Section 3

Physical Characteristics of the Study Area

With the completion of the investigative work presented in Section 2, the understanding of the physical characteristics of the SFB, specifically the subsurface around the TJ, RT, and NHW well fields, has been significantly improved. As discussed in other sections of this report, this section is an update of the 1992 RI (JMM 1992), and some information on the physical characteristics of the study area remains unchanged. In these cases, descriptions have been drawn from the 1992 RI Report and incorporated herein for completeness (e.g., information on Regional Geology, Structural Geology, and Stratigraphy).

- **Section 3.1: Climate.** This section provides a brief summary of the SFV climate, including rainfall, evapotranspiration, temperature, etc.
- **Section 3.2: Geology.** This section provides a summary of the SFV geology taken from the 1992 RI Report. Because no significant updates to stratigraphy, structural geology, or soils have been made since the 1992 RI, these sections generally summarize the discussions from that report.
- **Section 3.3: Hydrology.** The surface and groundwater hydrology are presented in this section along with a generalized water balance.
- **Section 3.4: Hydrogeology and Updated Hydrogeologic Conceptual Site Model.** This section includes an update of the hydrogeology of the SFB based on information from the investigations described in Section 2. This discussion includes an updated discussion on the SFB groundwater elevations and flow, groundwater geochemistry, and a description of the different water-bearing units.

3.1 Climate

The Los Angeles area climate is mild and characterized as Mediterranean because of its relative dryness, specifically during the summer months. The average monthly maximum temperature (calculated from the Los Angeles Downtown weather station data) is 75 degrees Fahrenheit (based on the period of 1990–2010) (LADWP 2010). The standard annual average evapotranspiration (ETo) rate is 50.26 inches per year. Total precipitation averages 15.58 inches per year, with over 90 percent of this total amount typically falling during the period of November through April (LADWP 2010). Precipitation is usually in the form of rainfall, with some snowfall occurring at the highest elevations of the San Gabriel Mountains. Large variations in the amount of precipitation falling onto the valley floor are observed from year to year as well as season to season (JMM 1992).

3.2 Geology

The SFV is located in the Transverse Ranges physiographic province, which is a large east-west trending fold belt. North-south compression along the San Andreas Fault system has produced trough-shaped basins that are elongated in an east-west direction. The rapid uplift of the mountains relative to the basins has generated sediment that has been deposited as alluvial fans. These sediments serve as the primary source of groundwater, as presented in the HCSM (Section 3.3).

Southern California is situated on an active boundary between two major crustal plates. The San Andreas Fault is the present boundary between the Pacific and North American plates. The Pacific Plate on the west has been moving northwest relative to the North American Plate for about 26 million years.

The SFV is an inland alluvial valley bordered by high mountain ranges within the South Coastal Basin of California. The valley is underlain and surrounded by relatively impermeable rock, forming a structural basin. A complex coalescing of alluvial fans deposited by streams that drain the surrounding mountains and hills is present in the valley fill (JMM 1992; CH2M Hill 2011). Along the western boundary of the SFV, the relatively gentle structural relief of the mountains has resulted in subdued topography and low stream profiles. In comparison, the higher elevations and deeply eroded bedrock of the uplifted mountains along the eastern boundary of the SFV have resulted in steeper stream profiles that contributed relatively coarse-grained sediment to the alluvial fans in the eastern portion of the SFV study area (JMM 1992; CH2M Hill 2011).

The following sections provide details on the SFV structural geology and stratigraphy

3.2.1 Structural Geology

This regional stress regime has produced two sets of strike-slip and reverse faults typical of this portion of the Southern California region (JMM 1992). The major fault zones in the eastern portion of the SFV are the Verdugo, Benedict Canyon, and Raymond Fault systems (JMM 1992). Further details on these fault zones and observations of their affect groundwater flow in the SFB are presented below and the fault traces are included on Figure 3-1:

- The **Verdugo Fault Zone** is part of a large west-northwest trending fault system that splays off from the frontal fault system of the Transverse Ranges. The faults of the Verdugo system define the northeast margin of the SFV Basin south of the Sunland-Tujunga area. This system was originally considered to be an apparent groundwater barrier as documented in the Report of Referee (ROR) (SWRCB 1962). However, CH2M Hill notes that more recent evaluations indicate that it is unlikely that the Verdugo Fault acts as an impermeable barrier throughout the Tujunga area (CH2M Hill 2011).
- The **Benedict Canyon Fault Zone** is a collection of small faults identified near the bend in the Los Angeles River (Weber 1980). This fault system defines the southern margin of the eastern portion of the SFV. Although this fault system has long been considered to not affect groundwater flow in the alluvium, the lack of sharp drawdown effects at shallow monitoring wells near the pumping area suggest that the impact of the fault system as an impediment occurs only at depths below the shallow zone (JMM 1992).
- The **Raymond Fault Zone** is located in the Los Angeles River Narrows, and extends westward across the Los Angeles River Narrows from fault scarps in the San Rafael Hills (JMM 1992). The fault acts as a groundwater barrier between the SFB and the Eagle Rock Basin. However, data from numerous wells in the area provide evidence that the fault acts as a groundwater impediment in the deeper alluvium but not the shallow alluvium.

3.2.2 Stratigraphy

The following stratigraphy discussion is summarized from the 1992 RI Report (JMM 1992). Late Quaternary water-bearing alluvium is the major source of groundwater in the SFV, and therefore is the focus of this RI Update Report. Rocks older than the Quaternary are important primarily as source materials for the valley fill, which in turn influence the type of sediment eventually deposited in the basin. The bedrock of the ULARA is referred to as pre-Quaternary non-water-bearing units and is considered the base of the valley fill. Figure 3-2 includes the generalized stratigraphic column adapted from the 1992 RI report.

3.2.2.1 Pre-Quaternary Units

The pre-Quaternary (non-water-bearing) units are significant because of their influence as source material for the Quaternary sedimentation. For example, the Cretaceous to Tertiary sedimentary rocks in the western ULARA are more easily eroded, yielding primarily fine-grained detritus during Quaternary time. In contrast, the pre-Tertiary basement complex is more resistant to erosion, thus forming steeper drainages in the San Gabriel and Verdugo mountains where more sand- and gravel-sized material was carried into the basin.

Pre-Tertiary Basement Complex

The oldest rocks in the region consist of Cretaceous and older crystalline igneous and metamorphic rocks exposed in the Verdugo Mountains, San Rafael Hills, and San Gabriel Mountains. The basement rocks bounding the SFB on the northeast (Verdugo and San Gabriel Mountains) are primarily medium to dark gray gneissic diorite of undetermined age, containing intrusive bodies of gray granitic rocks. Gabbro and anorthosite bodies underlie the west end of the San Gabriel Mountains. Thin, discontinuous layers of marble are also present (Weber 1980). Basement rocks of the Santa Monica Mountains crop out as erosional windows and consist principally of gray granitic rock with a smaller proportion of metamorphic inclusions than found in the Verdugo Mountains and San Rafael Hills. Distinctive black slate of the Jurassic Santa Monica Formation also occurs in the Santa Monica Mountains. Because of this contrast in basement terrain, an ancient major fault has been postulated between the Verdugo and Santa Monica mountains by the United States Geological Survey (USGS) (Weber 1980). This fault could be the Verdugo-Eagle Rock Fault Zone or it could be another fault to the south of the Verdugo Fault beneath the alluvium of the SFB. The pre-Tertiary basement complex exposed in the San Gabriel and Verdugo mountains is very resistant to erosion, thus forming steep drainages that contribute coarse-grained material to the basin.

Late Cretaceous to Early Tertiary Sedimentary Units

The bedrock underlying the valley fill of the western portion of the SFB and the adjacent mountains includes Late Cretaceous to Oligocene sedimentary rocks that are absent beneath the eastern portion of the SFB and in the adjacent mountains. These rocks consist principally of well-cemented marine conglomerate and sandstones from the Late Cretaceous to Eocene. The absence of these units in the eastern portion of the SFB area indicates that they were never deposited in this area or they were eroded before the Late Tertiary (Middle Miocene).

Late Tertiary Sedimentary Units

In the Middle Miocene, the area of the present SFV was part of the eastern portion of the Ventura Basin, which is noted for its remarkably thick accumulations of marine sedimentary rocks. Regional extension produced a basin that initially received coarse conglomerates and breccias from steep debris fans. Interlayered basaltic volcanics included submarine flows of pillow basalts (Topanga Formation). Upper Miocene and Pliocene sedimentary rocks are fine-grained sandstones and shales. The deep-water, organic-rich muds provided a source for petroleum and natural gas found in the area. The sea reached its maximum northeast extent during the late Miocene and then began to recede. A late Miocene or early Pliocene shoreline cited by Weber (1980) indicates that the western portion of the San Gabriel Mountains had not yet begun to be elevated at that time (about 5 million years ago). The Tertiary sedimentary units that dominate the watersheds of the western portion of the SFV are relatively easily eroded and have contributed primarily fine-grained material to the basin.

3.2.2.2 Quaternary Water-Bearing Units

The Saugus Formation is the lowermost sedimentary unit considered to be water-bearing (SWRCB 1962). Its presence is documented only in the north-central part of the basin in the Mission Hills-Tujunga Canyon area. The Saugus Formation lies in angular unconformity on rocks of all ages from the basement complex to the Pliocene Pico Formation. The non-marine Saugus Formation consists of poorly consolidated, light-colored conglomerate and sandstone that was deposited as alluvial fan sediments. Lenses of clayey gravel have been interpreted as the result of in-place weathering (SWRCB 1962). The Saugus Formation is thickest east of the city of San Fernando at the north edge of the SFV (6,400 feet thick) and thins rapidly two miles east to only 2,000 feet thick, and southwest to only 3,000 feet thick (SWRCB 1962). The Saugus is generally not considered to be valley fill where it outcrops at the north edge of the ULARA (SWRCB 1962).

The uncertainties concerning stratigraphic correlations of the Saugus and its lithologic similarity to the overlying alluvium in drill cuttings make it impossible to determine if it is present in the subsurface of the eastern portion of the SFB, although it has been intersected by oil wells in the north-central portion of the SFB.

Late Quaternary water-bearing units (Alluvium) of the eastern portion of the SFB are the focus of this RI Update Report. These deposits are discussed in detail in Section 3.4.

3.2.3 Soil Types

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has conducted extensive soil surveys throughout the United States, including the 1917 “Soil Survey of the San Fernando Valley” (USDA 1917). However, its focus has been primarily for agricultural purposes.

The only known spatial and physical data set available for the Los Angeles County SFB urban area is the countywide soils data set maintained by the Los Angeles County Department of Public Works (LACDPW). This data set divides the County into NRCS classifications. Generally speaking, valley and desert surface soils are alluvial and grade from coarse sand and gravel near canyon mouths to silty clay and clay in the lower valleys. Valley soils are generally well drained with relatively few perched water or artesian areas (LACDPW 2006). This is consistent with information reported in the 1992 RI, which cited the SWRCB (1962) and Tinsley and Fumal (1985) reports, stating that primarily coarse-grained gravels are found in the eastern portion of the SFV that originated in the San Gabriel Mountains and fine- to medium-grained sediments (clay, silt, and sand) are predominant in the western portion of the SFB. Figure 3-3 includes the location of different soil types in the SFV.

As previously described (Section 2.6), GSIS soil sampling was conducted for the purpose of verifying the waste classification of soil and evaluating the physical and chemical properties of the subsurface materials at each site. Soil samples were analyzed and characterized using the Unified Soil Classification System and the Munsell Soil Color Charts (Appendix A).

3.3 Hydrology

This section discusses the hydrology of the ULARA with an emphasis on the SFV and includes an overview of regional hydrology, followed by a discussion of the water budget and change in storage for the SFB. In addition, a review of the surface water system, with an emphasis on features and functions that impact the hydraulics of the basin, is presented. Key hydrologic features are shown on Figure 3-4.

3.3.1 Regional Hydrology

As previously described, the ULARA is bounded on the north and northwest by the Santa Susana Mountains, on the north and northeast by the San Gabriel Mountains, on the east by the San Rafael Hills, on the south by the Santa Monica Mountains, and on the west by the Simi Hills (Figure 1-1). The ULARA encompasses the entire hill and mountain watershed and the topographically lower and intervening valley floor areas of the Los Angeles River and its tributaries above (north of) a point in the river designated by LACDPW as Gaging Station F-57CR (Figure 3-4). This gage lies near the junction of the Los Angeles River and the Arroyo Seco. The ULARA watershed encompasses an approximate total of 328,500 acres of hill and mountain areas and intervening valley fill areas. Of this total watershed area, approximately 122,800 acres of valley fill form the four groundwater basins, whereas the remaining 205,700 acres comprise the tributary hills and mountains in the watershed (ULARA Watermaster 2013a; MWD 2007). From largest to smallest, the groundwater basins are:

- San Fernando
- Sylmar
- Verdugo
- Eagle Rock

Sources of water to the ULARA consist of precipitation and water imported from sources outside of the watershed (ULARA Watermaster 2013a). The groundwater reservoirs are recharged by:

- Deep percolation from direct rainfall
- Infiltration of surface water runoff
- Infiltration of excess delivered irrigation water
- Artificial recharge occurs in the SFB when excess rainfall and runoff are available

Water leaves the ULARA through evaporation, transpiration, surface water runoff, groundwater export, and subsurface flow (underflow). Surface water exits the watershed by way of the Los Angeles River, whereas groundwater leaves through the exportation of extracted groundwater and underflow. Pumped groundwater is both used within the watershed and exported from the watershed.

3.3.2 SFB Hydrology

The SFB is the largest of the four basins within the ULARA and has a surface area of approximately 112,000 acres, representing 91.2 percent of the total surface of all four groundwater basins (i.e., the total of all valley fill areas). The lateral or ground surface boundaries of this basin are formed by non-water-bearing bedrock and/or crystalline basement rock in the adjoining hills/mountains, as follows:

- On the east and northeast by the San Rafael Hills, Verdugo Mountains, and San Gabriel Mountains
- On the north by the San Gabriel Mountains and the eroded south limb of the Little Tujunga syncline, which separates it from the Sylmar Basin on the north, and on the northwest and west by the Santa Susana Mountains and Simi Hills
- On the south by the Santa Monica Mountains (ULARA Watermaster 2013a)

As part of this RI Update Report, a generalized water balance is presented in the following sections of this report. The primary source used for the hydrologic data was the ULARA Watermaster's most recent published annual report for WY 2011–12 (October 1–September 30) (ULARA Watermaster

2013a). Supplemental water budget information was obtained from other available references (i.e., JMM 1992; MWD 2008; CDWR 2003; SWRCB 1962).

3.3.2.1 Inflows

In addition to the inflows described under the regional hydrology subsection for the ULARA, the SFB receives groundwater imports from the Sylmar Basin plus a small amount of subsurface flow from the three adjacent basins: Sylmar, Verdugo, and Eagle Rock (ULARA Watermaster 2013a; JMM 1992). Inflows described herein include precipitation, subsurface inflow, imported water, and water spreading.

Precipitation

Precipitation falling directly on the valley floor as well as on the surrounding hill and mountains areas (hill and mountain runoff) constitutes the native supply of water to the SFB. Climate change and related changes in precipitation patterns affect the water supply and storage significantly. Precipitation is usually in the form of rainfall with some snowfall occurring at the highest elevations of the San Gabriel Mountains. Most precipitation is received during the winter months. Large variations in the amount of precipitation falling onto the valley floor are observed from year to year as well as season to season. Within the ULARA, approximately two-thirds of the total water from precipitation is from the surrounding hill and mountain areas because of the larger surface area and higher elevations. This distribution is important in that it affects the location and pattern of groundwater recharge, and thus groundwater movement. Precipitation also affects surface water flow and sediment transport, and in turn sediment deposition within the valley (JMM 1992).

The ULARA Watermaster (2013a) reports that average precipitation determined for all listed rain gages (stations) on all valley floor areas during WY 2011–12 was 10.81 inches; this value represents 66 percent of the calculated 100-year mean (16.48 inches). Average precipitation for all listed stations in the hill and mountain areas within the ULARA in WY 2011–12 was 12.01 inches; this value is 55 percent of the calculated 100-year mean (21.76 inches). The weighted average of 11.55 inches of precipitation for all stations throughout the ULARA was 59 percent of the 100-year mean (19.64 inches).

Subsurface Inflow

This is a small component of the water balance and occurs from the surrounding basins into the SFB (SWRCB 1962). These inflows were quantified as part of the 1992 RI work, using a 10-year average. JMM (1992) reported that the Sylmar Basin contributed the most subsurface inflow (approximately 740 AFY), with an addition small amount of subsurface inflow (approximately 70 AFY) coming from the Verdugo Basin near the mouth of Verdugo Canyon. Subsurface inflow from the Eagle Rock Basin is considered insignificant (JMM 1992).

Imported Water

Imported water refers to water brought into the SFB from sources located outside of the basin. Imported water is brought to the ULARA by the City's LAA that delivers water from the Eastern Sierra region (Owens Valley–Mono Basin) as well as the MWD's distribution system. These waters are conveyed through a complex array of pipelines and aqueducts. In addition, there are groundwater transfers from the Verdugo and Sylmar Basins. The portion of imported water that is not consumptively used, exported, or left the basin as surface outflow remains within the basin as recharge to groundwater.

Water Spreading

This is an artificial recharge practice used in the SFB via the ongoing use of existing spreading basins. These basins are described in more detail later in this section (3.3.4.2). Excess runoff and imported water is spread for groundwater recharge purposes. A total of 14,948 AF of water was spread in WY 2011–12. The average annual spreading of native water during the period 1968–2012 was 32,848 AF. The ULARA Watermaster summarizes total spreading by recharge basin for WY 2011–12 as shown Table 3-1 below (ULARA Watermaster 2013a; MWD 2007).

Table 3-1. ULARA Total Spreading for Water Year 2011–12

Spreading Facility	Amount Spread for WY 2011–12 (AF)
Branford	529
Hansen	9,357
Lopez	104
Pacoima[a]	4,853
Tujunga[b]	105
Basin Total	14,948

[a] *Water spread by both LACDPW and City of Burbank.*

[b] *Water spread by both LACDPW and City of Los Angeles.*

3.3.2.2 Outflows

Outflows leaving the basin include surface outflow, subsurface outflow, exported water, and evaporation and transpiration (collectively termed “consumptive use”).

Surface Outflow

Surface outflows leaving the basin are determined by measuring the flow of the Los Angeles River passing Gaging Station F-57C-R, which lies in the main channel of the Los Angeles River and records all surface outflows from the ULARA. Surface flow at this gage includes (ULARA Watermaster 2013a):

- **Stormwater runoff:** This is typically the largest component of the total surface flow, and storm flows principally occur in the winter months. Stormwater runoff recorded at the gage for WY 2011–12 was 36,603 AF.
- **Waste discharge:** This includes treated wastewater, which is a significant factor affecting surface water runoff in the Los Angeles area. Four water reclamation plants (WRPs) are currently in operation in the ULARA: Tillman, Burbank, Los Angeles-Glendale, and the Las Virgenes Municipal Water District. Releases from the Los Angeles-Glendale WRP, Burbank WRP, and Tillman WRP appear to have begun in 1976–77, 1967, and 1985, respectively. A total of 85,313 AF of wastewater was treated in the ULARA in WY 2011–12. Waste discharges for WY 2011–12 was 69,176 AF.
- **Industrial discharges and irrigation runoff:** This occurs upstream of the gage and is relatively small, contributing a moderate amount of surface flow to the Los Angeles River. Field inspections have recorded unmetered flows from residential areas, golf courses, and industrial sites.

- **Rising groundwater:** This is a constant source of loss from the Verdugo and San Fernando groundwater basins. Rising groundwater occurs above the Verdugo Wash Narrows and in the unlined reach of the Los Angeles River (Los Angeles River Narrows) immediately upgradient of Gage F-57C-R. Releases of treated wastewater also influence rising groundwater. These large year-round releases tend to keep the alluvium beneath the Los Angeles River saturated, even in dry years. Rising groundwater recorded at the gage for WY 2011–12 was 3,121 AF.

The ULARA Watermaster's annual reports separate the surface flows at this gage and use the procedures outlined in the ROR (SWRCB 1962, Volume II, Appendix O) to estimate approximate flow rates and sources of water outflow at Gage F-57C-R. Total flow at this gage in WY 2011–12 was 108,850 AF.

Subsurface Outflow

This is a small amount of water that is lost from the area through the alluvium beneath Gage F-57C-R (MWD 2007). The 1992 RI reported that the 10-year average for this outflow was only 420 AF (JMM 1992).

Exported Water

Water that is exported includes imported LAA and MWD water (pass-through water), as well as groundwater extracted by LADWP. Exports of wastewater are delivered via pipeline to the Hyperion Treatment Plant in the Playa del Rey area of the city of Los Angeles. For WY 2011–12 (ULARA Watermaster 2013a), 258,220 AF of water was exported. Of these total exports, 44,035 AF were from groundwater extractions, whereas the remaining 214,185 AF were from imported supplies (pass-through water) (ULARA Watermaster 2013a).

Consumptive Use

This is a component of the water budget composed of evaporation, transpiration, and water that is otherwise used. Quantification of this amount is complex. The 10-year average reported for the SFB in the 1992 RI was 248,340 AFY, which closely matched consumptive use calculated by the SWRCB of 227,200 AFY (SWRCB 1962).

3.3.3 Change in Storage

The SFB change in water storage is the net amount of water added to and/or depleted from surface water and groundwater reservoirs. The storage change in surface reservoirs is considered negligible compared to the overall quantity of water in the basin because there are no major surface water reservoirs. In contrast, the annual change in groundwater storage can be significant because the basin is managed for storage of water during wet years and for use during dry years. However, long-term change in storage is expected to be small.

Annual change in water storage is calculated by the ULARA Watermaster. The volume of groundwater in storage in the SFB is estimated to have increased by 10,338 AF between WYs 2010–11 and 2011–12. Based on the 2011–12 storage, approximately 449,573 AF of groundwater storage space was available in the SFB. This space can be used to capture and store additional native water or imported water supplies during wet years (ULARA Watermaster 2013a).

3.3.4 SFB Surface Water System

The surface water conveyance system in the SFB consists of the Los Angeles River and its major tributaries upstream. In addition, there are spreading basins, dams and reservoirs, and debris basins.

3.3.4.1 Los Angeles River

The Los Angeles River is considered to begin at the confluence of Bell Creek and Calabasas Creek, which flow down from the Santa Susana and Santa Monica mountains in the Canoga Park section of the city. The river flows southeast and is joined by the Santa Susana, Browns, Dayton, Chatsworth, Limekiln, Wilbur, Aliso, Woodley, Pacoima, and Burbank creeks that drain the surrounding mountains. The main trunk of the Los Angeles River is considered to begin in the southwest portion of the SFB, flowing eastward near the northern slopes of the Santa Monica Mountains, and then it turns south through the Los Angeles River Narrows. Once out of the ULARA, the river flows south through the Central and West Coast basins of the Los Angeles Coastal Plain and discharges to the Pacific Ocean near Long Beach.

The Los Angeles River has about 85 miles of natural tributary washes within the ULARA (California Superior Court 1979). In general, the tributary washes to the Los Angeles River in the SFB do not flow continuously because they carry water only as a result of seasonal storm runoff or industrial discharges. Big Tujunga Creek, Little Tujunga Creek, and Pacoima Creek are the most prominent tributaries of the Los Angeles River. Nearly half of the runoff from the entire hill and mountain area is carried by these tributaries. Most of the Los Angeles River and its main tributaries (more than 60 percent) have concrete-lined channels for flood-control purposes. All but the lower 7 miles of the Los Angeles River is concrete-lined. The unlined 7 miles of the river are located:

- Through the Sepulveda Flood Control Basin in the San Fernando Valley (3 miles)
- Near Griffith Park through Elysian Valley where groundwater levels prevent it from being paved (2.5 miles)
- At the River estuary in Long Beach where the River empties into the Pacific Ocean (3 miles)

The Tujunga and Pacoima washes are described in more detail below:

- **Tujunga Wash:** The Tujunga Wash Channel is a 13-mile-long stream tributary to the Los Angeles River. It provides approximately one-fifth of the Los Angeles River flow and drains 225 square miles. The channel is usually dry, especially the lower reaches, carrying significant flows only during and after storms.

  Tujunga Wash consists of two forks. The upper portion of Big Tujunga Wash is called Tujunga Creek, or Big Tujunga Creek. It travels roughly from east to west, and several tributaries from the north and south join it as it flows to Big Tujunga Reservoir, formed by Big Tujunga Dam. It continues its westward flow, enters the SFV, and is met by Little Tujunga Creek a mile before reaching Hansen Dam and Reservoir. Little Tujunga Creek comes from the north, draining the portion of the San Gabriel Mountains immediately north of Hansen Dam. Downstream of the dam, water in the Tujunga Wash flows south past the Hansen and Tujunga Spreading Grounds, meeting the Los Angeles River near Studio City.
- **Pacoima Wash:** Pacoima Wash is a 33-mile long tributary of Tujunga Wash. The wash flows southward from Pacoima Dam Reservoir, where it meets several other unnamed streams that enter the channel before the Lopez Dam reservoir area. South of Lopez Dam, Pacoima Wash is a concrete flood control channel that drains south.

3.3.4.2 Spreading Basins

There are five active spreading facilities located in the SFB, four of which are operated by LACDPW and the other by both LACDPW and the City (ULARA Watermaster 2013ab; MWD 2007). These spreading facilities are used for spreading native and imported water, when available. Projects are under way to deepen and improve the capacity of these spreading basins. Both LACDPW and the LADWP are also working to identify ways to maximize spreading, including possible changes to the operations at each spreading basin (ULARA Watermaster 2013b). The City of Burbank completed construction of MWD's new Foothill Feeder connection in 2010, which is capable of delivering 50 cubic feet per second (cfs) to the Pacoima Spreading Grounds, in order to enable Burbank to spread imported water when it is available. These facilities also allow Burbank to direct water to the Lopez Spreading Grounds. The spreading basins cover approximately 314 acres with an estimated total capacity of approximately 104,000 AFY. A summary of each spreading basin is provided in Table 3-2 below, adapted from ULARA Watermaster (2013b).

Table 3-2. Spreading Basin Operator and Capacity

Basin	Operator	Total Wetted Area (acres)	Capacity (AFY)
Branford	LACDPW	7	2,100
Hansen	LACDPW	107	35,000
Lopez	LACDPW	12	2,000
Pacoima	LACDPW	107	23,000
Tujunga	LACDPW in cooperation with City of Los Angeles	83	43,000
		Total	**105,100**

3.3.4.3 Dams and Reservoirs

Dams are located on major streams throughout the region, providing flood protection and water conservation. Several major dams serve the city of Los Angeles, described in Table 3-3 below.

Table 3-3. Dams Serving City of Los Angeles

Name	Function	Operated By	Tributary Area (square miles)	Tributary To
Big Tujunga Dam	Flood control and water conservation. Water captured at Big Tujunga is recharged to the groundwater aquifer at Hansen and Tujunga Spreading Grounds.	Los Angeles County Flood Control District (LACFCD)	82	Big Tujunga Creek
Pacoima Dam	Flood control, debris control, and water conservation. Water impounded behind the dam during the storm season is gradually released and diverted into the Pacoima and Lopez Spreading Grounds to recharge groundwater.		28	Pacoima Creek
Hansen Dam	Flood control and water conservation. Releases downstream to the Tujunga Wash or the Los Angeles River. Releases may be managed to match the spreading grounds capacity of the Hansen Spreading Grounds and the Tujunga Spreading Grounds.	USACE	150	Tujunga Wash
Sepulveda Dam	Provides flood risk management.		152	LA River
Lopez Dam	Attenuate large storm flows released from Pacoima Dam upstream.		34	Pacoima Wash

In addition, numerous surface water reservoirs in the hill and mountain portions of the ULARA are used for water storage and regulation. These reservoirs include:

- Los Angeles Reservoir located at the terminus of the LAA
- Pacoima and Big Tujunga reservoirs in the San Gabriel Mountains
- Eagle Rock Reservoir in the San Rafael Hills
- Encino Reservoir in the Santa Monica Mountains
- Chatsworth Reservoir located near the west end of the SFV

3.3.4.4 Debris Basins

Numerous debris basins in the ULARA are key components of LACFCD's flood control system. Typically located at the mouths of canyons, debris basins not only capture sediment, gravel, boulders, and vegetative debris that are washed out of the canyons during storms, but they also allow water to flow into the downstream storm drain system, thereby protecting drainage systems and communities in lower-lying watershed areas from possible flooding and property damage. The debris basin itself consists of an earth dam or other barrier constructed across a drainage way or other suitable location for collecting sediment.

3.4 Hydrogeology and Updated HCSM

The hydrogeology of the eastern SFB has been extensively studied for more than two decades, with each study incorporating new data as they become available. The hydrogeologic interpretations and recommended updates to the HCSM discussed here are based on new subsurface data generated during the last several years as part of the GSIS and other new multi-depth nested monitoring wells. The following sections either paraphrase discussions from the NHOU RI where no new data are available or interpretations warranted, or provide detailed explanations and rationale for HCSM updates where new data are available and modifications to existing interpretations are warranted.

3.4.1 Hydrogeologic Basins of the ULARA

As discussed in Section 3.3.1, The ULARA groundwater basins include the San Fernando, Verdugo, Sylmar, and Eagle Rock basins, as shown on Figure 1-3. Although the basins are considered to be hydrogeologically separated, the Verdugo, Sylmar, and Eagle Rock basins are tributary to the SFB and contribute, on average, less than 1,000 AFY of combined inflow into the SFB (JMM 1992). Except for the shared boundaries separating the groundwater basins, all of the basins are bounded by the non-water-bearing hills and mountain areas of the ULARA watershed.

3.4.2 Water-Bearing Formations and Groundwater Occurrence

The Quaternary-age water bearing formations of the SFB were deposited in an alluvial fan environment where precipitation on surrounding hills and mountains is concentrated in channels that transport sediments from higher elevations to lower elevations. The sediments are deposited when the ground surface gradient lessens and the energy in the flood channels decreases, allowing deposition to occur. Under natural conditions, the channels become filled or flooding occurs, new channels form, and a fan-shaped surface is created at the mouth of the river channel. This cut-and-fill mode of deposition creates coarse-grained laterally discontinuous deposits within former river channels, surrounded by finer-grained overbank deposits. Two major active stream channels have contributed the majority of the sediments in the SFB: the Pacoima Wash and the Tujunga Wash. The historical wash boundaries circa 1893 (SWRCB 1962) were digitized for this report and are shown on Figure 3-5. The braided nature of these cut-and-fill alluvial fan deposits is clearly observed in these pre-development conditions.

The water-bearing formations of the SFB include the Saugus Formation, Older Alluvium, and Recent Alluvium (Figure 3-2). The oldest of these formations is the early Pleistocene Saugus Formation described in Section 3.2.2. The Saugus Formation is unconformably overlain by late Pleistocene Older Alluvium. The Older Alluvium comprises fine- to coarse-grained, unconsolidated deposits of the present stream systems and has a maximum thickness of more than 2,000 feet (JMM 1992). The Saugus Formation and Older Alluvium are not readily distinguished in the eastern SFB. The Recent Alluvium overlies the Older Alluvium and comprises boulders, coarse gravels, sand, silt, and clays derived from the surrounding hills and mountains and has a maximum thickness of more than 100 feet (JMM 1992). The thickness of the water-bearing formations in the eastern SFB is described in detail in the following sections. In the west, the Recent Alluvium contains an average of 75 percent clays derived from the surrounding sedimentary hills. In the east, the Recent Alluvium contains an average of 20 percent clays, with the bulk of the unit being derived from surrounding granitic Basement Complex (JMM 1992).

The non-water-bearing Tertiary to Cretaceous Period sedimentary rocks to Pre-Tertiary Basement Complex underlie and surround the valley fill and may contain some groundwater; however, their yields are considered insignificant.

Groundwater occurs within the poorly to unconsolidated valley fill deposits and generally flows from the edges of the valley fill in a southeasterly direction toward the Los Angeles River Narrows, then south through the narrows and into the Central Basin. Locally, groundwater flow is affected by pumping, recharge, and faulting especially in the eastern portion of the basin. Groundwater production creates localized depressions where groundwater flows toward the well fields. Groundwater recharge at spreading basins may create short-term, localized mounding. Faulting may also create areas of steep groundwater gradients because of barrier effects. This is evident along portions of the Verdugo Fault, particularly below the Hansen Dam where groundwater elevations may be over 100 feet different across the fault. This system was originally considered to be an apparent groundwater barrier (SWRCB 1962). However, more recent evaluations indicate that it is unlikely that the Verdugo Fault acts as an impermeable barrier throughout the Tujunga area (CH2M Hill 2011).

3.4.3 Aquifer Characteristics and HCSM Update

A HCSM is used to organize and communicate technical information about site characteristics, and is typically a precursor to and the basis for a numerical groundwater model. To date, the most complete HCSM for the SFB is described in the 1992 RI (JMM 1992). Additional hydrogeologic information for the GSIS area is included in the USEPA NHOU FFS (USEPA 2009b), NHOU Second Interim Remedy Data Gap Analysis (AMEC 2012a), and Tujunga Integrated Site Investigation (ISI) (USEPA 2012). It should be noted that the Tujunga integrated site investigation (ISI) did not attempt to redefine the SFB hydrostratigraphic units and is therefore not discussed separately in this section. The current ULARA Watermaster, Richard Slade, has also defined hydrostratigraphic units within the SFB. However, they have not been formally published by the Watermaster (ULARA Watermaster 2015). Figure 3-6 presents a stratigraphic correlation diagram modified from the NHOU Data Gap Analysis (AMEC 2012a) that shows the relative position and nomenclature of the various hydrostratigraphic units (ULARA Watermaster units on Figure 3-6 are based on interpretations made from logs of LADWP production well RT-01).

Described herein are the most current and commonly used SFB unit designations. In addition, Section 3.4.3.4 presents the proposed GSIS hydrostratigraphic zones based upon data derived from the new GSIS monitoring well construction and testing. As will be noted in Section 6 (groundwater model discussion), the layering proposed in this HCSM update have not been incorporated into any existing groundwater model and is intended to provide a framework for later model updates.

3.4.3.1 SFV 1992 RI Hydrostratigraphic Zones and Model Layers

The 1992 RI divided the alluvial valley fill of the eastern portion of the SFB into four hydrostratigraphic zones, with the following approximate depths in the NH area (Figure 3-6):

- **The Upper Zone**, the shallow aquifer that occurs between the present ground surface and 200 to 250 feet bgs and is composed of variable alluvial deposits.
- **The Middle Zone**, a relatively lower permeability zone that typically occurs between approximately 250 and 300 feet bgs, averages 50 feet thick and is characterized by relatively abundant fine-grained sands, silts, and clays.
- **The Lower Zone**, the main water supply aquifer that occurs between approximately 300 and 850 feet bgs, is approximately 300 to 500 feet thick and is characterized primarily by coarse sand and gravel horizons.
- **The Deep Zone**, which occurs to a depth of at least 1,200 feet bgs and is composed of fine to coarse alluvium with variable permeability.

The Middle Zone rises with the topography toward the northwest from the NH to the TJ area and pinches out near the TJ well field. The Middle Zone drops in elevation to the south and is locally over 50 feet below the water table.

The 1992 RI SFBGM (and every subsequent model) incorporated four layers to represent the SFB aquifers:

- The uppermost layer, Layer 1, was the water table layer and included the RI-defined Upper Zone and Middle Zone. The Middle Zone was included in Layer 1, because (1) the top of the zone was not as clearly defined as the bottom, and (2) water level fluctuations in the Upper Zone resulted in the Upper Zone becoming unsaturated in some areas, creating model instability (JMM 1992).
- Layer 2 included the upper 150 feet of the Lower Zone, because (1) this portion of the Lower Zone contained a high proportion of coarse gravels, (2) a large proportion of groundwater extracted from the aquifer comes from this interval, and (3) geophysical logs indicate that this interval contains highly transmissive materials.
- Layers 3 and 4 represent the remaining portions of the Lower and Deep Zones. The thicknesses of these layers and their vertical boundaries are somewhat arbitrary, as there was insufficient information at the time of development for the boundaries to be definitively identified (JMM 1992).

3.4.3.2 NHOU FFS Depth Regions

In the USEPA FFS for the NHOU (USEPA 2009b), the alluvial valley fill is divided into four depth regions; all are below the water table and correspond to common screened intervals (typically placed in more permeable strata) for monitoring and production wells in the NHOU. Additional USEPA investigations with the Tujunga ISI continued the use of these depth regions:

- **Depth Region 1** is present from approximately 200 to 280 feet bgs; this is where shallow RI monitoring wells, older production wells, and facility monitoring wells (at sites under the jurisdiction of the RWQCB, Los Angeles Region) are screened. The NHOU extraction (aeration) wells are screened in Depth Region 1 and the upper part of Depth Region 2.
- **Depth Region 2** is present from approximately 280 to 420 feet bgs and has a high hydraulic conductivity (permeability); most production wells are screened in this region.
- **Depth Region 3** occurs from approximately 420 to 700 feet bgs. Newer production wells, such as those in the RT and TJ well fields (located north of the NHOU treatment system) and the wells in the western portion of the NH well field, are screened in Depth Region 3.

- **Depth Region 4** includes all of the basin-fill alluvial deposits deeper than 660 feet bgs, with a typical thickness ranging from 100 feet to more than 500 feet; it generally corresponds with the lower part of the 1992 RI Deep Zone, which few wells had penetrated prior to the new GSIS monitoring wells.

As shown on Figure 3-6, the four USEPA depth regions are generally similar to the 1992 RI hydrostratigraphic zones, except that the 1992 RI Middle Zone low permeability zone is split between Depth Regions 1 and 2.

3.4.3.3 NHOU Data Gap Analysis Hydrostratigraphic Units

As part of the NHOU Second Interim Remedy, a data gap analysis (DGA) was performed to achieve the following (AMEC 2012a):

- Evaluate the basis of design for the existing NHOU system and review its historical performance
- Develop a refined NHOU conceptual site model
- Identify data gaps of critical importance to the Second Interim Remedy design
- Propose recommendations and a schedule to fill critical data gaps

As part of the refinement of the conceptual site model, the aquifer characteristics were reviewed and new definitions of aquifer zones were presented. Three hydrostratigraphic units were defined, as follows (Figure 3-6):

- The **A-Zone** comprises sediments extending from the water table to the bottom of the Middle Zone. This depth is also coincident with the bottom of the Watermaster-defined AA group, and extends approximately 20 to 80 feet below the base of Depth Region 1.
- The **B-Zone** comprises sediments extending from the base of the A-Zone to the base of the Watermaster-defined BB group.
- The **Deeper Units** represent the remaining water-bearing material below the base of the B-Zone.

3.4.3.4 GSIS Hydrostratigraphic Correlations and Hydrogeologic Model Layers

Based upon data generated during the installation and testing of the GSIS monitoring wells, 11 new cross-sections were prepared to capture the new GSIS monitoring well data, shown in Figures 3-7 through 3-17, and extended cross-section including USEPA model layering are including in Appendix-E. The cross-section locations are shown on Figure 3-5 and are generally oriented either northwest-southeast or northeast-southwest. The wells shown on the cross-sections were selected based on the quality of the data available for that location (i.e., high-quality geophysical logs and detailed geologist descriptions). Not all of the wells along a particular section were included on the section. Wells were excluded from a section if they did not add any new information or clarify existing data and for clarity of high-quality data.

Geologic modeling of the stratigraphy of the GSIS area was performed using EVS Pro by C Tech (www.ctech.com). EVS is a 3D interpolation (kriging) and visualization modeling software that generates a fully rendered model of subsurface geology and aquifer systems.

A total of five hydrostratigraphic units (and six surfaces) were spatially modeled and are discussed below. The contact with bedrock, which also creates the mountain-forming outcrops along the perimeter of the model domain, was simulated at land surface to represent higher-elevation land features as well as the impermeable bedrock surface at the bottom of the basin. It should be noted that the EVS geologic model domain does not extend north of the Verdugo Fault because of lack of data.

Lithologic data were derived from well logs collected during various drilling activities within the basin. These logs were interpreted by BC team geologists and assigned elevation-specific contacts between major hydrostratigraphic units (aquifer zones). These contact elevations were compiled in an Excel spreadsheet and formatted to be compatible with standard EVS input formats. Well completion information, including well screens, were also derived from the well logs and SFB databases. Land surface elevations for boring locations were derived from the SFB GSIS EQuIS Database, USEPA SFV groundwater database, or original well logs. Previously-published elevation contours for geologic contacts were also used locally to refine the model geometry at depth.

The base of the valley fill was created in the EVS model by digitizing the contours of the base of the valley fill from the ROR (SWRCB 1962). In areas where data indicated the base of the valley fill was deeper than that of the ROR, the base was lowered to the depth of the new data. The SFV RI model base of valley fill was also used to refine the EVS model.

Faults were treated as vertical planes projected downward from the trace of the faults in the project GIS and associated base maps. The water table surface was also interpolated within the 3D model for reference and was derived from the groundwater elevation contours shown on Figure 3-18.

Analysis of the cross-sections and correlation of prominent stratigraphic horizons was based primarily on geophysical logs (specifically guard resistivity) of the GSIS monitoring wells. Additional geophysical logs (typically single-point resistivity) from wells drilled prior to the GSIS monitoring wells were used to supplement data where GSIS monitoring well data did not exist. Correlation of stratigraphy based upon geologic descriptions of drill cuttings proved to be of little value because of the nature of the drilling method and the highly interbedded nature of the stratigraphy.

Cross-section B-B’ was used as a key to correlating layers throughout the GSIS investigation area. B-B’ extends from TJ-MW-12 southeasterly to NH-MW-11 (Figure 3-5). This particular section was used because it transects nine of the new GSIS monitoring wells that have high-quality and spatially-dense data, including the deepest well in the area, TJ-MW-06, which was drilled to 1,400 feet. In addition to the density of high-quality data, the bottom of the Middle Zone and the top and bottom of the Lower Zone are clearly observed in the resistivity logs in NH-MW-11, NH-MW-06, RT-MW-06, RT-MW-01, and RT-MW-03. However, these contacts become less clear or nonexistent between RT-MW-03 and TJ-MW-06 (Figure 3-8).

Several other high- and low-resistivity stratigraphic units can be correlated across B-B’, including the ULARA Watermaster-defined Blue Star marker bed discussed with the ULARA Watermaster (ULARA Watermaster 2015). Although not formally published, the current ULARA Watermaster has defined several stratigraphic units, including the Blue Star Marker Bed (AMEC 2012a). This high-resistivity unit occurs at a depth of approximately 650 feet, is about 40 feet thick, and is generally composed of gray to brown coarse sands and gravels, which become finer-grained south of RT-MW-06. The unit dips to the south similar to the ground surface, and may be observed in resistivity data as far south as USEPA monitoring wells NH-C04 and CS-C04 at depths of approximately 650 feet. The significance of this unit is that it appears to be present across most of the eastern SFB, including the area north of the Tujunga well field, and can be used to establish the basis for the correlation of other stratigraphic units and ultimately the basis for refining the conceptual model and subsequent numerical groundwater model layering.

Five hydrostratigraphic layers are proposed as part of this HCSM update and are described below. These layers are equivalent to potential future model layers, but these layers have not been used in the numerical modeling performed as part of Section 6.

Layer 1

Layer 1 is generally the same as the 1992 RI model Layer 1, with the base of the layer coincident with the base of the Middle Zone where present. In areas where the Middle Zone is not observed in the data (primarily north and west of the Tujunga well field) it either remains unchanged from the original 1992 RI layering or it generally follows the underlying stratigraphic layers. For example, on Section B-B’, near RT-MW-01, RT-MW-03, and RT-MW-06, the bottom of the Middle Zone is clearly observed in the resistivity data, and Layer 1 was adjusted accordingly. This process was carried out on all of the other cross-sections; if the bottom of the Middle Zone could be clearly identified and was different from the 1992 RI Layer 1, it was adjusted; otherwise, it was left unchanged.

Because the Middle Zone is important both as the base of Layer 1 and as potentially behaving as a lower permeability unit, it is important to delineate its spatial extent. Prior to the drilling of the GSIS monitoring wells, little data west of the CA-170 freeway showed the western extent of the Middle Zone. It is now evident that the Middle Zone does not exist west of Coldwater Canyon Avenue as a distinguishable unit (Figure 3-7). In fact, most of the identifiable units in the NHOU area become less distinguishable west of Coldwater Canyon Avenue, with a higher percentage of fine-grained sediments and lower resistivity values in the geophysical logs. Figure 3-5 shows the approximate western and northern extent of the Middle Zone.

Layer 2a

Layer 2a generally corresponds with the original 1992 RI Layer 2 and straddles the lower and deep zones resented in the 1992 RI. Any changes made to this layer are based upon new GSIS monitoring well data and other correlation trends seen in underlying sedimentary layers. This layer comprises the coarse-grained, high-permeability, and high-resistivity layer observed in many of the geologic and geophysical logs from wells in the area of the NH and RT well fields. The top of this layer generally occurs at a depth of approximately 360 feet and is marked by a sharp increase in resistivity values from geophysical logs. The bottom of Layer 2a is approximately 470 feet bgs and is indicated in the geophysical logs as a sharp decrease in resistivity. This is clearly observed in the guard resistivity logs from new GSIS monitoring wells near the RT well fields. For example, resistivity logs from RT-MW-06, RT-MW-04, and RT-MW-07 shown on cross-section E-E’ (Figure 3-11) demonstrate a clear definition of Layer 2a. The top of Layer 2a correlates with the top of the screened intervals of the production wells in the RT well field, and the uppermost screened intervals of the new GSIS nested monitoring wells are partially or completely within Layer 2a.

As it relates to other hydrostratigraphic interpretations, Layer 2a generally corresponds with the Watermaster’s BB unit, the FFS Depth Region 2, and the DGA B Zone, as shown in Figure 3-6.

Layer 2b

The base of Layer 2b correlates with the base of the Watermaster-defined Blue Star Marker Bed (ULARA Watermaster 2015), a high-resistivity layer that occurs at a depth of approximately 650 feet bgs and dips to the south at an angle similar to the ground surface. The Blue Star Marker Bed is clearly observed in resistivity logs from north of the TJ well field (e.g., TJ-MW-06, Figure 3-9) to approximately the NH well fields along Vanowen Street, and becomes somewhat less distinct south of Vanowen Street and west of Coldwater Canyon Drive. Layer 2b exhibits alternating high- and low-resistivity layers, but is generally characterized as lower resistivity than Layer 2a. Geologist’s descriptions of drill cuttings derived within this layer indicate primarily sands with interbedded silts and silty sands.

The majority of the Zone 2 screened intervals (see Section 2.6.4.2) of the new GSIS nested monitoring wells are located within Layer 2b. As it relates to other hydrostratigraphic interpretations, Layer 2b generally corresponds with the Watermaster's E, M, and Blue Star units; the FFS Depth Region 3; and the DGA Deeper Units, as shown in Figure 3-6.

Layer 3

The base of Layer 3 occurs at a depth of approximately 850 to 900 feet and dips parallel to ground surface. The base of Layer 3 is delineated by another sedimentary layer that exhibits high resistivity values in geophysical logs. Layer 3 includes the deepest zone from which existing production wells are screened, typically around 780 feet bgs. Like Layer 2b, Layer 3 exhibits alternating high- and low-resistivity layers. Geologist's descriptions of drill cuttings derived within this layer indicate primarily sands with interbedded silts and silty sands.

The majority of the Zone 3 screened intervals of the new GSIS nested monitoring wells are located within Layer 3. As it relates to other hydrostratigraphic interpretations, Layer 3 generally corresponds with the Watermaster's Q and Deeper units, the lower portion of the FFS Depth Region 3 and upper portion of Depth Region 4, and the DGA Deeper Units, as shown in Figure 3-6.

Layer 4

Layer 4 occurs from the base of Layer 3 to the top of the non-water-bearing basement rock. The base of Layer 4 remains relatively undefined, as few wells in the SFB have encountered non-water-bearing material. One new GSIS monitoring well, TJ-MW-06, was drilled to a depth of 1,400 feet. Geologic and geophysical data indicate water-bearing material was encountered the full depth of the borehole, which is several hundred feet deeper than the base of the 1992 RI model Layer 4. NH-MW-07 and NH-MW-08, shown on cross-sections H-H' and I-I' (Figures 3-14 and 3-15), respectively, also indicating that the water-bearing material exists deeper than the 1992 RI model Layer 4. These are the only new GSIS monitoring wells that penetrated depths below the 1992 RI model Layer 4. At these locations, the Layer 4 base was refined so that it is below these wells and then smoothed in EVS to represent a natural erosional surface.

3.4.4 Aquifer Geochemistry

An evaluation of the water quality data collected from the production and monitoring well network during the 2012/2013 and 2014 monitoring events was conducted to characterize aquifer geochemistry, examine vertical and spatial chemistry trends, and distinguish areas of contamination. This information can be used to determine different sources of groundwater in the SFB, the source soil or rock effects on water quality, identify areas of mixing of groundwater zones, and also assist in determining how the aquifer geochemistry might impact the fate and transport of contaminants, specifically metals.

3.4.4.1 Major Ion Chemistry

Two graphical methods, Piper and Stiff diagrams, were used to compare major ion chemical constituents in groundwater from wells in the basin. Piper diagrams show the relative concentrations of several major ions including calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), sulfate (SO_4), bicarbonate (HCO_3) and carbonate (CO_3). These eight ions represent the majority of the ions in solution for most natural waters. Water quality data were converted from concentrations to milliequivalents (meq) based on the valence (charge) and atomic weight of the constituent. For Piper diagrams, the percentage of each ion relative to the total is calculated. The resulting relative percentage of each ion is plotted on a trilinear plot and projected onto the central diamond shape plot to make up the Piper diagram. Piper diagrams enable a visual comparison of multiple water samples with a wide range of constituent concentrations on one diagram. Piper diagrams indicate the relative proportions of major ions, which can aid in grouping samples based on similar proportions of major ions. Analyses of Piper diagrams can help to identify relationships between groundwater zones and increase the understanding of the basin-wide hydrogeochemical processes affecting groundwater quality. Piper diagrams for individual well fields are included in Appendix F, with specific Piper diagrams for the TJ, RT, NH (with Whitnall and Erwin data), Verdugo, and Pollock well fields on Figures 3-19 and 3-20.

Stiff diagrams are visual representations of the major ion chemistry and are used to illustrate differences in water quality. The shape of the Stiff diagram indicates the various concentrations in meq/L of major ions in the water. Major ions used in the Stiff diagrams include Ca, Mg, Na, K, HCO_3, SO_4, Cl, and NO_3. Nitrate was included with the major ions because it was considered an important indicator of processes operating in the basin. The width of the Stiff diagram is an indication of ionic strength, meaning Stiff diagrams that plot closer to the centerline of the diagram typically have lower total dissolved solids (TDS) concentrations. When plotted on maps, the Stiff diagram's size and shape can show the spatial relationship of changing water quality data. Figure 3-19 and 3-20 plot Stiff diagrams from shallow and deep wells, respectively, on basin-wide topographic maps with groundwater and TDS contours. In order to simplify the maps, Stiff patterns from shallow wells and deep wells which exhibit similar chemistry were grouped together and instead of plotting all Stiff diagrams on a single map, representative Stiff diagrams for the groups were plotted instead. The shallow and deep Stiff maps were used to analyze spatial and vertical relationships in groundwater chemistry (Figures 3-19 and 3-20).

The following observations were made of the TJ, RT, and NH production and monitoring wells using the Piper and Stiff diagrams.

Tujunga

Water analyses plotted on Piper diagrams indicate that calcium is the dominant cation, and bicarbonate is the dominant anion in the TJ well field. All production wells in the TJ well field are assumed to be producing groundwater from Zones 2 and 3 (as noted in Section 3.4.3 these Zones roughly correspond with Layers 2b and 3) are considered "deep wells." On the Piper diagram (Appendix F and Figure 3-20), the 12 production wells predominantly cluster around a calcium-bicarbonate ($Ca\text{-}HCO_3$) water type. A weak trend in anion concentration from bicarbonate toward higher relative percentage sulfate ($Ca\text{-}HCO_3\text{-}SO_4$) is observed in the anion tertiary diagram with higher relative sulfate in southwestern production wells (Figure 3-19). This may indicate a different contribution of groundwater being captured in the south end of the well field, but overall it appears that $Ca\text{-}HCO_3$ dominant water sources are contributing to the production wells, likely from the three spreading grounds (Hansen, Tujunga, and Pacoima).

The TJ monitoring wells (TJ-MW-06 through TJ-MW-14) are mostly located to the north and northwest (upgradient) of the TJ production well field. Other TJ area monitoring wells include TJ-MW-01 through TJ-MW-03, EV-01, -02, -08, -09 (shallow and deep), NH-VPB-13, and HR-MW-01. The TJ monitoring wells are predominantly $Ca\text{-}HCO_3$ water type regardless of sample depth (Figures 3-19 and 3-20). However, subtle vertical changes in groundwater quality were distinguished on the Stiff maps (Figures 3-19 and 3-20). Stiff patterns for shallow TJ monitoring wells(shallow wells correspond with Zone 1 monitoring wells and hydrostratigraphic Layers 1 and 2a) (Figure 3-19) indicate a zone of $Ca\text{-}HCO_3$ groundwater with elevated nitrate in the central and western portion of the TJ well field.

Three shallow monitoring wells in the northern portion of the TJ area (TJ-MW-12, TJ-MW-14, and HR-MW-01) are Ca-HCO_3 type, but with relatively higher sulfate (Ca-HCO_3-SO_4). Ca-HCO_3 water also dominates in the deep TJ monitoring wells. Ca-HCO_3 groundwater with elevated nitrate is confined to the center of the TJ well field in deep groundwater (Figure 3-20). West of the TJ production well field, TJ-MW-08 indicates that Ca-HCO_3-SO_4 water persists in deep samples. Deep Ca-HCO_3-SO_4 groundwater also exists in the north/northeast corner of the well field (TJ-MW-12 and TJ-MW-14). The deepest sample, from TJ-MW-12, is anomalously high in sodium and bicarbonate with almost no sulfate (Na-HCO_3). The Piper diagrams (Appendix F) indicate that monitoring wells TJ-MW-03 and a deep sample from TJ-MW-08 indicate a shift towards higher sodium as well. On the western side of the TJ well field deep groundwater from EV-09 is uncharacteristically low in Ca, but higher in Mg with bicarbonate being the dominant anion.

It appears that the southwest TJ production wells (TJ-01 and TJ-02) have higher sulfate concentrations relative to most of the northeast TJ production wells (Figure 3-20). The artificial spreading of imported water and extraction by the TJ production wells may create vertically homogeneous groundwater chemistry in the TJ area with only subtle differences, which include elevated sulfate in the outer edges at depth and elevated nitrate near the center.

Rinaldi-Toluca

Water analyses plotted on Piper diagrams for the RT production wells indicate that Ca-HCO_3 is also the dominant water type in this well field (Figures 3-19 and 3-20, Appendix F). All RT production wells are assumed to be producing groundwater Layers 2b and 3 and are considered deep wells. Similar to the TJ production well field, anion concentrations range from high relative bicarbonate to higher relative sulfate in the anion tertiary diagram (Figure 3-20, Appendix F). Unlike TJ production wells, the anion concentrations do not generally correlate with the location of the wells. Wells RT-04 and RT-05 have the highest relative sulfate proportions of the RT production wells as noted on the Piper diagram (Figure 3-20) and are located near the center of the well field, but other RT production wells are also elevated in sulfate. One anomalous production well, RT-10, located adjacent to the northern part of the Hewitt Pit, plots closer to the sodium-chloride water type.

The RT monitoring wells (RT-MW-01 through RT-MW-10) are located mostly to the east and north of the production well field; however, a few are located west of Highway 170. Other RT area monitoring wells include EV-04 (shallow only). RT monitoring well data are dominated by the calcium cation, while the dominant anion ranges from bicarbonate in most wells to sulfate in a few monitoring wells (Figures 3-19 and 3-20). Shallow groundwater in the RT area is dominated by Ca-HCO_3 (Figure 3-19). The shallow Stiff map (Figure 3-19) shows an area of relatively higher nitrate concentrations in RT monitoring wells adjacent to and to the south of the RT production well field. The western RT monitoring well field is dominated by Ca-HCO_3-SO_4 shallow groundwater (RT-MW-09 and RT-MW-06). In addition, shallow groundwater from the northernmost RT monitoring well, RT-MW-10, located west of the TJ production well field, is Ca-SO_4 type and represents the northern extent of Ca-SO_4 groundwater in the western basin. The deep groundwater Stiff map (Figure 3-20) indicates Ca-HCO_3 groundwater occurs in the central and eastern areas of the RT well field, with relatively higher sulfate in some deep monitoring wells. Groundwater with elevated nitrate is not observed in the deep samples of the RT well field. Deep samples from RT monitoring wells located along and west of Highway 170 tend to be calcium-sulfate (Ca-SO_4) water type (Figure 3-20). A few wells (RT-MW-01, RT-MW-06, and RT-MW-09,) exhibit Ca-HCO_3 water from shallow samples and Ca-SO_4 water in deep samples. These three wells along with RT-MW-10 appear to delineate the vertical and spatial boundary between Ca-HCO_3 in shallow groundwater of the eastern basin and Ca-SO_4 in deeper groundwater of the western basin and potentially approximate a mixing zone between the two water types.

It appears that the majority of the RT production wells produce Ca-HCO_3 water with a few that are elevated with respect to sulfate (Figure 3-20). RT area monitoring wells mostly produce Ca-HCO_3 water. However, a few RT monitoring wells that penetrate deep groundwater west and north of the RT production well field are close to Ca-SO_4 type, or appear to be a mixture between Ca-HCO_3 and Ca-SO_4 types (Appendix F, Piper diagrams). The artificial spreading of imported water and extraction by the RT production wells may create vertically homogeneous groundwater chemistry in the RT area with only subtle differences, which include elevated nitrate in shallow groundwater near the RT production wells and south, and elevated sulfate in the western basin.

North Hollywood

The NH production well field consists of 25 municipal supply wells located in the central SFB, west of the Verdugo Mountains and south of the RT production wells. The NH production wells cluster near Vanowen Street and Highway 170 and spread east along Vanowen to Vineland Avenue and west to Ethel Avenue. Groundwater production in the NH production well field varies between shallow and deep zones. Piper diagrams on Figures 3-19 and 3-20 (and Appendix F) indicate NH production well data are split into three distinct water types based predominantly on location within the basin. NH production wells located east of the Highway 170 (shallow NHE wells; NH-40, NH-16, and NH-17) are dominated by Ca-HCO_3 like much of the RT and TJ well fields; however, deep groundwater from NH production wells located near Highway 170 (NH) tends to be Ca-SO_4 type. Some of the NH production wells are located near the mixing zone between Ca-HCO_3 and Ca-SO_4 water, which likely explains why a select few plot between Ca-SO_4 and Ca-HCO_3 types on the Piper diagrams (and in Figures 3-19 and 3-20). NHW are production wells located west of Highway 170 (NH-04, NH-07, NH-25, NH-33, and NH-32). Deep groundwater from NHW wells tends to have higher relative concentrations of sodium and slightly lower sulfate (Na-Ca-SO_4) than other nearby Ca-SO_4 groundwater (Figures 3-19 and 3-20).

Most NH monitoring wells are located west of Highway 170 between Roscoe and Oxnard; however, others are scattered east of Highway 170 near the NHE well field (NH-C01 to NH-C05 and NH-VPB-06) and as far south as the Verdugo production well field (NH-C06). The shallow and deep Stiff maps (Figures 3-19 and 3-20) and Piper diagrams inset show that, regardless of sample depth, most NH monitor wells located west of Highway 170 are Ca-SO_4 water type, while those located east of Highway 170 are Ca-HCO_3 water type (Piper diagrams in Figures 3-19 and 3-20). The shallow monitoring well, NH-C03, located near the NHE production well field, also exhibits Ca-HCO_3 water (Figure 3-19). Shallow groundwater north of the NHE production well field at NH-C01 contains Ca-HCO_3 water with elevated calcium, bicarbonate, and TDS relative to other wells in the area. In shallow groundwater south of NHE, monitoring wells NH-C02 (near Whitnall) and NH-C06 (near Verdugo) the water type is Ca-HCO_3 with elevated nitrate. Elevated nitrate also occurs in Ca-HCO_3 groundwater west and north of the NHE production wells. The high nitrate area is delineated by NH-C05, NH-VPB-06, NH-VPB-02, NH-MW-11, NH-MW-06, and two RT monitoring wells (RT-MW-05 and RT-MW-06). Shallow NH monitoring wells west of Highway 170 delineate a large area of Ca-SO_4 groundwater. The Ca-SO_4 groundwater extends north to RT-MW-10, south to NH-MW-07, west to NH-MW-08 and NH-MW-09, and east to NH-MW-01 and production well NH-25. Deep groundwater west of Highway 170 is also dominated by Ca-SO_4 water. However, a subset of NH monitoring well samples exhibit a sodium-calcium-sulfate (Na-Ca-SO_4) water type in the deepest groundwater samples. These Na-Ca-SO_4 monitoring wells (NH-MW-05, -07, -08, -09, and -10) are located on the west side of Highway 170 in the southern portion of the Ca-SO_4 delineated groundwater shown on Figure 3-20.

It appears that two different sources of groundwater are being contributed to the NH well field, $Ca\text{-}HCO_3$ from the east and $Ca\text{-}SO_4$ to $Na\text{-}Ca\text{-}SO_4$ from the west, which are captured and mixed by the production wells.

Whitnall, Erwin, and Verdugo

Whitnall production wells are located south of the NH area and are assumed to produce water from the deep groundwater zones. The two northern Whitnall wells, WH-04 and WH-05, produce $Ca\text{-}HCO_3\text{-}SO_4$ groundwater, while the two southern Whitnall wells, WH-6A and WH-07, produce $Ca\text{-}Na\text{-}HCO_3\text{-}SO_4$ water with elevated chloride (Appendix F). The two southern wells appear to extend the mixing zone between $Ca\text{-}SO_4$ groundwater in the western basin and $Ca\text{-}HCO_3$ groundwater to the north.

Erwin production wells are located immediately west of the Whitnall area and also produce groundwater from the deep zones. Erwin well EW-10, located furthest west of the two, produces $Na\text{-}Ca\text{-}SO_4$ groundwater with elevated bicarbonate, similar to NHW wells. In contrast, EW-06, located further east, produces $Ca\text{-}HCO_3\text{-}SO_4$ groundwater (Appendix F). These two wells appear to extend the mixing zone between $Ca\text{-}SO_4$ groundwater in the western basin and $Ca\text{-}HCO_3$ groundwater south of the NH well field.

Verdugo production wells, V-11 and V-24, are assumed to produce deep groundwater and are predominantly $Ca\text{-}SO_4$ type with slightly elevated bicarbonate (Figure-20 and Appendix F). In contrast, the shallow monitoring well, NH-C06, located north of Verdugo production wells is $Ca\text{-}HCO_3$ with elevated nitrate. This well along with NH-C02 near the Whitnall and Erwin production areas delineates an area of shallow groundwater that is $Ca\text{-}HCO_3$ type with elevated nitrate (Figure 3-19). The two production wells and deep monitoring well delineate a small area of $Ca\text{-}SO_4$ water separate and south of the NHW area.

Pollock

Pollock production wells are located in the southeastern portion of the basin in the Los Angeles River Narrows area near the I-5 interchange with Highway 2. The Pollock production wells are assumed to produce water from the shallow groundwater zone. Production wells, P-04 and P-06, produce $Ca\text{-}HCO_3\text{-}SO_4$ groundwater that is elevated in nitrate, while the two shallow monitoring wells are also $Ca\text{-}HOC_3$ type with elevated nitrate and sulfate (Appendix F).

San Fernando Basin Overview

The Stiff plots in Figure 3-19, along with inset Piper diagrams, were used to delineate two main water types in shallow groundwater, $Ca\text{-}HCO_3$ and $Ca\text{-}SO_4$. The $Ca\text{-}HCO_3$ groundwater occurs in the eastern basin and extends north to TJ-MW-12 along highway 170 and south to NH-C06 (near the Verdugo area). The $Ca\text{-}SO_4$ groundwater occurs in the western basin and extends north to RT-MW-10 and south to NH-MW-07. Spatial variations in shallow groundwater chemistry within these two delineated areas are subtle. Shallow groundwater along the centerline of the $Ca\text{-}HCO_3$ type have elevated nitrate while eastern basin wells adjacent to the $Ca\text{-}SO_4$ water in the western basin tend to have elevated sulfate indicating apparent mixing along the boundary between the two water types.

The Stiff plots in Figure 3-20, along with inset Piper diagrams, were used to delineate three main water types in deep groundwater of the SFB, $Ca\text{-}HCO_3$, $Ca\text{-}SO_4$, and $Na\text{-}Ca\text{-}SO_4$. The $Ca\text{-}HCO_3$ groundwater occurs in the eastern basin and extends to the north end of the TJ monitoring well field, includes the TJ, RT, and NHE production well fields, and south to the Erwin/Whitnall area. The $Ca\text{-}SO_4$ groundwater occurs in the western basin extending north to RT-MW-10, east to highway 170 and south to Erwin area, west to NH-MW-08, and south to NH-MW-07. The $Ca\text{-}SO_4$ area is larger in the deep groundwater compared to the shallow groundwater. A small $Ca\text{-}SO_4$ area is delineated near the Verdugo production well area just north of Highway 101. Spatial variations in deep groundwater chemistry within these delineated areas are subtle. Northwest of the TJ production well field, deep groundwater is elevated in nitrate. The outer edge of the TJ well field has Ca-HCO_3 groundwater with elevated sulfate. At certain well locations, the eastern basin Ca-HCO_3 groundwater adjacent to the western basin Ca-SO_4 groundwater areas contains elevated sulfate. The southern end of the Ca-HCO_3 groundwater area has elevated sulfate as well. A well-defined area of Na-Ca-SO_4 groundwater occurs in the deepest monitoring wells in the southern portion of the Ca-SO_4 area.

3.4.4.2 Metals Constituents

Concentrations of arsenic, boron, cobalt, chromium, lead, manganese, mercury, molybdenum, nickel, and zinc vary by several orders of magnitude across the SFB monitoring well network (Appendix F). The wide range in concentration of these metals could be due to potential anthropogenic contamination or natural processes such as leaching from source rock or soils. Further investigations as to the spatial distribution and correlation between metals and major ion concentrations was conducted to evaluate whether the metals concentrations are related to anthropogenic sources such as landfills, industrial sites, or agricultural sites. Furthermore, understanding the fate and transport of metals through the aquifer system can provide additional information on the hydrologic and physical properties of the aquifer.

Metals data were examined from monitoring wells to identify vertical changes in the water chemistry within each hydrostratigraphic layer and spatial changes across the basin. Three distinct water types, Ca-HCO_3, Ca-SO_4, and Na-Ca-SO_4, were noted in the monitoring well data. Comparison of metals concentrations with sulfate, bicarbonate, and sodium was used evaluate if the concentrations of metals were exclusive to a particular type of water.

Mercury, nickel, lead, and zinc data show bimodal populations with sulfate where several samples have elevated metals and elevated sulfate while another set of data have high concentrations of metals and low sulfate concentrations (Appendix F). Cr(VI) shows a trend of elevated Cr(VI) with low sulfate concentrations for the TJ well data and a bimodal trend for RT and NH well data. A bimodal population between bicarbonate and metals is much less noticeable (Appendix F). This is most likely due to the narrow range of bicarbonate concentrations compared to the sulfate concentration range. The bimodal populations suggest that these metals are equally affecting the three different types of waters, Ca-HCO_3, Ca-SO_4, and Na-Ca-SO_4. Sulfate correlates moderately well with arsenic and manganese in NH monitoring wells (Appendix F), indicating that elevated arsenic and manganese concentrations, unlike the other metals, are mostly associated with Ca-SO_4 groundwater. Mercury shows a positive correlation with bicarbonate in the NH and RT monitoring wells, indicating that the Ca-HCO_3 water type is associated with elevated mercury concentrations.

Sodium positively correlates with molybdenum and boron in some NH monitoring wells (Appendix F). The highest molybdenum and sodium concentrations are in deeper groundwater samples from NH (Appendix F). The strong positive correlation between sodium and molybdenum indicates that molybdenum has mostly affected the Na-Ca-SO_4 water type in the NH area. Furthermore, the increase in sodium and molybdenum concentrations from shallow to deep groundwater may indicate that the source of molybdenum and sodium to the aquifer is older than the source for other metal constituents, such as zinc and Cr(VI), which exhibit the opposite trend of decreasing concentrations from shallow to deep groundwater (Appendix F).

Cr(VI) does not correlate with the major ions bicarbonate, sodium, or sulfate, or with any of the other metals reported in groundwater in the SFB (Appendix F). This indicates that Cr(VI) is not likely linked to a particular water source, but is more dependent on source rock/soil, redox conditions of the aquifer and anthropogenic releases. Cr(VI) shows a strong 1:1 concentration trend with total chromium for all well fields with the exception of a few NH samples that have slightly higher concentrations of total chromium than Cr(VI). The 1:1 correlation indicates that Cr(VI) is the dominant valence state in the SFB groundwater.

3.4.4.3 Physical Water Quality Characteristics

The pH for the TJ, RT, and NH monitoring wells ranges between 6.46 and 8.07 (Appendix F). NH groundwater has the most variation in pH values (Appendix F). All of the monitoring wells samples have pH values within the acceptable drinking water range of 6 to 9. No well-defined correlation between pH and any metals was observed in any of the well fields.

DO concentrations range from 0.16 to 9.98 milligrams per liter (mg/L) (Appendix F). Elevated concentrations of DO (above (greater than 1.0 mg/L) are seen in all zones in all of the monitoring wells (Appendix F). The elevated DO in all zones, including the deep groundwater samples, indicates that DO from both natural and artificial recharge, such as through the spreading basins, is being transported through the unsaturated zone and the shallow groundwater to the deep water-bearing layers.

The pH and DO are positively correlated in groundwater from the RT and TJ wells (Appendix F). In contrast, a negative correlation was observed in pH and DO from the NH monitoring wells. The NH monitoring wells, as shown by the Piper diagrams, are chemically different from other well fields with higher proportions of sulfate and sodium. Sulfate and sodium trends with pH and DO illustrate the differences in the NH, RT, and TJ monitoring wells (Appendix F). High sulfate and low DO concentrations in the NH wells is an indication that the area of the basin where Ca-SO_4 water type is prevalent does not receive as much infiltration of oxygenated water from spreading or other forms of recharge. Alternatively, water infiltrating in the areas where Ca-SO_4 is prevalent could be moving through the vadose zone at a slower rate, allowing for more microbial reduction of DO resulting in lower concentrations (Rose and Long, 1988).

DO can affect the speciation and therefore the fate and transport of metals in groundwater (Cherry et al. 1984). Metals concentrations were evaluated with DO and indicate a correlation of elevated Cr(VI) with DO concentrations for TJ, RT, and NH monitoring well data DO for the RT and TJ monitoring wells. Arsenic concentrations show no correlation with DO (Figures 3-21 and 3-22). Areas with elevated dissolved oxygen concentrations also have elevated Cr(VI) concentrations for both the shallow and deep zones. The NH area where Ca-SO_4 is the dominate water quality type has low DO and low Cr(VI) concentrations in both shallow and deep groundwater (Figure 3-21 and 3-22). Concentrations of dissolved oxygen and Cr(VI) are higher in the shallow (hydrostratigraphic Layers 1 and 2a) than the deeper layers (Figure 3-21 and 3-22). These elevated concentrations in the shallow zone could indicate that oxygenated water with higher concentrations of metals infiltrates to the deep groundwater zones then mixes with water that has lower DO and metals concentrations and metals concentrations. Zinc also has a positive correlation with dissolved oxygen for the RT and TJ monitoring wells (Appendix F). Arsenic concentrations show no correlation with dissolved oxygen.

3.4.5 Groundwater Levels

Groundwater levels in the SFB have been consistently monitored since the 1969 adjudication and reported annually by the ULARA Watermaster. The most recent Watermaster report (ULARA Watermaster 2013a) provides water level data from key monitoring points throughout the SFB. In addition, groundwater level contour maps were created from numerical model runs of spring and fall 2012 conditions. For both time periods, groundwater elevations in the SFB ranged from over 900 feet in the west end of the basin to less than 350 feet in the Los Angeles River Narrows. The regional groundwater gradient is toward the southeast, with a local groundwater depression at the Burbank OU well field. A simulated change in the groundwater elevation map was also prepared by the ULARA Watermaster, depicting the relative simulated change in groundwater elevation between fall 2011 and fall 2012. The most significant areas showing change in the SFB are near the Hansen Dam, Tujunga Basins, and Pacoima Basins where artificial recharge operations occur. During WY 2010-11, over 79,000 AF were recharged by LADWP in the SFB, approximately 75,000 AF of which was recharged in the Hansen, Pacoima, and Tujunga basins. In contrast, during WY 2011–12, less than 12,000 AF was recharged in the same basins, resulting in significant simulated water level declines at the recharge basins (ULARA Watermaster 2013a).

A fall 2013 groundwater elevation contour map was prepared as part of the HCSM update, and it is presented as Figure 3-18. Data were derived primarily from field data generated during the construction of the GSIS monitoring wells and from the USEPA SFV groundwater database, and are representative of water table or near water table groundwater conditions. If data from nested or clustered monitoring wells were available, then shallow well data were used.

The groundwater level measurement dates ranged from June 2012 through February 2014; however, the majority of the data points were between September and December 2013, and are representative of fall 2013 conditions. Data outside the fall 2013 period were used to infill areas where data were unavailable, primarily north and northeast of the Tujunga well field. Most notably, fall 2013 water level data were unavailable for all of the new monitoring wells constructed by USACE, all of the EV wells and the three wells in the Sun Valley area east of RT-MW-07. Appendix G presents the 181 groundwater elevation data points used to create the fall 2013 groundwater elevation contour map (Figure 3-18).

Groundwater elevations in the eastern portion of the SFB, east of the I-405 freeway, range from approximately 550 feet to less than 320 feet msl in the southeast where the SFB discharges at the Los Angeles River Narrows. The regional groundwater gradient is approximately 0.0017 ft/ft to the east and southeast within the main SFB and increases to approximately 0.0051 ft/ft through the Los Angeles River Narrows. Localized pumping depressions occur around the main well fields, including TJ, RT, NHW, and the Glendale OU. The groundwater elevation contours also indicate groundwater mounding near the Pacoima spreading basins and along the historical Tujunga Wash below the Hansen Dam, where the Verdugo Fault Zone may be less restrictive to groundwater flow.

Groundwater elevations between the Verdugo Fault Zone and the Hansen Dam are based upon data from seven wells. The groundwater elevations range from over 780 feet msl just below Hansen Dam to around 650 feet msl just above the Verdugo Fault Zone, with a relatively steep gradient of approximately 0.03 ft/ft. Groundwater elevation differences of over 150 feet occur between wells on either side of the fault, indicative of groundwater flow restriction likely resulting from low permeability zones along fault planes.

3.4.6 Aquifer Hydraulic Properties

The 1992 RI included a detailed discussion of hydraulic properties of the SFB including specific capacity, hydraulic conductivity and transmissivity, and storativity. The data presented in the 1992 RI were the result of several aquifer tests performed in the SFB as part of the RI or by private entities in the SFB. This section of the RI Update Report includes a summary of the findings from the 1992 RI along with results of geotechnical testing from the well installation (Section 2.6.2.4).

3.4.6.1 1992 RI Report

As part of the investigation activities during the 1992 RI two pump tests were performed and data from other aquifer tests in the SFB were compiled. The aquifer testing performed as part of the 1992 RI included one aquifer test in the North Hollywood area pumping NH-28 and observing water level in the multi-level well NH-C03 installed as part of the RI, and the second test was performed in the Crystal Springs area pumping GV-11 and monitoring CS-C03 (Figure 1-1). The results of the aquifer testing performed as part of the 1992 RI are presented in Table 3-4 below, adapted from the 1992 RI Report (JMM 1992).

Table 3-4. Summary of 1992 RI Aquifer Testing Results

Pumped Well	Observation Well	Aquifer Zone	Range of Estimated Transmissivity (square feet per day [ft^2/day])	Range of Estimated Hydraulic Conductivity (feet per day [ft/day])	Range of Storativity
NH-28	**NH-C03**	**North Hollywood Aquifer Testing Results**			
292 - 392		L	63,900 – 69,400	639 – 693	
	340 – 380	L	20,200 – 38,600	505 – 966	1.2x10^{-3} – 5.1 x10^{-5}
535 - 610		L	28,600 – 31,000	381 – 413	
	540 – 580	L	10,800 – 18,700	271 – 468	3.2x10^{-4} – 9.3 x10^{-5}
610 – 660		L	5,100 – 5,500	102 – 110	
	640 – 680	L – D	3,100 – 7,800	77 – 194	4.7x10^{-4} – 1.0 x10^{-5}
760 - 800		L – D	5,500 – 12,000	137 – 297	1x10^{-3} – 1.0 x10^{-5}
GV-11	**CS-C03**	**Crystal Springs Aquifer Testing Results**			
	60 – 100	U	3,900	97	
	295 – 325	L	5,100 – 15,000	170 – 491	1.0x10^{-3} – 6.2 x10^{-4}
312 – 332		L	3,200 – 3,700	160 – 187	
352 – 372		L	4,400 – 5,100	221 – 254	
394 – 474		L	29,500 – 34,600	369 – 433	
	425 - 465	L	6,500 – 19,000	164 - 468	2.0x10^{-3} – 1.5 x10^{-4}

U – Upper Zone, generally corresponds with Hydrostratigraphic Unit (Layer) 1 as presented in Section 3.4.3.4.

L – Lower Zone, generally corresponds with Hydrostratigraphic Unit (Layer) 2a and 2b as presented in Section 3.4.3.4.

D – Deep Zone, generally corresponds with Hydrostratigraphic Unit (Layer) 3 and 4 as presented in Section 3.4.3.4.

As can be noted from Table 3-4, the transmissivity was observed to be significantly higher in the Lower Zone where most production wells are screened, as opposed to the Upper Zone. Overall the aquifer testing results in the SFB indicated aquifer characteristics vary vertically from zone to zone and also areally within zones indicating aquifer heterogeneity in the eastern SFB.

3.4.6.2 Soil Geotechnical Testing and Analysis

As presented in Section 2.6.2.4, geotechnical samples were collected as part of the GSIS well installation project. These 2-inch by 6-inch core samples were collected using the Simulprobe® sampler during drilling of the pilot borehole and were submitted to PTS Laboratories for analysis of a variety of properties such as hydraulic conductivity and effective porosity. Results of the testing are presented within Table 2-4, and laboratory reports are included in the GSIS Well Completion Report (Appendix A).

Hydraulic conductivity testing was performed on the soil cores using a falling head-permeability test, which measures the volume of water moving through the soil core over a specified time. This test is dependent on several factors including the method of sample collection and preservation of the soil core. Results from the testing included values of hydraulic conductivity that range from 0.01 to 19 feet per day (ft/day). The values are significantly lower than those from the aquifer testing performed during the 1992 RI, but this kind of relationship between the testing of soil cores versus pump testing is common for several reasons including, but not limited to the following:

- Soil cores are only collected where the lithology is conducive to recovery of cores. Coarse grained (typically greater than 1-inch diameter) materials are not recoverable using these insitu soil collection methods, so high conductivity soils are generally not recovered.
- The Simulprobe® is hammered into place for collection of the soil sample. This tends to compact the soil and reduce measurements of hydraulic conductivity.

With the above said, the wide range in values of hydraulic conductivity observed in the soil cores corresponds with the heterogeneous nature of the SFB, with values of individual soils being up to several orders of magnitude different in hydraulic properties both areally and with depth.

3.4.7 Vertical Hydraulic Gradients

The SFB groundwater aquifer is generally considered to be unconfined, lacking any competent or laterally extensive aquitards (AMEC 2012a). Aquifer testing in the NH area, relatively small vertical head gradients, and lack of significant and laterally continuous clay layers indicate unconfined conditions. However, complex patterns of groundwater flow and analytical variations exist at various depths within the SFB. These groundwater flow and analytical complexities result in part because of the operation of large-capacity well fields throughout the area (AMEC 2012a).

The 1992 RI evaluated groundwater flow patterns using equipotential-line analyses of both non-pumping and pumping conditions, and concluded that vertical groundwater gradients are influenced primarily by groundwater extractions. During high pumping in the NH well field, groundwater flow near the pumping area is primarily toward the upper portions of the Lower Zone (Layer 2a) with some downward flow from the Upper Zone. Horizontal flow dominates in areas away from the pumping area. During non-pumping periods, local groundwater flow patterns are dominated by horizontal flow (JMM 1992).

Recent groundwater elevation data generated during the construction and testing of the new GSIS nested monitoring wells indicate that the SFB aquifer exhibits some degrees of confinement; however, it is minor. Groundwater elevation differences between nested wells are usually less than a few feet.