irrigation, turf irrigation or local domestic purposes. The spatial distribution of the extraction, and general rates of those extractions are described in later Technical Memoranda.

1.1.3.1.1 Alluvium

The Quaternary Alluvium (Qa) is of Holocene (Recent) geologic age, ranging from 10,000 years in age to the present. These recent alluvial deposits consist primarily of stream channel and floodplain materials along the course of the Santa Clara River and its tributaries. The alluvial sediments are composed of complexly interlayered and interfingered beds of unconsolidated gravel, sand, silt, and clay containing variable concentrations of cobbles and boulders. The source material for this alluvium is from weathering and erosion of the surrounding hills and mountains bordering the Santa Clarita Valley. In general, alluvium along the main reach of the Santa Clara River ranges from medium-grained sand in the west, to cobbly- or gravelly-sand in the east. The maximum thickness of the alluvium varies along the course of the Santa Clara River, but can attain a maximum thickness of ± 200 feet. Typically, the alluvium tends to be thickest near the central portion of the river channel and thins or pinches out as the base of the adjoining hills is approached.

The alluvium in the tributary canyons is generally thinner than that along the main river valley. Larger watershed areas such as Castaic Creek and Bouquet Canyon are typically underlain by more extensive and thicker accumulations of alluvium than what exists within the smaller tributaries, such as the Oak Spring or Pico canyons. In these latter canyons, the maximum alluvial thickness occurs near the confluence with the main river valley, where it may be from 75 to 125 feet in thickness.

1.1.3.1.2 Terrace Deposits

Terrace deposits (Qt) are isolated remnants of what was, during the late Pleistocene (129,000 years or less in age), a continuous blanket of alluvial material covering the entire floor of the Santa Clara River Valley (Winterer and Durham, 1962). Tectonic uplift of the valley floor led to downcutting and incision of this somewhat geologically older alluvial material by the Santa Clara River, leaving the terrace deposits restricted to platforms or benches that are topographically higher than the Santa Clara River, and hence above the regional water table. Sediments comprising the terrace deposits include crudely stratified, poorly consolidated reddish-brown gravel, sand and silt (Winterer and Durham, 1962). Terrace deposits are sometimes weakly cemented by iron oxides, clay minerals, or calcium carbonate.

Terrace deposits may be up to 200 feet thick in some areas, but because of the limited areal extent of these deposits and because they are generally above the regional water table, they are not a viable source for the development of groundwater resources. However, limited zones of perched groundwater may be locally present in some areas on a seasonal basis within these terrace deposits.

1.1.3.1.3 Saugus Formation

The Saugus Formation (QTs), of late-Pliocene to early-Pleistocene geologic age (ranging from approximately 3.6 to 1.8 million years in age), has traditionally been divided into two stratigraphic units: a lower, geologically older Sunshine Ranch Member of mixed marine to terrestrial origin; and an overlying, upper portion of the formation which is entirely terrestrial (non-marine) in origin (Winterer & Durham, 1962). Figure 1-5. "Generalized Saugus Formation Stratigraphy", graphically illustrates these two stratigraphic units and the overall characteristics of each.

The Upper stratigraphic unit of the Saugus Formation consists of terrestrial fluvial and floodplain deposits that are composed of slightly cemented, interfingered and interbedded conglomerate, sandstone and clay/mudstone layers. These deposits generally extend to a maximum depth of 5,300 feet in the local groundwater basin, based on an electric log (E-log) for a deep oil well[1] located in the approximate center of the basin; these depths vary in other parts of the basin. This deep wildcat (exploratory) oil well was drilled near the east end of a prominent topographic high (called Round Mountain), which is an isolated outcrop of the Saugus Formation, just southeast of Rye Canyon Rd and Avenue Stanford, within the course of the Santa Clara River.

Strata within the Saugus Formation tend to become coarser-grained and generally more permeable in an upward direction, which is from the older and less permeable beds within the Sunshine Ranch Member to the coarser and somewhat younger beds within the main part of the formation. The formation consists mainly of lenticular beds of light-gray and brown sandstone and conglomerate intercalated with lesser amounts of reddish-brown sandy mudstone. These terrestrial sediments were deposited in stream channels, floodplains and alluvial fans of an ancestral drainage system in the Santa Clarita Valley. The coarser-grained sand and gravel beds of the Saugus Formation were deposited in the main channels of the ancient drainage system, and these more permeable beds constitute the principal, potential water-bearing materials within the present-day Saugus Formation. As the locations of the ancestral drainage channels changed during the approximately 3 million-year period of deposition of the Saugus Formation strata, the

[1] Badger Oil Co. Magic Mountain No. 1 - 04N/16W-17Ka

distribution of the coarse-grained channel deposits also changed, both laterally and vertically (in space and time).

In contrast, the underlying and older Sunshine Ranch Member of the formation is comprised of interfingered, fine-grained, shallow marine, brackish-water to non-marine deposits of generally thinly interbedded gray to greenish-gray sandstone and siltstone. The base of this member occurs at a depth of approximately 7,700 feet below ground surface (bgs) and attains a maximum thickness of approximately 2,400 feet in the central part of the local groundwater basin.

Because of the marine origin and the fine-grained nature and relatively low-permeability of the Sunshine Ranch Member, it is not considered to be a target for groundwater exploration or production. Wells drilled near the periphery of the Saugus Formation surface exposures in the Santa Clarita River Valley (i.e., in those areas where the Sunshine Ranch Member is at or very near to ground surface) have typically produced groundwater at rates too low for municipal-supply purposes, but may provide sufficient water for small capacity domestic supply wells, depending on water quality. Evidence from oilfield E-logs suggests that the groundwater in much of the Sunshine Ranch Member may be brackish and hence not useful for municipal supply purposes.

1.1.3.2 *Geologic Formations Surrounding the Basin*

There are a number of geologically older formations that underlie the Alluvium and the Saugus Formation and that occur outside of the Basin; refer to Figure 1-4 for DWR-derived boundaries of this local groundwater basin. Each of these older formations are considered to be non-water bearing for large scale water-supply purposes (i.e., high-volume production wells), though groundwater in these formations could possibly be utilized for small-scale residential or landscape purposes (depending on water quality). Because they are not a significant source of groundwater for municipal water-supply purposes, these essentially non-water bearing formations will only be discussed briefly in this section. As noted above, none of these older geological formations lie within the local groundwater basin as defined by DWR Bulletin 118, update 2016 (DWR, 2016).

The formations that are present differ slightly on the north and south sides of the San Gabriel Fault as defined in Figures 2 and 3 of the report by Oakeshott (1958). Many of the named formations in those figures are not exposed at ground surface in the Basin and some of their names have been reassigned to other formations or have been renamed by others over time.

Thus, the formations discussed below are in accordance with, and confined to, only those depicted on the surface geology shown on Figure 1-4 within the Basin.

1.1.3.2.1 South of the San Gabriel Fault

South of the San Gabriel Fault, the Saugus Formation lies conformably and gradationally upon the Pico Formation of late-Pliocene to Pleistocene geologic age (ranging approximately from 3 to 1.8 million years old). The Pico Formation is of marine origin and consists of gray clay, siltstone, fine-grained sandstone and light-colored sandstone and conglomerate. The Pico Formation is present at or near ground surface on the west end of the Basin where the Saugus Formation ceases to exist (or "pinches out"). Local residents sometimes refer to an area called "blue cut", which is a location where the Santa Clara River has incised into the Pico Formation; sediments in the Pico Formation often exhibit a blue-colored hue.

Conformably underlying the Pico Formation (Tp) is the Towsley Formation (Tt) of late-Miocene to early-Pliocene geologic age, approximately 6 to 3(?) million years in age. This unit is composed of terrestrial fluvial deposits consisting of well consolidated to cemented and interbedded shales, siltstones, sandstones and conglomerates. The Towsley Formation is, in turn, unconformably underlain by sedimentary rocks of the Modelo Formation (Tms) of middle- to late-Miocene age, ranging from approximately 16 to 7 million years ago, and consisting chiefly of cemented sandstone and siliceous, diatomaceous shales.

The above-described bedrock units unconformably overlie pre-Tertiary basement complex rocks (bc) of the San Gabriel Mountains. These geologically old materials consist of the crystalline rocks of quartz diorite, hornblende diorite gabbro and gneiss; they were likely emplaced during the Cretaceous period; i.e. approximately 145 to 90 million years before the present.

1.1.3.2.2 North of the San Gabriel Fault

North of the San Gabriel Fault, the formations below the Saugus Formation are not the same as those on the south side of the fault. Movement along the fault during and following formation of the Basin-area sediments caused the Saugus Formation to be deposited on top of different, but geologically-older formations. On the north side of the fault, the Saugus Formation unconformably overlies Miocene-aged (ranging from 23 to 5.2 million years ago) terrestrial sediments of the Castaic (Tc), Tick Canyon (Tt), Mint Canyon (Tm), Vasquez (Tv) formations and the Violin Breccia (Tvb, located northwest of Castaic Lake); refer to Figure 1-4. These older formations that underlie the water-bearing alluvium and Saugus Formation (within the local groundwater basin) tend to be well-consolidated and cemented and have relatively low porosity and permeability. The Violin Breccia, in particular, of late Miocene age, is considered to be a facies of the Ridge Basin Group and is an assemblage of hard sand, gravel and breccia derived from basement rocks southwest of the San Gabriel Fault (Dibblee, 1997a). These rocks were deposited as debris flows, talus and alluvial fans accumulating along the San Gabriel Fault scarp (Link & Osborne, 1978, Link, 2003), during development of the San Gabriel Fault at that time.

These older rocks essentially form the local bedrock and are not considered water-bearing in terms of their ability to supply groundwater in useable quantities and of acceptable quality for municipal or agricultural supply purposes. Wells and test holes drilled into these bedrock materials have typically encountered low groundwater production rates and sometimes less than favorable water quality.

The assemblage of bedrock units, discussed above, also unconformably overlie all pre-Tertiary basement complex rocks of the San Gabriel Mountains. The rocks in this area of the mountains consist of crystalline, intrusive igneous rock granite and metamorphic rocks of the Pelona Schist, both of late Mesozoic age (approximately 80 to 66 million years in geologic age) and augen gneiss, of Pre-Cambrian geologic age (approximately 1.65 billion years old).

1.1.3.3 *Regional Geologic Structures*

The Quaternary alluvium along the Santa Clara River and its tributaries generally overlies the older terrace deposits and the Saugus Formation in the area. As such, a significant unconformity (a separation of two or more units by a geologic time gap) occurs between those two older formations and the alluvium. The alluvium appears to be undeformed by any recent tectonic activity (occurring since the beginning of the Holocene period), such as folding or faulting. To some extent this is also the case for the terrace deposits, although they have been tectonically uplifted in some areas and are slightly folded. One such fold has been mapped in an area where the terrace deposits crop out in the hills east of San Fernando Road and the South Fork of the Santa Clara River

However, the alluvium generally exhibits sedimentary structures associated with deposition by the typical mode of meandering rivers and streams. Examples of such sedimentary structures are cross-bedding (where one set of sediments have been laid at an angle to previously deposited sediments) and cut and fill structures (where one stream bed has cut into underlying previously deposited sediments and then subsequently filled in by more recent material).

The general overall structure of the slightly geologically older Saugus Formation is one of an isolated "bowl" that has been cut (at least in part) by two major faults, namely the San Gabriel Fault and the Holser Fault, and also folded along a number of generally east-west trending folds. The sedimentary layering in the Saugus Formation and in the underlying bedrock dips (i.e., the beds are inclined) generally toward the center of the "bowl" from all locations along the outer (perimeter) contact of the Saugus Formation. However, there is some degree of localized folding of the layers along the San Gabriel Fault, resulting in small and large anticlinal and synclinal structures with axes trending from the northwest to the southeast (Dibblee, 1996a).

The San Gabriel Fault system and the Holser Fault generally cut across the Saugus Formation and all older formations in the region. These two faults have a relative right-lateral movement (where land on one side or the other moves to the right, relative to the other side). However, these two faults also show some vertical component of movement. The San Gabriel fault is theorized to have a horizontal displacement on the order of 20 miles, and vertical displacement of 1,400 feet (Crowell, 1954). Further, these two faults divide the Saugus Formation into three distinct fault-bounded blocks, sometimes referred to as the South, Central and Northern blocks.

1.1.4 Principal Aquifer Systems

1.1.4.1 *Alluvial Aquifer System*

The alluvial aquifer system overlies the Saugus Formation and serves as one major source of groundwater to groundwater users in the region. Data from the numerous shallow wells in the valley show that the maximum thickness of alluvium varies along the Santa Clara River and it appears to reach a maximum depth to 200 feet bgs in several wells in the approximate center of the valley. The alluvial sediments generally thin and pinch out traversing from the valley center and progressing outward towards the surrounding hills. The alluvial aquifer is replenished/recharged chiefly by rainfall and infiltration of surface water runoff in the Santa Clara River and its tributaries, as evidenced by static water level changes shown on hydrographs from the numerous wells in the valley that obtain groundwater solely from this aquifer. Those hydrographs (presented here in the Groundwater Conditions Technical Memorandum, by others) show that static water levels exhibit rapid responses and large fluctuations during rainfall events and intervening drought periods. The alluvial aquifer along the main-stem of the river is also replenished from discharge of treated wastewater from the Saugus and Valencia Water Reclamation Plants (WRPs).

1.1.4.2 *Saugus Formation Aquifer System*

Depending on location within the local basin groundwater basin, the Saugus Formation may exist under confined, semi-confined or even unconfined conditions. This formation serves as the other major source of groundwater in the region. In the center of the valley, the sedimentary layering of the formation is nearly horizontal and some confining layers of low permeability (fine-grained silts and clays) may limit groundwater movement in an upward or downward direction. Consequently, groundwater occurs under pressure within the intervening sand and gravel units, and water levels in Saugus Formation water wells tend to be above the top of the perforated casing intervals that intersect these coarse-grained aquifer units, thereby providing evidence that groundwater is under confined or semi-confined conditions.

In contrast, near the outer perimeter of the Saugus Formation, near the boundaries of the groundwater basin, the sedimentary layering is tilted downward toward the center of the “bowl” and the permeable sand and gravel beds of the formation are in direct contact with either the ground surface or with highly permeable alluvial or terrace deposit materials. In these areas, the Saugus Formation aquifer may be essentially under unconfined, water table conditions.

Virtually all known existing and historic Saugus Formation water wells have been drilled south of the San Gabriel Fault. Only one known attempt has been made to drill and construct a Saugus Formation water well into the lower and geologically older Sunshine Ranch Member of the Saugus Formation, which predominates in the area north of the San Gabriel Fault. That well did not produce groundwater in sufficient quantities or acceptable quality for municipal-supply purposes, and it was subsequently destroyed.

As discussed above, the San Gabriel and Holser faults divide the Saugus Formation into three distinct blocks: the South, Central and North blocks. These fault blocks control the geographic distribution of potential sand and gravel aquifers within the Saugus formation; wherein the Central block contains the thickest accumulation of potentially water-bearing sediments, the South block has the second greatest accumulation of such sediments, and the North block has the thinnest accumulation of sediments. Details regarding the sediment thickness of the Saugus Formation within each block are described below under "Depth to Base of Fresh Water."

Slade (2002) identified an important stratigraphic zone of coarse-grained sediments near the base of the Upper Saugus Formation through the correlation of E-Logs of several existing oil wells and water wells. This correlated stratigraphic zone was informally termed the Santa Clarita Aquifer Zone by Slade (2002). This zone in the subsurface can be identified on E-Logs of wells over a wide area of the Basin and generally occurs at depths ranging from 800 to 1,500 feet bgs. Existing Saugus Formation water wells with the highest pumping rates generally tend to produce groundwater from within and stratigraphically above this Santa Clarita Aquifer Zone.

1.1.4.3 *Aquifer Properties*

1.1.4.3.1 Alluvial Aquifer

The alluvial aquifer generally consists of unconsolidated and intercalated (i.e., interfingering lenticular beds) deposits of clay, silt, sand and gravel. Groundwater within the alluvial aquifer in the study area occurs under unconfined (i.e., water table conditions) and groundwater within this aquifer is generally contained within the interstitial pore spaces (known as porosity). Moreover, the degree of interconnectedness of these pore spaces is a measure of its permeability, which is the ability of the material to transmit water. Permeability values are generally used in groundwater flow and transport modeling studies.

Groundwater in the alluvial aquifer system, because it is under the direct influence of atmospheric conditions of pressure (water table conditions), moves (flows) from higher to lower elevations via the force of gravity. Thus, the slope of the water table surface is known as the hydraulic gradient and is governed by both elevation and the amount of groundwater moving through the alluvium. In addition, because of the unconsolidated nature of the aquifer materials, the permeability (hydraulic conductivity) of the alluvial aquifer is relatively higher than that of the underlying Saugus Formation. As such, wells perforated in the alluvial aquifer system tend to be relatively efficient, compared to that in the less permeable aquifer systems in the underlying Saugus Aquifer system.

1.1.4.3.1.1 Porosity & Specific Yield

The porosity of the alluvial aquifer system may range from 10% to 30%, or slightly greater, depending on the grain size distribution in the type of earth materials present; an average value of 20% is often assumed for the purposes of evaluating aquifer characteristics. The porosity of the alluvial sediments is governed by the type of earth materials present in the aquifer system. Generally, clays tend to have the highest porosities whereas sands and gravels tend to have lower porosity values. However, porosity values for the alluvial sediments of the Santa Clarita Valley were estimated based on a review of over 300 driller's logs for historic alluvial water-supply wells throughout the basin. These porosities were estimated by Slade (1986) to range from 9% to 16%.

Specific yield is a measure of the amount of groundwater that can flow to a well under gravity drainage only. For unconsolidated alluvial sediments, the porosity is approximately equal to the specific yield. Thus, the specific yield for the alluvium is estimated to be in that aforementioned range of 9% to 16%.

1.1.4.3.1.2 Hydraulic Conductivity, Transmissivity, & Storativity Values

As noted above, hydraulic conductivity is a measure of the ability of geologic media to transport water through the pore spaces in the sediments of an aquifer system. Generally, clays have the lowest hydraulic conductivities whereas gravels tend to display the highest values. This character is usually determined through aquifer testing of wells, although values can be estimated using empirical relationships. Based on the results of aquifer testing, calculation of the aquifer coefficients of transmissivity (T) and storativity (S) can be made. The parameter T is a measure of the transmitting property of an aquifer and can expressed in units of square feet per day (ft^2/day). The parameter S is a measure of the volume of water that can be released from an aquifer per unit area of the aquifer and per unit reduction in hydraulic head (water level change). This value is usually expressed in cubic feet per square foot per foot, ft^3/ft^3 and thus is a dimensionless quantity. In alluvial aquifer systems, S can be considered to be equal to the specific yield. Hydraulic conductivity, which is a measure of the velocity at which groundwater moves through a formation, is expressed as k, in units of feet per day, ft/day). This parameter can be calculated directly from T values, by dividing T by the saturated thickness of the aquifer section perforated in a well. As such, calculated k values reflect the intrinsic property of the aquifer and do not change, whereas T values could change, based on the differences in the saturated thickness of the aquifer system.

For the alluvial aquifer system, Slade (1986, Plate 7 and updated with results of constant rate pumping test data from numerous alluvial wells constructed between 1986 and 2009) provided values for T and k values. These values tend to vary spatially in the alluvial aquifer system. The following table summarizes the ranges of those T and k values for the alluvial aquifer system along the Santa Clara River and its tributary watersheds, from the west (near the Ventura County Line) to the east (near Lang):

RIVER SECTION	k VALUES (ft/day)	T VALUES (ft^2/day)
Dell Valle to Castaic Junction	40 to 735	2,850 to 67,300
Castaic Valley Tributary	25 to 710	1,778 to 60,600
San Francisquito Canyon Tributary	11 to 285	1,000 to 22,000
Castaic Junction to Bouquet Junction	3 to 460	3,000 to 29,400
Bouquet Canyon Tributary	10 to 440	700 to 55,200
Bouquet Junction to Newhall (South Fork of Santa Clara River)	2 to 47	1,400 to 19,300
Saugus to Solemint	<7 to 935	<670 to 84,600
Solemint to Lang	<7 to 930	<670 to 67,600

The above table shows that both T and k values in the alluvium tend to show a great degree of variability. Such variability is likely due to local lithologic differences in the alluvial sediments between different well locations, methods of well construction, depth interval of the perforated section(s) of the well, degree of plugging of the casing perforations, and/or differences between the efficiency of the well, or a combination of some or all of these factors.

1.1.4.3.1.3 Historic Groundwater in Storage Calculations

The amount (i.e., the total volume) of groundwater contained within pore spaces within the alluvial sediments that is present at any one particular time is known as the groundwater in storage. The amount of groundwater in storage in the alluvial aquifer system depends on the following:

- the total volume of the alluvial sediments in the defined alluvial aquifer system of the local groundwater basin;
- the specific yield of those sediments;

- the proportion of those sediments that is saturated with groundwater at a specific water level monitoring date.

Because the volume of sediments and specific yield of an aquifer do not generally change over time, the amount of groundwater in storage in the alluvial aquifer is directly related to its saturated thickness (i.e., to a specific water level monitoring date for wells in the alluvium). This is indicated by measured groundwater levels at a specific date in water wells within the alluvial sediments. A rising water table increases the thickness of the saturated water-bearing section, thereby increasing the volume of groundwater in storage; the converse is true for a declining water table.

Groundwater levels in the alluvial aquifer are highly influenced by local rainfall and recharge (a highly variable factor in southern California). The amount of groundwater in storage in the alluvial aquifer has varied considerably over the past 50 to 60 years as the local climate has experienced periods of both higher than average rainfall (wet years) and lower than average rainfall (dry years). Slade (1986 & 2002) estimated the volume of groundwater in storage (in units of acre feet, AF) for years 1945, 1965, 1985, and 2000; those volumes ranged from 100,000 AF to 200,000 AF. As part of the GSP development, current groundwater storage estimates will be calculated using a groundwater flow model, and reported in forthcoming Technical Memoranda.

1.1.4.3.2 Saugus Aquifer System

Groundwater moves slowly through the Saugus Formation because it is slightly more consolidated, in comparison to that in the overlying alluvial sediments, and groundwater must travel through more restricted pore spaces within the individual sand and gravel aquifer units in the Saugus Formation. The groundwater velocity at any location within this formation depends on the hydraulic conductivity (permeability) of the aquifer materials, which differs from one individual sand and gravel unit to the next, and on the hydraulic gradient that drives the groundwater movement. The hydraulic gradient is defined as the slope of the water level surface (or more correctly, the slope of the piezometric surface where the formation is under confined conditions), and this slope will vary on both seasonal and longer-term cycles over time.

1.1.4.3.2.1 Hydraulic Conductivity, Transmissivity, & Storativity Values

T and k values of the Saugus Formation sediments also show some degree of variation across the local groundwater basin. T values determined from aquifer (pumping) tests in several Saugus Formation wells located in different parts of the local groundwater basin have generally ranged from 400 ft^2/day to as high as 24,300 ft^2/day (Slade, 1988, 1989, 2001). Calculated k values for wells exhibiting these T values ranged from 1 ft/day to 34 ft/day. Only a few additional Saugus Formation wells have been constructed since 1988. Testing of these more recently-constructed deep wells have yielded T values of 3,300 ft^2/day and 8,300 ft^2/day (VWD-207 and VWD-206, respectively). Values of k for these two wells were 1 ft/day to 34 ft/day, respectively. The distribution of the T and k values in the wells indicates a general trend from lower transmissivity values near the southeastern edge of where the Saugus Formation is exposed at ground surface to higher transmissivity values near the center of the local groundwater basin.

Storativity, which is a term typically used for confined aquifer systems, is a dimensionless measure of the volume of water that will be discharged from an aquifer per unit area of the aquifer and per unit reduction in hydraulic head. These values for wells in the Saugus Formation are on the order of 1.0×10^{-4}.

1.1.4.3.2.2 Depth to the Base of Freshwater and Santa Clarita Zone

Groundwater in the Saugus Formation is classified into two basic divisions, depending upon water quality conditions. These conditions exist where the groundwater grades from freshwater, considered to be 3,000 parts per million (ppm) or less in salinity, to brackish and saline groundwater which may display salinity values above 3,000 ppm. Estimation of the maximum depth to which fresh groundwater occurs within the Saugus Formation, defined as the base of fresh water, had been performed with some degree of accuracy through an evaluation of both water well and oil well E-Logs. More than 250 of these E-Logs, located throughout the river valley, were utilized in previous studies (Slade 1988, 2002), as a part of the effort to define the base of fresh water within the local groundwater basin. On some E-Logs, the vertical transition from the overlying fresh water to the underlying saline water is very abrupt and unambiguous, and thus can be identified at a specific depth. On other E-logs, the transition from fresh water to saline water is gradual and may occur over a vertical distance of hundreds of feet. In such cases, and in order to be conservative, the base of fresh water was chosen, insofar as possible, at the top of the zone of transition from fresh water to saline water (Slade, 1988, 2002).

The depth and thickness of the water bearing deposits in each of the fault blocks in the valley are as follows:

- North Block. Northeast of the San Gabriel fault, the maximum depth to the base of fresh water within the Saugus Formation is approximately 1,500 ft. By comparison, the maximum total thickness of the Saugus Formation, based on E-Logs, is on the order of 2,000 ft in this area. In this fault block, the Santa Clarita Aquifer Zone does not exist and, instead, only deposits of the underlying Sunshine Ranch Member are considered to occur.
- Central Block. In the wedge-shaped central fault block between the San Gabriel fault and the Holser fault, the maximum depth to the base of fresh water within the Saugus Formation is approximately 5,500 ft. In this area, the maximum total thickness of the Saugus Formation is approximately 8,500 ft. The top of the Santa Clarita Aquifer Zone in this fault block was determined to occur at a depth ranging from 100 ft in the north-northwestern portion of the block, to 1,500 ft in the southeastern corner of the block adjacent to the San Gabriel fault, and to as great as 2,900 ft bgs in the central (deepest) portion of this block.
- South Block. Southwest of the Holser fault, the maximum depth to the base of fresh water within the Saugus Formation is approximately 5,000 ft. The Saugus Formation obtains a maximum total thickness on the order of 7,500 ft in this block. The depth to the top of the Santa Clarita Zone is estimated to be roughly 2, 200 ft bgs.

1.1.4.3.2.3 Confining Beds

The Saugus Formation generally contains disconnected and interbedded layers of clay, silt, sand and gravel. The interbedded clay layers may act as local aquitards, thereby providing at least a partial barrier to the vertical migration of groundwater. Interbedded clay layers range in thickness from 10 ft to as much as 50 ft. However, the depths and thicknesses of these clay layers have not been defined to date in any studies of the groundwater basin, but, depending on the locations of a well in the basin, there is likely to be several such clay layers dispersed throughout a vertical section of the formation.

1.1.5 Cross Sections

As part of the geologic and hydrostratigraphic characterization of the basin, five geologic cross-sections have been prepared to further describe and illustrate the vertical and lateral extent of the aforementioned geologic formations and units. Figure 1-4, “Geologic Map showing Cross Sections,” illustrates the ground surface traces and alignments of these cross sections plotted on a geologic map of the Basin. Cross sections AA-AA’ through EE-EE’ are presented in Figures 1-6 through 1-10, respectively and illustrate the subsurface interpretation based on a comparative review of available geologic data and electric log data.

1.1.5.1 *Cross Section Preparation*

Preparation of the five cross sections utilized a step-wise multifaceted approach combining previous studies with additional more recent geologic data. Cross section data were obtained from previous basin wide studies completed by RCS (1986, 1988, 2001, & 2002), as well as from review of published geologic maps and geophysical well logs (E-logs) from the Geologic Energy Management Division (CalGEM) well database. Some data were reinterpreted, and prior interpretations were updated based on the availability of newer subsurface data that were available in some areas of the local groundwater basin.

1.1.5.2 *Cross Section Traces*

Cross section traces were selected to illustrate the stratigraphy and general geologic structure of the groundwater basin. Section line traces AA-AA', DD-DD', EE-EE' (see Figure 1-4) extend past opposite basin boundaries in a semi-orthogonal orientation to provide representative subsurface illustrations of the long and short axes of the Basin. Obliquely oriented sections BB-BB' and CC-CC' illustrate subsurface conditions along the northern Santa Clara River plain and the southeastern zone of the basin, respectively. Each of these sections is presented at the same vertical scale, but due to the small horizontal scales of the sections, the sections are vertically exaggerated, as shown on the Figures. Cross Section FF-FF' (the section trace is shown on Figure 1-4 for reference), was created by others for a separate purpose to be covered in a separate Technical Memorandum, and does not possess the same horizontal or vertical scale as the other cross sections discussed herein.

1.1.5.3 *Geologic Structures*

Construction of the five cross-sections required derivation and correlation of geologic formations in the subsurface using various data and methods. First, shallow formation contacts were interpreted and derived from mapped surface contacts and structural geology features. Surface mapped contacts and bedding orientations were plotted and projected from surface to depth, allowing for an initial starting point to correlate geologic formations.

Additional review of regional geologic structures was conducted with respect to previous studies. Fault traces and contact planes were compared to available geographic information system (GIS) data sets. Similarly, local fold structures, escarpments, and topography GIS data sets were reviewed to provide a summary representation of local fault structures and geologic contacts.

1.1.5.4 *Well Log Analysis & Interpretation*

After plotting surficial contacts and regional structural features, formation depth intervals were derived from analysis of available groundwater and oil/ gas well E-logs. Formation identification and interpretation based on E-logs is a common method and is a practice that is routinely used in the energy and resource sectors. The process involves comparing different geophysical logs such as gamma-ray, spontaneous potential, resistivity, and density-neutron in combination with other geologic data gathered during drilling (core, cuttings, drilling progression, etc.) to help identify formations and changes in subsurface materials. For further detail on well logging see, for example, Asquith and Krygowski (2004).

Due to the nature and availability of E-logs from the CalGEM database, short and long normal resistivity logs were primarily used to identify and correlate the respective formations within the Basin. To demonstrate how the well log and E-log information was correlated, Figure 1-11, "Detailed Stratigraphic Interpretation," plots three sequential (west to east) resistivity logs that were used to correlate formation contacts in cross-section AA-AA'. Higher resistivity values (ohm meters per meter) plotted in Figure 1-11 infer higher porosity within the local subsurface material, which can be inferred to be "coarser grained" strata. Thus, the vertical resistivity profile can show a stratigraphic package(s) of geologic units (and may even suggest depositional environments) when coupled with drill hole cuttings and core logs. These geologic or stratigraphic packages or units were correlated with similar geologic units in selected E-logs to infer the subsurface extent and continuity of each respective formation as shown on the cross sections.

Additionally, lithologic interpretation of the resistivity logs shown in Figure 1-11 was also conducted to show sedimentary variance within the Saugus Formation. Interpretation of lithology based on resistivity is provided in a color sequence in Figure 1-11. Lithologic comparison between resistivity logs of wells VWD-160 and VWD-203 show correlative units of coarser grained sediments but with varying intensity of resistivity. The lithology logs show finer grained (lower resistivity) units are interbedded with coarser-grained units within both well logs as documented in previous studies (Winterer & Durham, 1962). Moreover, resistivity signatures in the well log for the wildcat oil well Magic Mountain 1 indicate coarser grained sediments at the same elevation where finer grained sediments are correlated in well VWD-160, further indicating lateral formation variation within the Saugus Formation.

1.2 Groundwater Recharge and Discharge Areas within the Basin

1.2.1 Groundwater Recharge

1.2.1.1 *Alluvial Aquifer System*

Groundwater in the alluvial aquifer is recharged by both natural and artificial (man-made) sources. The relative volume of each of the recharge sources discussed below is variable depending on a number of factors, including annual variations in precipitation and temperature.

Sources of natural recharge to the sediments of this aquifer include:

- Streamflow infiltration from runoff along the Santa Clara River and its tributaries.
- Deep percolation of direct rainfall.
- Subsurface groundwater inflow from upstream areas along the Santa Clara River or its tributaries.
- Upward groundwater flow from certain portions of the Saugus Formation where it is overlain by alluvium. This interaction between the alluvium and the underlying Saugus Formation is discussed in the 2003 Groundwater Management Plan for the Basin (LSCE 2003). In general, groundwater moves from the Saugus Formation aquifers to the alluvial aquifer in areas west of Bouquet Canyon (LSCE, 2003).

Sources of anthropogenic (man-made) recharge to the sediments of this aquifer include:

- Recharge to the alluvium also occurs from deep percolation of irrigation water and is obtained from urban irrigation (landscape irrigation) in the developed areas of the groundwater basin and from areas that are farmed. Agricultural irrigation was historically widespread in the valley; current irrigated acreage is on the order of 1250 acres.
- Recharge also occurs indirectly as a result of the infiltration of reclaimed water that is actively treated by and discharged from two water reclamation plants (WRPs) in the area, namely: the Saugus WRP, placed into operation in 1962, and located east of the intersection of Cinema Drive and Bouquet Canyon Road; and the Valencia WRP, in operation since 1967, and located west of the intersection of Rye Canyon Road and the Old Road. Both plants are operated by the Los Angeles County Sanitation Districts, and together discharge approximately 18 million gallons of treated water per day to the Santa Clara River, with an average annual discharge of approximately 20,000 AF/Y. The treated water from the Saugus WRP is either discharged to the Santa Clara River north east of the intersection of Bouquet Canyon Road and Valencia Boulevard, or conveyed to the

Valencia WRP for additional treatment and then it is released to the Santa Clara River west of Interstate 5.

- Artificial recharge of the alluvial aquifer system, via spreading basins or injection wells, has not been conducted within the Santa Clarita Valley; however, SCV Water is presently conducting studies to evaluate the feasibility of managed aquifer recharge.

1.2.1.2 *Saugus Aquifer System*

Direct natural recharge to the Saugus Formation occurs via deep percolation of rainfall within and around the perimeter of the outcrop area where the permeable sand and gravel beds are either exposed at ground surface or lie directly beneath the relatively thin, permeable alluvial and terrace deposits. Natural recharge to the Saugus Formation also takes place in the eastern end of the outcrop area due to leakage from overlying portions of the saturated alluvium, as originally discussed by Slade (1988). Groundwater recharge from the alluvium to the Saugus Formation generally occurs in areas east of Bouquet Junction where the alluvium overlies the Saugus (LSCE, 2003).

Anthropogenic sources of recharge to the Saugus Formation chiefly include deep percolation of landscape irrigation water in areas where the Saugus Formation crops out at the surface. Agricultural returns are not likely to contribute significant amounts of recharge, as agricultural operations have generally been situated over alluvial areas. On the other hand, landscape irrigation water in developed areas overlying the Saugus Formation will be increasing in extent and these areas will likely provide some amount of irrigation recharge.

To date, artificial recharge of the Saugus Formation via injection wells or highland spreading basins has not been undertaken in the region (RCS, 2001). However, an injection and recovery study carried out in 2000 at Saugus Formation well VWD-205 located in the vicinity of McBean Parkway and Valencia Blvd (Slade 2001) demonstrated that it is feasible to conduct and operate an aquifer storage and recovery (ASR) program in the Saugus Formation.

1.2.2 Groundwater Discharge

1.2.2.1 *Alluvial Aquifer System*

Discharges from the alluvial aquifer system occurs primarily through pumping extraction for municipal-supply use by the water purveyors and for agricultural-supply use by others. As previously noted, Fivepoint farms utilizes irrigation-supply water wells in the western end of the basin. In the eastern end of the Basin, other agricultural operations and golf courses extract water. There are also an unknown number of other privately-owned wells that utilize groundwater from the alluvial aquifer system for private irrigation and/or domestic use.

Evapotranspiration by phreatophyte vegetation is also a significant component of discharge of groundwater from the alluvium. Phreatophytes are plants such as willows and cottonwoods, as well as invasive species such as Arundo, that root directly into the water table in areas of shallow groundwater.

The westernmost part of the basin is also an area of groundwater discharge from the alluvium to the Santa Clara River. The amount of surface water flow into the river will depend largely on water levels within the alluvium. Groundwater also flows out of the basin into Ventura County, but this occurs solely as underflow from groundwater present within relatively thin alluvium at the Los Angeles-Ventura County Line. The only other water to flow from the valley into Ventura County is via surface water flow along the Santa Clara River, including releases from Castaic Reservoir into Castaic Creek that flows into the Santa Clara River and WRP discharges to the River, and from direct discharge via an agricultural supply line operated by Fivepoint, which is supplied via their alluvial wells located at the western end of the valley.

1.2.2.2 *Saugus Aquifer System*

Discharge from the Saugus Aquifer System has historically occurred primarily through the pumping of the several municipal-supply water wells in the Saugus Formation that are situated throughout the central portion of the valley. There are currently no water wells that extract groundwater from the Saugus Formation for agricultural-supply purposes. The only Saugus Formation wells currently in operation for irrigation purposes are located at Vista Valencia Golf Course and Valencia Country Club. An additional natural discharge source occurs at the west end of the valley where Saugus Formation groundwater is considered to flow upward into the overlying alluvium in the western portion of the Saugus Formation (LSCE, 2003).

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