Common name ***Scientific name***	**Status[1] Federal/State**	**Potential to occur in Fillmore Groundwater Basin[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in Fillmore Groundwater Basin**
Southwestern willow flycatcher *Empidonax traillii extimus*	FE/SE	Likely	Cienega, East Grove, Santa Clara River Riparian Shrubland	CNDDB, CAFSD	Indirect	Dense brushy thickets within riparian woodland often dominated by willows and/or alder, near permanent standing water. Reliant on groundwater dependent riparian vegetation, including for nest sites that are typically located near slow-moving streams, or side channels and marshes with standing water and/or wet soils (Rohde et al. 2019). Feeds on insects, fruits, and berries. Occurrences throughout the Santa Clara River (CDFW 2019, eBird 2021). Critical habitat located along the Santa Clara River in the East Grove, Santa Clara River, and Cienega GDE units (USFWS 2013).
Western yellow-billed cuckoo *Coccyzus americanus occidentalis*	BLMS, FSS, FT/SE	Likely	East Grove, Santa Clara River Riparian Shrubland	CNDDB	Indirect	Summer resident of valley foothill and desert riparian habitats; nests in open woodland with clearings and low, dense, scrubby vegetation. Reliant on groundwater dependent riparian vegetation for habitat (Rhode et al. 2019). Occurrences along Santa Clara River in the East Grove GDE (CDFW 2019, eBird 2021), and in TNC's Hedrick Ranch Nature Area (East Grove) (WFVZ 2020b). Historical populations documented along Sespe Creek west of Fillmore in 1924 are presumed extant (CDFW 2019).

Common name ***Scientific name***	**Status[1]** **Federal/State**	**Potential to occur in Fillmore Groundwater Basin[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in Fillmore Groundwater Basin**
White-tailed kite *Elanus leucurus*	BLMS/SFP	Likely	Cienega, East Grove, Santa Clara River Riparian Shrubland	CNDDB	Indirect	Lowland grasslands and wetlands with open areas; nests in trees near open foraging area. Predominately preys on small mammals, but its diet also includes birds and lizards. Occurrences along Santa Clara River (CDFW 2019, eBird 2021, WFVZ 2020c). Breeding documented in CDFW's Cienega Springs Ecological Preserve (Cienega and Santa Clara River Riparian Shrubland) (WFVZ 2020a).
Yellow warbler *Setophaga petechia*	–/SSC	Likely	Cienega, East Grove, Santa Clara River Riparian Shrubland, Sespe Creek Riparian,	CNDDB	Indirect	Open canopy, deciduous riparian woodland close to water, along streams or wet meadows. Reliant on groundwater dependent riparian vegetation for breeding habitat (e.g., willows, alders, and cottonwoods). Typically eats insects. Occurrences along Santa Clara River (CNDDB 2019, eBird 2021, WFVZ 2020c) and near Sespe Creek at Grand Avenue terminus (CNDDB 2019, eBird 2021). Breeding documented in CDFW's Cienega Springs Ecological Preserve (Cienega) (WFVZ 2020a), and TNC's Taylor property and the Hedrick Ranch Nature Area (East Grove) (WFVZ 2020b).

Common name ***Scientific name***	**Status[1] Federal/State**	**Potential to occur in Fillmore Groundwater Basin[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in Fillmore Groundwater Basin**
Yellow-breasted chat *Icteria virens*	–/SSC	Likely	Cienega, East Grove, Santa Clara River Riparian Shrubland	CNDDB, CAFSD	Indirect	Early successional riparian habitats with a dense shrub layer and an open canopy. Occurrences along Santa Clara River (CDFW 2019, eBird 2021, WFVZ 2020c). Breeding documented in CDFW's Cienega Springs Ecological Preserve (Cienega) (WFVZ 2020a), and suspected breeding in TNC's Hedrick Ranch Nature Area (East Grove) (WFVZ 2020b).

[1] Status codes:

Federal
FE = Listed as endangered under the federal Endangered Species Act
FT = Listed as threatened under the federal Endangered Species Act
FSS = Forest Service Sensitive Species
PFT = Proposed for listing as threatened under the federal Endangered Species Act
BLMS = Bureau of Land Management Sensitive Species

State
SE = Listed as Endangered under the California Endangered Species Act
SSC = CDFW species of special concern
SFP = CDFW fully protected species

[2] Potential to Occur:
Likely: the species *has* documented occurrences and the habitat is high quality or quantity
Possible: no documented occurrences and the species' required habitat is moderate to high quality or quantity
Unlikely: no documented occurrences and the species' required habitat is of low to moderate quality or quantity
None: no potential to occur due to lack of habitat and/or the population is assumed extirpated

[3] Query source:
CAFSD: California Freshwater Species Database (TNC 2020)
CNDDB: California Natural Diversity Database (CDFW 2019)
eBird: (eBird 2021)

[4] Groundwater Dependent Ecosystem (GDE) association:
Direct: Species directly dependent on groundwater for some or all water needs
Indirect: Species dependent upon other species that rely on groundwater for some or all water needs

[5] Formerly *Emys marmorata marmorata*

Fish

Fish are dependent on groundwater if they use interconnected surface water as part of their life cycle, including spawning, rearing, and migration. As discussed in Section 3.3, interconnected surface waters in the Fillmore Groundwater Basin occur in the East Grove and Cienega GDE units of the Santa Clara River and likely in portions of Sespe Creek.

The mainstem Santa Clara River likely supports limited native fish populations because of the presence of sub-optimal water conditions (e.g., high temperature, low dissolved oxygen), poor habitat quality (e.g., low amounts of cover that provides refuge from predators and high flows), insufficient surface water connectivity (e.g., the watershed is 'flashy' during and following storm events (NMFS 2012) and large portions of this reach lose surface flows quickly following storms or drought conditions), and the presence of non-native fish (Stoecker and Kelley 2005), although there is minimal literature regarding fish populations within these reaches (Kelley 2004). Sespe Creek supports diverse native and non-native fish species assemblages as it has more instream shelter cover and more riparian vegetation than the Santa Clara River (Stoecker and Kelley 2005). Instream cover supports suitable spawning, feeding, and rearing habitat for fish. Disconnected ephemeral tributaries in the Fillmore Groundwater Basin can be used by fish species seasonally, but do not contain surface water year-round and are not connected to groundwater and thus not considered here.

Four special-status fish species (southern California steelhead, Pacific lamprey, arroyo chub, and unarmored threespine stickleback) have the potential to occur in the interconnected reaches of the Fillmore Groundwater Basin (Table 5.2-7). An additional species, the Santa Ana sucker, occurs in the Fillmore Groundwater Basin and is listed as threatened under the federal Endangered Species Act, but those occurring in the Santa Clara River and tributaries have no special status due to uncertainties at the time of its listing regarding whether it is native to the Santa Clara River watershed. In the Fillmore Groundwater Basin, the National Marine Fisheries Service (NMFS) designated critical habitat for southern California steelhead in the mainstem Santa Clara River and Sespe Creek (Figure 5.2-1).

Within the Fillmore Basin, the Santa Clara River and Sespe Creek are listed as critical habitat for migration, spawning, and rearing southern California steelhead (Figure 5.2-1), although the degree of spawning and rearing in the Fillmore Basin has not been studied. Similar to the Piru Basin, it is assumed the Santa Clara River in the Fillmore Groundwater Basin is primarily a migration corridor for adult and juvenile *O. mykiss* (Kelley 2004, Stoecker and Kelley 2005), but there have been few studies of *O. mykiss* occurrence or habitat suitability. *O. mykiss* are known to utilize the mainstem Santa Clara River for passage to suitable spawning areas in Sespe Creek and further upstream to Piru Creek and to emigrate from the Santa Clara River to the estuary and/or Pacific Ocean as smolts. A small population of *O. mykiss* may utilize Pole Creek, but access issues within the Fillmore and Piru Basin may limit migration (Stoecker and Kelley 2005, Kajtaniak 2008). Similar to the Piru Subbasin, rising groundwater supplies only a small portion of the flows required for anadromous steelhead passage to upstream spawning grounds, calculated by comparing the measured rising groundwater flows shown in Figure 3.3-1 with minimum passage requirements from the literature. As mentioned above, TRPA (2005) and Gard (2021) assessed passage conditions downstream of the Basin (120 cfs and greater than 500 cfs, respectively). Harrison et al. (2006) found anadromous steelhead passage in the mainstem Santa Clara River within the Fillmore Basin required discharges of 500 cfs downstream of the confluence with Sespe Creek. These flows range from 8-35% of the maximum measured rising groundwater flows near Willard Road in Figure 4.3-1. Similar to the Piru Basin, under its FERC license, United Water releases water downstream of Santa Felicia Dam from Lake Piru to support southern California steelhead passage through the Santa Clara River when criteria for instream flows are triggered.

The United groundwater model suggests that decreasing groundwater pumping by half reduces the flow of interconnected surface water by an average of 4.7 cfs, and ranges from 0.7–10 cfs at Willard Road at the downstream end of the East Grove GDE (see section 2.2.2.7 of the GSP for a discussion of these modeling results). Reducing groundwater pumping by half would therefore supply approximately <1–8% of the discharge required for anadromous steelhead passage. However, the critical riffles identified by Harrison et al. (2006) do not correspond to areas of rising groundwater, further reducing the effects of groundwater pumping on passage flows.

As discussed in the Piru Basin connected surface water and 0.4 feet of water depth is generally necessary for smolts to migrate downstream (CDFW 2017). However, necessary flows for downstream migrants within the Fillmore Groundwater Basin has not been studied and is unknown. Juvenile downstream emigration may occur between January and June (Booth 2020), although the majority of smolts captured downstream of Fillmore Groundwater Basin occurred between mid-March and late May in the Santa Clara River (Booth 2020). Because the minimum surface water flows required for downstream passage are unknown for emigrating smolts, the influence of groundwater pumping on downstream passage is not clear for the Fillmore Groundwater Basin. Additional data on emigrating passage requirements is necessary to assess the influence of groundwater pumping on surface flows during downstream passage.

Native fish, including *O. mykiss*, Pacific lamprey, unarmored threespine stickleback, and Santa Ana sucker, and the non-native, protected (i.e., CDFW species of special concerns species) arroyo chub could utilize perennial reaches of the Santa Clara River for movement, spawning, and rearing along the East Grove and Cienega GDE units and the upper portions of Sespe Creek year-round and intermittent reaches when water is present. However, there are few studies of fish occurrence in these reaches. *O. mykiss* utilizing the mainstem Santa Clara River for spawning and rearing in the Fillmore and Piru basin is thought to be unlikely (Stoecker and Kelley 2005) but has not been widely investigated, and is a data gap.

Table 5.2-7. Groundwater dependent special-status fish with known occurrence or suitable habit in the Fillmore Groundwater Basin.

Common name ***Scientific name***	**Native or introduced**	**Status[1] Federal/ State**	**Occurrence in interconnected reaches**	**Source(s)**	**Habitat and occurrence within the Fillmore Groundwater Basin**
Southern California steelhead *Oncorhynchus mykiss irideus*	Native	SE, FE	Santa Clara River (migration likely, spawning and rearing unlikely), Sespe Creek (likely migration, spawning, and rearing)	Howard et al. 2015, Howard and Booth 2016, United 2018, ACS 2002, Stoecker and Kelley 20005	Occurs in freshwater systems and requires adequate water conditions suitable for migration (i.e., flow, dissolved oxygen levels within the surface water, and water temperature suitable for passage) and suitable substrate (i.e., gravels) for spawning. Juvenile *O. mykiss* require suitable cover, flow, foraging conditions, and cool temperatures for rearing. Juvenile emigration (i.e., outmigration to the ocean) requires water conditions suitable for migration. *O. mykiss* migration (both upstream and downstream) can occur in all surface water reaches of the Fillmore Groundwater Basin when flows are sufficiently high (Stoecker and Kelley 2005). *O. mykiss* spawning and rearing occurs in Sespe Creek. Rearing is unlikely in the Santa Clara River due to poor habitat and temperature conditions (Stoecker and Kelley 2005).
Pacific lamprey *Entosphenus tridentatus*	Native	SSC	Santa Clara River (likely migration, pre-spawning holding, rearing), Sespe Creek (likely migration, pre-spawning holding, spawning, rearing)	Chase 2001, Stoecker and Kelley 2005, Reid 2015, United 2018	Occurs in freshwater systems and requires adequate flows for migration, suitable substrate (i.e., gravels) for spawning, and adequate cover for pre-spawning holding. Juveniles (called ammocoetes) spend an extended period of time (between four and 10 years) rearing while burrowed in sediments filter feeding on organic material and require suitable cover, flow, foraging conditions, and cool temperatures. Juvenile migrant (called macropthalmia) emigration (i.e., outmigration to the ocean) requires water conditions suitable for migration (i.e., water velocity and water depth, dissolved oxygen levels within the surface water, and water temperature suitable for passage). Pacific lamprey have not been observed upstream of the Freeman Diversion in the mainstem Santa Clara River, however Pacific lamprey spawning and rearing is documented in Sespe Creek (Reid 2015); therefore, logically, Pacific lamprey must migrate through the mainstem Santa Clara River portion of the Fillmore Groundwater Basin to get to Sespe Creek.

Common name ***Scientific name***	**Native or introduced**	**Status[1] Federal/ State**	**Occurrence in interconnected reaches**	**Source(s)**	**Habitat and occurrence within the Fillmore Groundwater Basin**
Unarmored threespine stickleback *Gasterosteus aculeatus williamsoni*	Native	SE, FE, SFP	Possible in the Santa Clara River and Sespe Creek	ACS 2002, Swift et al. 1993, Richmond et al. 2014, CDFW 2019, USFWS 2021	Occurs in freshwater rivers and streams. There is a 'non-specified bounded area' unarmored threespine stickleback population occurrence within the within the interconnected mainstem Santa Clara River (CDFW 2019). However, the species is not known to occur currently or have occurred historically downstream of the Ventura/Los Angeles County line (Richmond et al. 2014, USFWS 2021). Because of difficulty with identification between similar subspecies, identification via genetic and/or plate counts is needed to confirm subspecies. Migration is largely localized and opportunistic; this species does not exhibit defined migration.
Santa Ana sucker *Catostomus santaanae*	Native	FT (not in Santa Clara River watershed)[3]	Likely in the Santa Clara River and Sespe Creek	Howard and Booth 2016, United 2018, ACS 2002, Swift et al. 1993, CDFW 2019	Occurs in freshwater rivers and streams. The species occurs within all surface water reaches in the Fillmore Groundwater Basin (CDFW 2019, United 2018, Howard and Booth 2016). Recent genetics studies reveal the presence of the Santa Ana and Owens sucker hybrid (*Catostomus santaanae* x *fumeiventris*) within Fillmore Groundwater Basin.

Common name ***Scientific name***	**Native or introduced**	**Status[1] Federal/ State**	**Occurrence in interconnected reaches**	**Source(s)**	**Habitat and occurrence within the Fillmore Groundwater Basin**
Arroyo chub *Gila orcutti*	Introduced (but native to other nearby watersheds)	SSC	Likely in the Santa Clara River, possible in Sespe Creek	Howard et al. 2015, United 2018, ACS 2002, CDFW 2019	Occurs in freshwater rivers and streams. Although arroyo chub, a CDFW SSC, is not native to the Santa Clara River watershed, CDFW protects the species within the watershed. Arroyo chub occurs in the perennial mainstem within Fillmore and is likely to occur in the perennial tributary reaches and ephemeral reaches when conditions are conducive to passage (CDFW 2019, Howard et al. 2015, United 2018). Arroyo chub does not exhibit defined migration and the species' movement is largely localized and opportunistic.

[1] Status codes:

Federal		State	
FE	= Listed as endangered under the federal Endangered Species Act	SE	= Listed as Endangered under the California Endangered Species Act
FT	= Listed as threatened under the federal Endangered Species Act	SSC	= CDFW species of special concern
FSS	= Forest Service Sensitive Species	SFP	= CDFW fully protected species
BLMS	= Bureau of Land Management Sensitive Species		

[2] Potential to Occur:

Likely: the species *has* documented occurrences and the habitat is high quality or quantity

Possible: no documented occurrences and the species' required habitat is moderate to high quality or quantity

Unlikely: no documented occurrences and the species' required habitat is of low to moderate quality or quantity

None: no potential to occur due to lack of habitat and/or the population is assumed extirpated

[3] The Santa Ana sucker is federally threatened; however, because of previous uncertainty regarding whether it is native to the SCR watershed, United States Fish and Wildlife Service (USFWS) does not currently consider the species federally threatened within the SCR watershed (USFWS 2017)

5.3 Invasive Species

Non-native and invasive species are distributed throughout the Santa Clara River watershed, including the Fillmore and Piru groundwater basins. Invasive species have a negative impact on the riparian corridor and threaten native species populations. Two invasive plant species, arundo (giant reed; *Arundo donax*) and saltcedar (*Tamarix* spp.), are widely distributed within the Fillmore and Piru groundwater basins. Arundo and tamarisk were included as vegetation community types (see Section 4.1.1). The extent of vegetation units dominated by arundo and saltcedar is shown in Figure 5.3.-1 and acreages of the communities are presented in Appendix A.

Arundo is a highly aggressive, naturalized landscape plant that invades riparian zones by establishing dense, monospecific clonal stands (DiTomaso and Healy 2007). It spreads quickly and severely impacts the ecology of the riparian corridor (Stillwater Sciences and URS 2007) and uses a large amount of water to fuel its growth (Bell 1997, Geissow et al. 2011). In California, giant reed is known to increase the risk of flooding, create fire hazards, outcompete indigenous plant species for scarce water resources, and reduce the value of riparian habitat for wildlife (Bell 1994, Bell 1997, DiTomaso 1998). The least Bell's vireo and other riparian birds require structural diversity provided by riparian scrub and mature forest communities for breeding (Zembal 1990, Bell 1994, Bell 1997). When natural riparian vegetation types are replaced by thick stands of giant reed, bird species' abundance and other native wildlife have been found to decline (Bell 1994, Bell 1997, Herrera and Dudley 2003, Kisner 2004, Labinger and Greaves 2001).

In general, invading tamarisk significantly lowers wildlife habitat value in riparian ecosystems by decreasing available food sources and altering structural characteristics (Shafroth et al. 2005). Monotypic stands provide limited cover for large mammals and fewer nesting sites for birds and herpetofauna in more southern latitudes due to lack of shading in mid- to late summer (Hunter et al. 1988, Lovich and DeGouvenain 1998, Shafroth et al. 2005). Both the endangered southwestern willow flycatcher and the threatened western yellow-billed cuckoo prefer native forests in some cases, but incorporate some habitat with tamarisk into their breeding territory (Shafroth et al. 2005).

Invasive amphibian species, American bullfrog (*Lithobates catesbeianus*) and African clawed frog (*Xenopus laevis*), are documented on the Santa Clara River, including near the confluence with lower Sespe Creek and Piru Creek (Santa Clara River Trustee Council 2008). These amphibian species are found within or adjacent to aquatic habitat, including ponds, streams, reservoirs, and lakes. Both species likely prey on native species and have negative impacts on native amphibian species (e.g., arroyo toad).

Many non-native fish species, including black bullhead (*Ameiurus melas*), various sunfish species (*Lepomis* sp.) (e.g., green sunfish [*Lepomis cyanellus*] and bluegill [*Lepomis macrochirus*]), and bass species (*Micropterus* sp.) (e.g., largemouth bass [*Micropterus salmoides*]), have been documented within the Piru and Fillmore perennial tributaries year-round or within the other reaches within the SCR watershed (Stoecker and Kelley 2005). The distribution of invasive species within the mainstem and tributaries is not fully known; however, these species are either likely to occur or have the potential to occur within the perennial mainstem and ephemeral reaches due to observation of the species throughout the SCR watershed. Non-native predatory fish may have a large impact on native fish populations (e.g., salmonids), reducing the size of already diminished populations and limiting their ability to recover in response to habitat restoration efforts. In the NMFS (2012) southern California steelhead recovery plan, non-native species were designated a "very high threat" to the steelhead population in the Santa Clara River.

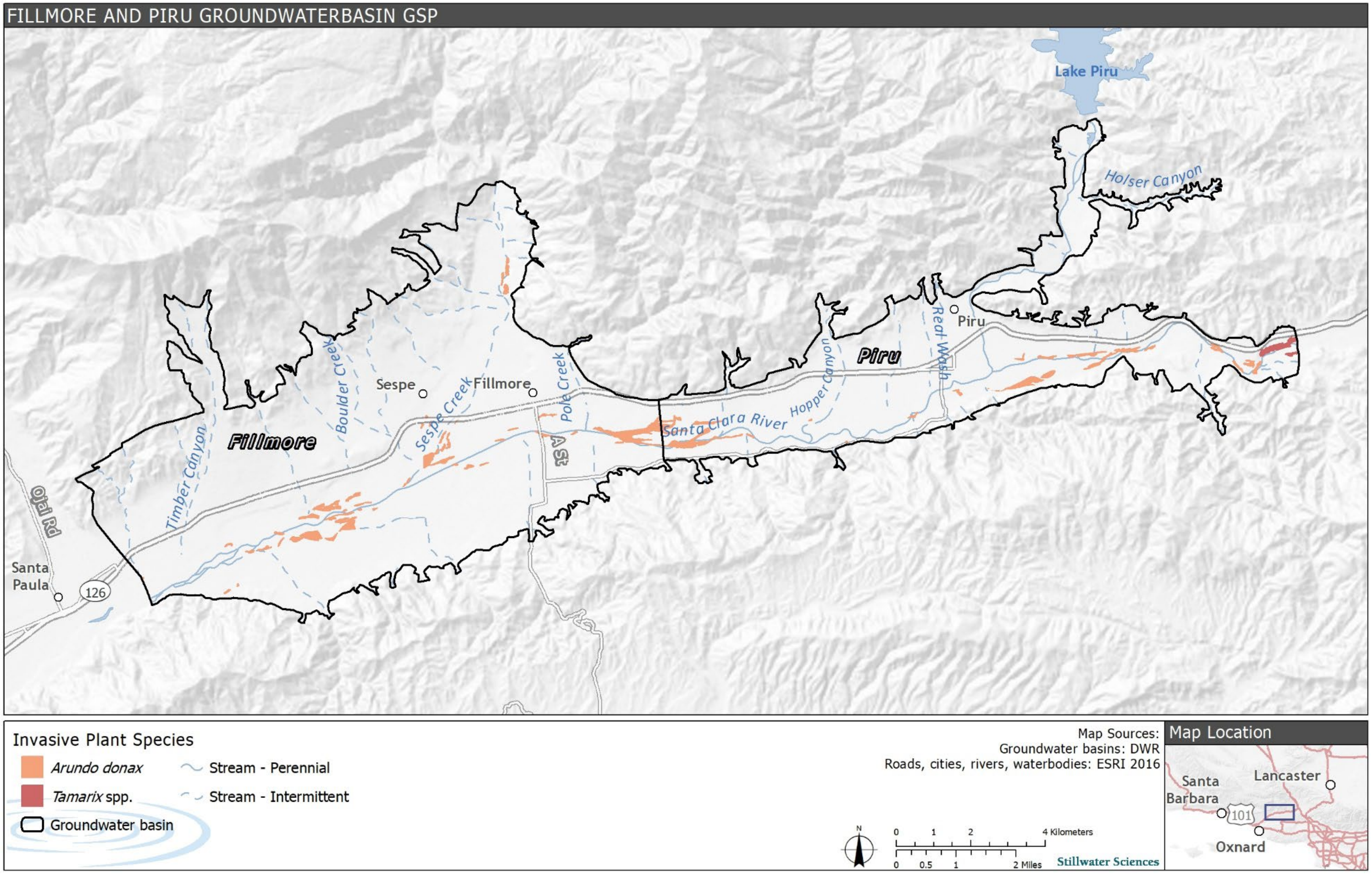

Figure 5.3-1. Vegetation stands dominated by arundo and saltcedar within the Fillmore and Piru groundwater basins.

5.4 Ecological Value

The ecological value of each GDE unit was characterized by evaluating the presence and groundwater-dependence of special-status species and ecological communities and the vulnerability of these species and their habitat to changes in groundwater levels (Rohde et al. 2018). Following Rohde et al. (2018) ecological value is divided into three categories (Table 6.1-1).

Table 5.4-1. Ecological value of GDE units (Rohde et al. 2018).

Ecological value classifications	
High Ecological Value	• GDE unit has been designated as important habitat (e.g., designated critical habitat). • Contains species that are dependent upon groundwater for their survival or are rare and unique. • Contains species that are vulnerable to slight-moderate changes in groundwater elevation that would result in substantial spatial redistribution
Moderate Ecological Value	• GDE unit contains species that are not legally protected but may be designated as a beneficial use. • Contains species that are partially dependent on groundwater. • Contains species that are somewhat vulnerable to slight-moderate changes in groundwater elevation that would result in some spatial redistribution.
Low Ecological Value	• GDE unit does not contain legally protected species. • Contains only species that are partially dependent on groundwater. • Contains species that are not vulnerable to slight-moderate changes in groundwater elevation.

In addition, the presence of natural or near-natural conditions and ecosystem function was also considered.

5.4.1 Piru

Del Valle GDE Unit

The Del Valle GDE Unit was determined to have **high ecological value** because: (1) it supports a relatively large number of special-status species and ecological communities (Tables 5.2-2, 5.2-3, and 5.2-4), (2) contains 433 acres of designated critical habitat for southwestern willow flycatcher and 436 acres of designated critical habitat for least Bell's vireo (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (two plants, three natural communities, two reptiles, and one fish; Tables 5.2-2, 5.2-3, and 5.2-4), and (4) includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The reach of the Santa Clara River in the Del Valle GDE Unit is considered perennial and is typically connected to groundwater. The degree to which interconnected surface waters in this reach are maintained by releases from upstream effluent sources is unknown, but is believed to be significant. It provides important habitat for special-status aquatic and semi-aquatic species, potentially including southwestern pond turtle, two-striped gartersnake, unarmored threespine stickleback, and arroyo chub, and this habitat is vulnerable to groundwater uses that reduce the amount and quality of riverine habitat. Southern California steelhead and Pacific lamprey are not known to occur in or upstream of this reach. The Del Valle GDE Unit contains 34% of the total GDE acreage in the Piru Groundwater Basin (Table 3.1-2).

Santa Clara River Riparian Shrubland GDE Unit

The Santa Clara River Riparian Shrubland GDE Unit was determined to have **moderate ecological value** because: (1) it supports a moderate number of special-status species and ecological communities (Tables 5.2-2, 5.2-3, and 5.2-4), (2) contains 317 acres of designated critical habitat for southwestern willow flycatcher and approximately 3.8 miles of designated critical habitat for southern California steelhead (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (three natural communities and three fish; Tables 5.2-2, 5.2-3, and 5.2-4), and (4) includes species and ecological communities that are somewhat vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The Santa Clara River in this GDE unit is considered intermittent and is not connected to groundwater. It may provide migration habitat for anadromous species (i.e., southern California steelhead), but this habitat has low vulnerability to groundwater reduction because most migration occurs during seasonal high flow periods. The unit contains 25% of the total GDE acreage in the Piru Groundwater Basin (Table 3.1-2).

Cienega GDE Unit

The Cienega GDE Unit was determined to have **high ecological value** because: (1) it supports a moderate number of special-status species and ecological communities (Tables 5.2-2, 5.2-3, and 5.2-4), (2) contains 154 acres of designated critical habitat for southwestern willow flycatcher and approximately 0.2 miles of designated critical habitat for southern California steelhead (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (one plant, two reptiles, and four fish; Tables 5.2-2, 5.2-3, and 5.2-4), and (4) includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The reach of the Santa Clara River in the Cienega GDE Unit is considered perennial and is connected to groundwater except during droughts. It provides important habitat for special-status aquatic and semi-aquatic species, potentially including southwestern pond turtle, two-striped gartersnake, southern California steelhead, unarmored threespine stickleback, and arroyo chub, and this habitat is vulnerable to groundwater uses that reduce the amount and quality of riverine habitat. The unit contains 12% of the total GDE acreage in the Piru Groundwater Basin (Table 3.1-2).

Piru Creek Riparian GDE Unit

The Piru Creek Riparian GDE Unit was determined to have **high ecological value** because: (1) it supports a relatively high number of special-status species and ecological communities (Tables 5.2-2, 5.2-3, and 5.2-4), (2) contains 246 acres of designated critical habitat for southwestern willow flycatcher and approximately 4.9 miles of designated critical habitat for southern California steelhead (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (one plant, five natural communities, two reptiles, and five fish; Tables 5.2-2, 5.2-3, and 5.2-4), and (4) includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). Piru Creek in this GDE unit is considered perennial, though baseflows are maintained by releases from Santa Felicia Dam, which likely also raises the groundwater level in this area. The lower portion of Piru Creek near the confluence with the Santa Clara River periodically lacks surface flow. Piru Creek provides important habitat for special-status aquatic and semi-aquatic species, potentially including southwestern pond turtle, two-striped gartersnake, southern California steelhead, unarmored threespine stickleback, and arroyo chub. Because surface flows in Piru Creek are mostly controlled by upstream releases rather than interconnected groundwater, this habitat is not vulnerable to groundwater uses that reduce the amount and quality of stream habitat. The unit contains 25% of the total GDE acreage in the Piru Groundwater Basin (Table 3.1-2).

Tributary Riparian GDE Unit

The Tributary Riparian GDE Unit was determined to have **moderate ecological value** because: (1) it supports a relatively low number of special-status species and ecological communities (Tables 5.2-2 and 5.2-3), (2) contains 5.6 acres of designated critical habitat for least Bell’s vireo (Figure 5.2-1), (3) supports few native special-status species and natural communities with a likely or possible groundwater dependence (three plants and one natural community; Tables 5.2-2 and 5.2-3), and (4) primarily includes species and ecological communities with little vulnerability to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). They do, however, support valuable riparian habitat and likely movement corridors for a variety of native wildlife species. The tributary streams in this GDE unit are considered ephemeral and are not interconnected with groundwater. Typically, these streams only support surface flow immediately after storm events and thus provide little habitat value for fish and other aquatic species. Hopper Canyon Creek may have perennial flow at its upstream end within the basin and may have historically supported aquatic species. The connection to groundwater in Hopper Canyon Creek is unknown. The unit contains 5% of the total GDE acreage in the Piru Groundwater Basin (Table 3.1-2).

5.4.2 Fillmore

Santa Clara River Riparian Shrubland GDE Unit

The Santa Clara River Riparian Shrubland GDE Unit was determined to have **moderate ecological value** because: (1) it supports a relatively high number of special-status species and ecological communities (Tables 5.2-5, 5.2-6, and 5.2-7), (2) contains 952 acres of designated critical habitat for southwestern willow flycatcher and approximately 7.6 miles of designated critical habitat for southern California steelhead (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (four natural communities, one reptile, and two fish; Tables 5.2-5, 5.2-6, and 5.2-7), and (4) includes species and ecological communities that are somewhat vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The Santa Clara River in this GDE unit is considered intermittent and is not connected to groundwater or to upstream and downstream perennial reaches in most years (Figure 4.1-1). It provides migration habitat for special-status anadromous species (i.e., southern California steelhead, Pacific lamprey) but this habitat has low vulnerability to groundwater reduction because most migration occurs during seasonal high flow periods. The unit contains a relatively large amount of GDE area (1,046 acres), accounting for 40% of the total GDE acreage in the Fillmore Groundwater Basin (Table 3.1-2).

Cienega GDE Unit

The Cienega GDE Unit was determined to have **high ecological value** because: (1) it supports a relatively large number of special-status species and ecological communities (Tables 5.2-5, 5.2-6, and 5.2-7), (2) contains 116 acres of designated critical habitat for southwestern willow flycatcher and approximately 1.1 miles of designated critical habitat for southern California steelhead (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (one plant, one natural community, and four fish; Tables 5.2-5, 5.2-6, and 5.2-7), and (4) includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The reach of the Santa Clara River in the Cienega GDE Unit is considered perennial and is connected to groundwater except during droughts. It provides important habitat for special-status aquatic and semi-aquatic species, potentially including southwestern pond turtle, southern California steelhead, unarmored threespine stickleback, and arroyo chub, and this habitat is vulnerable to groundwater uses that reduce the amount and quality of riverine habitat. The unit contains 5% of the total GDE acreage in the Fillmore Groundwater Basin (Table 3.1-2).

East Grove GDE Unit

The East Grove GDE Unit was determined to have **high ecological value** because: (1) it supports a relatively large number of special-status species and ecological communities (Tables 5.2-5, 5.2-6, and 5.2-7), (2) contains 923 acres of designated critical habitat for southwestern willow flycatcher and approximately 3.2 miles of designated critical habitat for southern California steelhead (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (one plant, four natural communities, one reptile, and three fish; Tables 5.2-5, 5.2-6, and 5.2-7), and (4) includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could substantially alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The reach of the Santa Clara River in the East Grove GDE Unit is considered perennial and is typically connected to groundwater. It provides important habitat for special-status aquatic and semi-aquatic species, potentially including southwestern pond turtle, southern California steelhead, Pacific lamprey, unarmored threespine stickleback, and arroyo chub, and this habitat is vulnerable to groundwater uses that reduce the amount and quality of riverine habitat. The unit contains a relatively large amount of GDE area (1,101.9 acres), accounting for 43% of the total GDE acreage in the Fillmore Groundwater Basin (Table 3.3-2).

Tributary Riparian GDE Unit

The Tributary Riparian GDE Unit was determined to have **moderate ecological value** because: (1) it supports a relatively low number of special-status species and ecological communities (Tables 5.2-5, 5.2-6, and 5.2-7), (2) contains no designated critical habitat (Figure 5.2-1), (3) supports few native special-status species and natural communities with a likely or possible dependence on groundwater (two plants and one natural community; Table 5.2-5), and (4) primarily includes species and ecological communities with little vulnerability to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). They do, however, support valuable riparian habitat and likely movement corridors for a variety of native wildlife species. The tributary streams in this GDE unit are considered ephemeral and are not connected to groundwater. Typically, these streams only support surface flow immediately after storm events and thus provide little habitat value for fish and other aquatic species. Pole Creek may have perennial flow at its upstream end within the basin and may have historically supported aquatic species. The connection to groundwater in Pole Creek is unknown. The Tributary Riparian GDE Unit contains 8% of the total GDE acreage in the Fillmore Groundwater Basin (Table 3.3-2).

Sespe Creek Riparian GDE Unit

The Sespe Creek Riparian GDE Unit was determined to have **moderately high ecological value** because: (1) it supports a moderate number of special-status species and ecological communities (Tables 5.2-5, 5.2-6, and 5.2-7), (2) contains approximately 3.2 miles of designated critical habitat for southern California steelhead (Figure 5.2-1), (3) supports native special-status species and natural communities with a known or high likelihood of direct groundwater dependence (two natural communities, two reptiles, and three fish; Tables 5.2-5, 5.2-6, and 5.2-7), and (4) includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The upper 2 miles of Sespe Creek in this GDE unit are considered perennial, while the lower portion of Sespe Creek is likely intermittent (Figure 3.1-1). Sespe Creek's connection to groundwater is undetermined. Sespe Creek provides important habitat for special-status aquatic and semi-aquatic species, likely including southwestern pond turtle, two-striped gartersnake, southern California steelhead, Pacific lamprey, unarmored threespine stickleback, and arroyo chub, and this habitat is vulnerable to groundwater uses that reduce the amount and quality of stream habitat. The unit contains 4% of the total GDE acreage in the Fillmore Groundwater Basin (Table 3.3-2).

6 Potential Effects Of Groundwater Pumping On GDEs

This section presents the methods and results of our analysis to identify how groundwater pumping could affect GDEs in the Fillmore and Piru groundwater basins. Adverse effects (impacts) on GDEs are considered undesirable results under SGMA (State of California 2014). The analysis is based on the hydrologic conditions affecting GDEs and their susceptibility to changing groundwater conditions, trends in biological condition of the GDEs, and climate change projections and other anticipated conditions or management actions likely to affect GDEs in the future.

6.1 Approach

SGMA describes six groundwater conditions that could cause undesirable results, including adverse impacts on GDEs. These are (1) chronic lowering of groundwater levels, (2) reduction of groundwater storage, (3) seawater intrusion, (4) degraded groundwater quality, (5) land subsidence, and (6) depletion of interconnected surface waters. Rohde et al. (2018) identify chronic lowering of groundwater levels, degraded water quality, and depletions of interconnected surface water as the most likely conditions to have direct effects on GDEs, potentially leading to an undesirable result. Following this guidance and based on available information for the Fillmore and Piru groundwater basins, we have eliminated reduction of groundwater storage, seawater intrusion (the subbasins are not located in close proximity to the ocean), and land subsidence from consideration because they are not relevant to GDEs in the Fillmore and Piru groundwater basins.

We evaluated the potential for chronic lowering of groundwater levels, degraded groundwater quality, and depletion of interconnected surface waters to cause direct effects on GDEs compared to baseline conditions, with a focus on effects related to groundwater levels. First, we identified baseline hydrologic conditions for the GDE units using available information (Section 1.2 and Section 4). Next, we determined each GDE unit's susceptibility to changing groundwater conditions using available hydrologic data, climate change projections, and the GDE susceptibility classifications (Rohde et al. 2018), summarized in Table 6.1-1.

Table 6.1-1. Susceptibility classifications developed for evaluation of a GDE's susceptibility to changing groundwater conditions (Rohde et al. 2018).

Susceptibility classifications	
High Susceptibility	Current groundwater conditions for the selected hydrologic data fall outside the baseline range.[1]
Moderate Susceptibility	Current groundwater conditions for the selected hydrologic data fall within the baseline range but future changes in groundwater conditions are likely to cause it to fall outside the baseline range. The future conditions could be due to planned or anticipated activities that increase or shift groundwater production, causing a potential effect on a GDE.
Low Susceptibility	Current groundwater conditions for the selected hydrologic data fall within the baseline range and no future changes in groundwater conditions are likely to cause the hydrologic data to fall outside the baseline range.

[1] For purposes of this analysis, the baseline range is defined as the range of variability of the shallow groundwater depth for the period of record through 2015, with a minimum of 10 years (2005–2015).

We used these susceptibility classifications to trigger further evaluation of potential effects on GDEs. The elevation of groundwater relative to the rooting depth is crucial to assessing the impact of groundwater level change on groundwater dependent vegetation, with mortality of groundwater dependent vegetation generally increasing as groundwater levels decline (Kibler et al. 2021). Moreover, a rapid rate of declining groundwater can add additional stress to trees, even if the groundwater elevation is above the maximum rooting depth (Stella et al., 2021). If we determined a GDE unit to have moderate or high susceptibility to changing groundwater conditions, we used biological information to assess whether evidence exists of a biological response to changing groundwater levels or degraded groundwater quality. The biological response analysis was based on changes in Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) data for individual vegetation polygons within the GDE units (Klausmeyer et al. 2019). The polygons correspond to different GDE mapping units (i.e., different species compositions), and the size of the GDE polygons varied.

NDVI, which estimates vegetation greenness, and NDMI, which estimates vegetation moisture, were generated from surface reflectance corrected multispectral Landsat imagery corresponding to the period of July 9 to September 7 of each year, which represents the summer period when GDE species are most likely to use groundwater (see Klausmeyer et al. 2019 for further description of methods). Vegetation polygons with higher NDVI values indicate increased density of chlorophyll and photosynthetic capacity in the canopy, an indicator of vigorous, growing vegetation. Similarly, high NDMI values indicate that the vegetation canopy has high water content and is therefore not drought stressed. These indices are both commonly used proxies for vegetation health in analyses of temporal trends in health of groundwater dependent vegetation (Rouse et al. 1974 and Jiang et al. 2006 as cited in Klausmeyer et al. 2019).

Based on the NDVI and NDMI data, groundwater quality data from wells in or near GDE units in the Fillmore and Piru groundwater basins, and the likely susceptibility of the terrestrial and aquatic species and natural communities in each GDE unit to reported groundwater quality constituents, we found no evidence of a biological response associated with groundwater quality in any of the GDE units. Groundwater quality is therefore not addressed further in the analysis of potential effects.

Discharge of interconnected surface water in areas of rising groundwater is generally a function of groundwater elevation (see GSP Section 2.2.2.7), which is tied to water year type, groundwater pumping, and surface water releases from upstream reservoirs and water treatment plants. There is not sufficient data on the population of aquatic species that rely on interconnected surface water in the Fillmore and Piru Basins to track the health of these GDEs through time. Evidence suggests that aquatic species such as steelhead were more widespread prior to development of the Santa Clara River Valley since the mid-1900s, and the decline in populations is likely due to many factors, including dams within the Santa Clara River watershed, declining habitat quality outside of the groundwater basins, ocean conditions, and non-native species among many factors. Moreover, the degree to which *O. mykiss* spawn or rear in the basin is poorly understood. Because of these factors, use of the Santa Clara River and its tributaries is an existing data gap, and this analysis does not explore changes in aquatic ecosystem health.

6.2 Biological Data

Tracking the health of all components of groundwater dependent ecosystems through time would involve systematic tracking of populations through time and accounting for changes in driving variables such as floods, climate, and other stressors on populations. This section focuses on changes in vegetation through time using remote sensing data. While increases or decreases in vegetation health do not provide a definitive indication that other components of the ecosystem are thriving or under stress, it provides a reasonable first-order check on the clear linkage between groundwater and the other communities that compose the ecosystem. Previous work has shown that decreases in vegetation vigor are correlated to decreases in remote sensing metrics such as NDVI (e.g., Huntington et al. 2015) and that decreases in vegetation health often correlate with decreases in overall ecosystem health. Tracking the change in NDVI and NDMI for individual polygons shows how the greenness of those polygons changes through time. It is crucial to remember that the Santa Clara River and its tributaries in the Fillmore and Piru groundwater basins are dynamic braided rivers that shift through time. This shifting uproots vegetation and creates new surfaces upon which seedlings can establish. Following floods, the proximity to the river channel (and hence distance to surface water and associated groundwater) as well as the relative elevation (which relates to depth to groundwater) of a given vegetation polygon may change. It is therefore useful to average changes over the different GDE units to account for these changes.

To assess potential groundwater thresholds for vegetation health, we compared the average summer NDVI in each GDE unit to depth to water at corresponding monitoring wells. For each vegetation polygon within a GDE unit, the average NDVI for each year was downloaded from the GDE Pulse tool (TNC2021). This tool calculates the mean summer NDVI for each mapped vegetation polygon based on NDVI values from Landsat imagery from July 9 to September 7 (Klausmeyer et al. 2019). The annual average NDVI for each GDE unit was then calculated as the area-weighted mean of the vegetated polygons. These data are used to assess both NDVI trends through time as well as to compare NDVI data with groundwater depth changes.

For each GDE unit, the representative groundwater elevation for comparison with NDVI data was determined for the wells in Table 4.1-1. We used the depth to water measurement for the well in

Section 4.1 on the closest date to August 8 (the median of the date of the summer NDVI data), for measurements taken from June 24 to September 22, a period of three months. If no groundwater data were available during this period, the water depth was not included in the analysis.

Because the NDVI analysis above does not account for changes in the extent of groundwater dependent vegetation during the 2012–2016 drought, we also analyzed the change in summer NDVI over the entire GDE unit and adjacent area from 2011–2020. For this analysis linear regression was used to fit a line to the data to track changes in NDVI through time to identify areas of NDVI decline and areas where NDVI increased using code provided by Zach Nelson of the Inyo County Water Department on Google Earth Engine.

NDVI is not a useful tool to track changes in interconnected surface water and the effect of these changes on the aquatic ecosystems. While Figure 4.3-1 shows changes to the magnitude and extent of rising groundwater through the recent drought and subsequent recovery, the effect of these changes on the aquatic ecosystem is difficult to quantify because of a paucity of species data and a lack of data on changes in surface water flows in various tributaries.

6.2.1 Piru Groundwater Basin

Del Valle

The mean NDVI and NDMI for the Del Valle GDE Unit from 1985–2018 were 0.41 and 0.08, respectively. The Del Valle GDE Unit had relatively steady NDVI values, with drops during the early 1990s drought, the 2005 flood, and after 2015. The NDVI values were lower than the other forested riparian complexes (e.g., the East Grove and Cienega GDE units), but the declines during the drought were much less severe than for the Cienega GDE unit. Mean NDMI has declined slowly since 1995, but the overall change was relatively small. This site has experienced extensive changes in vegetation in response to floods, as visible from comparison of aerial photographs. The Santa Clara River in this GDE unit has a highly dynamic braided channel that is subject to extensive erosion and deposition, even during smaller floods, which uprooted vegetation at the site. There is no evidence that the decline in NDVI (which is very small) was due to changes in groundwater elevation (Figure 6.2-1), and NDVI changes may be due to vegetation uprooting due to floods or other factors.

From 2011–2020, NDVI increased as indicated by the slope of a best-fit line to NDVI values through time (Figure 6.2-2). Using the slope of NDVI through time limits the importance of individual years and gives a more representative picture of NDVI changes. For the Del Valle GDE Unit, NDVI increased from 2011–2020 in the upstream sections of the riparian complex and decreased at the downstream end, likely due to decreased extent of rising groundwater during the drought.

There is no apparent correlation between NDVI at Del Valle and depth to water at Well 04N18W27B025 (Figure 6.2-3). The highest NDVI values, between 0.45 and 0.50, occur at a wide range of depth to water values, from 30 ft bgs to 108 ft bgs.

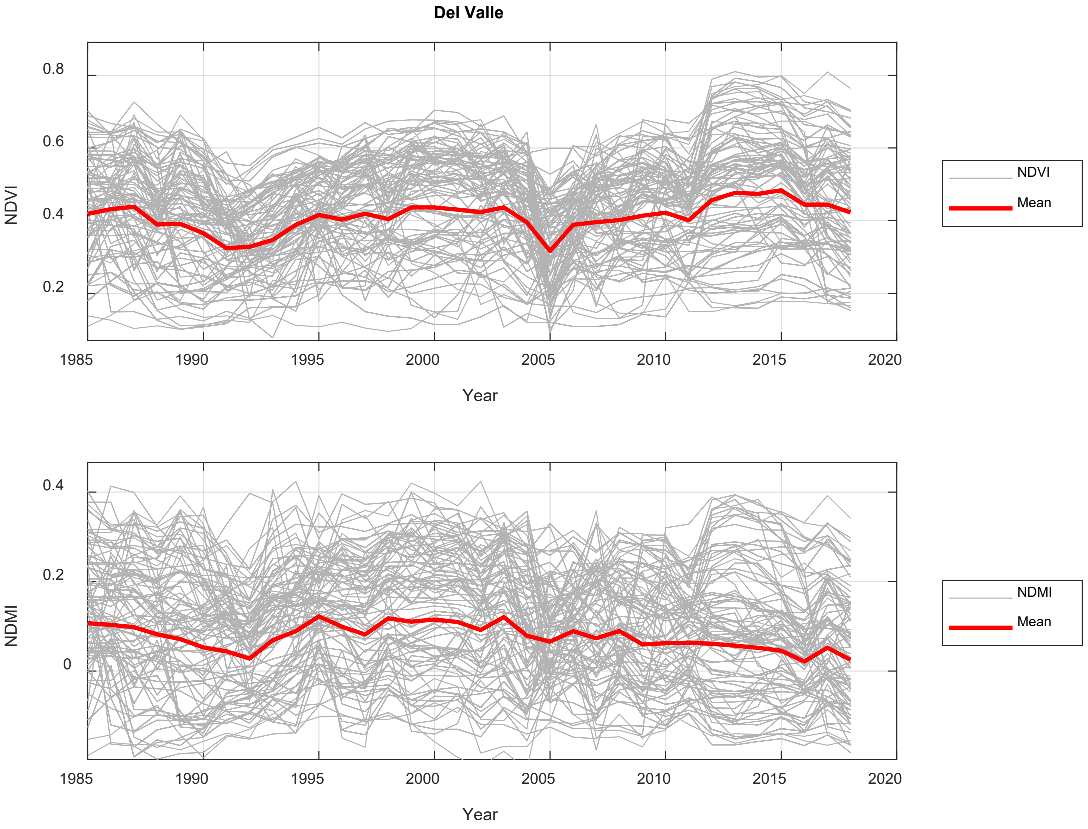

Figure 6.2-1. NDVI and NDMI for the Del Valle GDE Unit in the Piru Groundwater Basin. Gray lines track individual vegetation polygons.

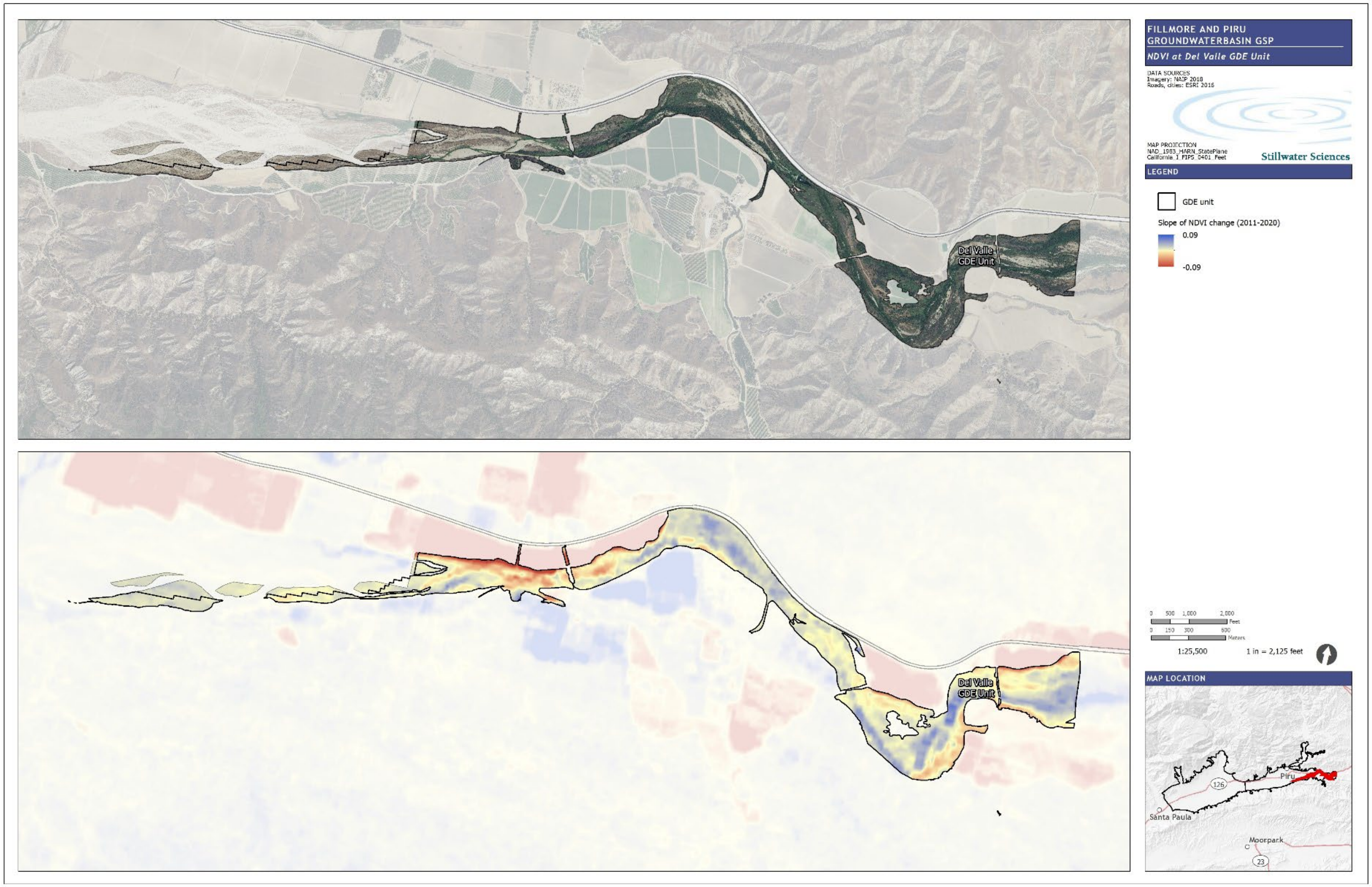

Figure 6.2-2. Slope of NDVI changes from 2011–2020 for the Del Valle GDE Unit. Blue represents increases in NDVI while red represents decreases in NDVI.

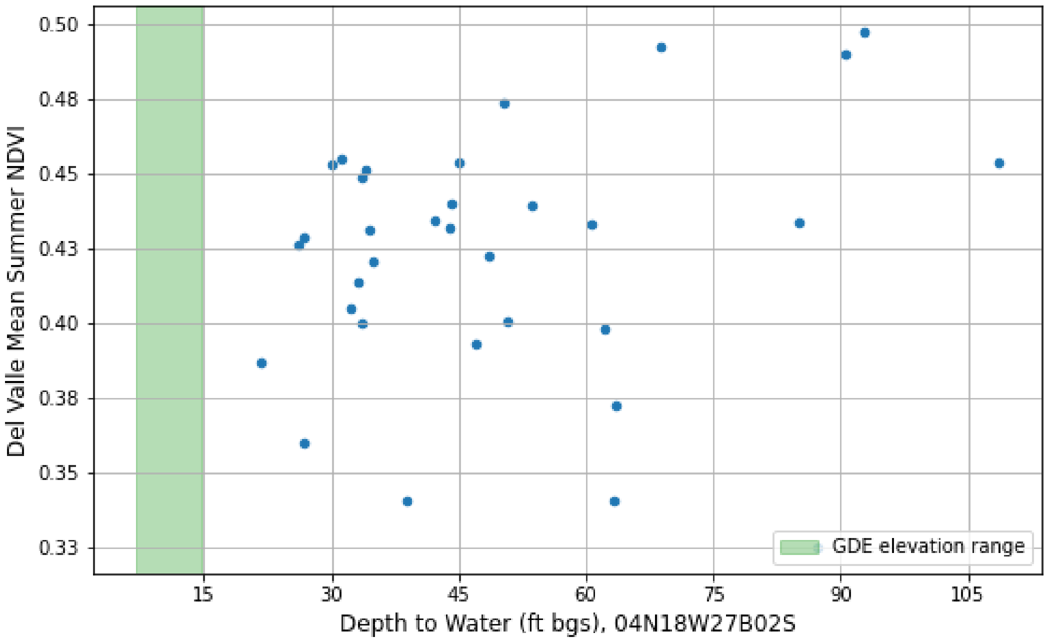

Figure 6.2-3. Mean Summer NDVI in the Del Valle GDE unit versus depth to water at Well 04N18W27B02S. Depth to water data selection method is outlined in Section 5.2.

Piru Basin Santa Clara River Riparian Shrub

The mean NDVI and NDMI for the Santa Clara River Riparian Complex in the Piru Groundwater Basin from 1985–2018 were 0.21 and -0.11, respectively (Figure 6.2-4). These values are relatively low compared to other GDE units in the Fillmore and Piru groundwater basins. The NDVI and NDMI peaked in 1995, 2006, and 2011, following relatively wet years, and declined back to background levels between these peaks. There is no long-term trend in either NDVI or NDMI for this GDE unit (Figure 6.2-4).

The highest NDVI values (>0.26) in the Santa Clara River (Piru Basin) unit typically occur when depth to water in Well 04N19W34K01S is less than 14 ft bgs, within 1 foot of the lowest potential GDEs (Figure 6.2-5).

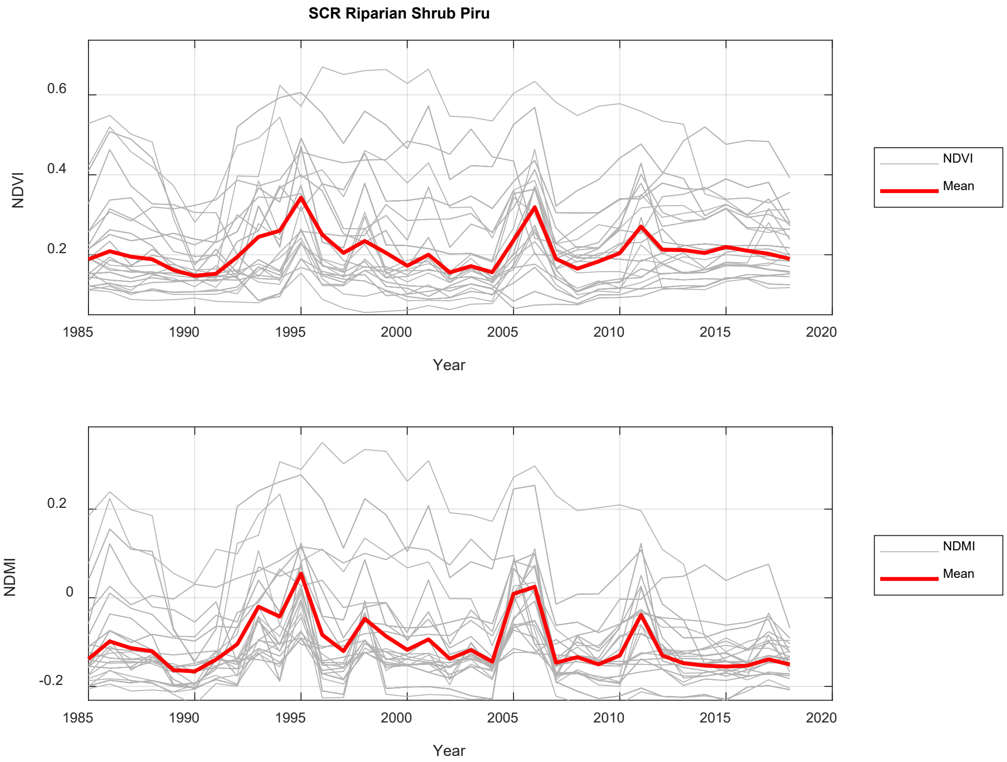

Figure 6.2-4. NDVI and NDMI for the Santa Clara River Riparian Shrub GDE Unit in the Piru Groundwater Basin.

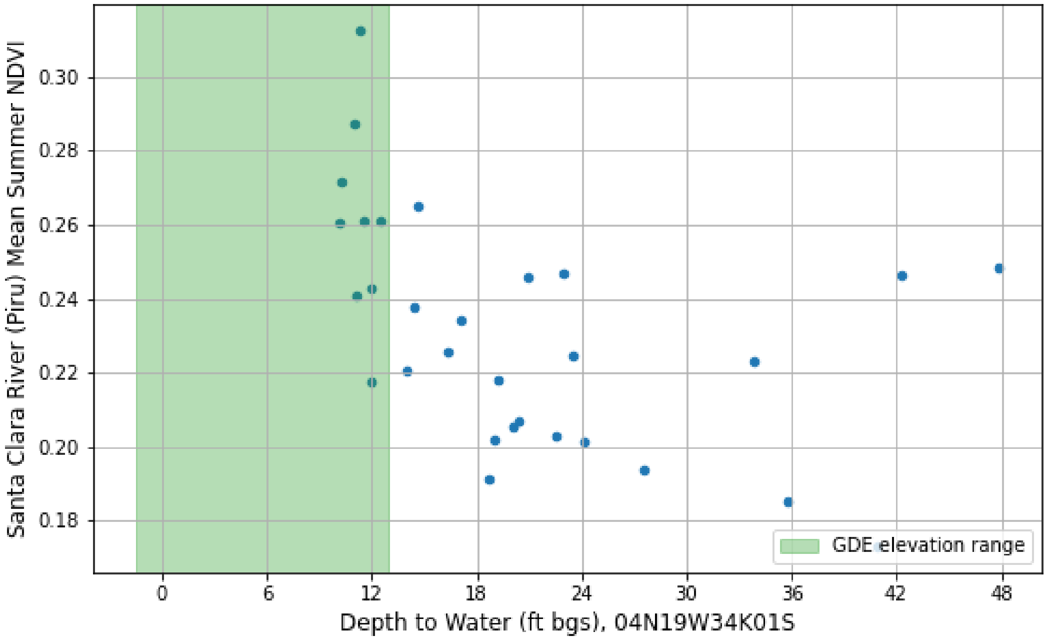

Figure 6.2-5. Mean Summer NDVI in the Piru Basin Santa Clara River GDE unit versus depth to water at Well 04N19W34K01S. Depth to water data selection method is outlined in Section 5.2.

Piru Creek Riparian GDE Unit

The mean NDVI and NDMI for the Piru Creek Riparian GDE from 1985–2018 were 0.36 and -0.026, respectively. NDVI values have been relatively steady, with a small decrease in 1996 and a gradual increase starting in 2006 through 2018 (Figure 6.2-6). There was only a small decline in NDVI during the 2012–2016 drought.

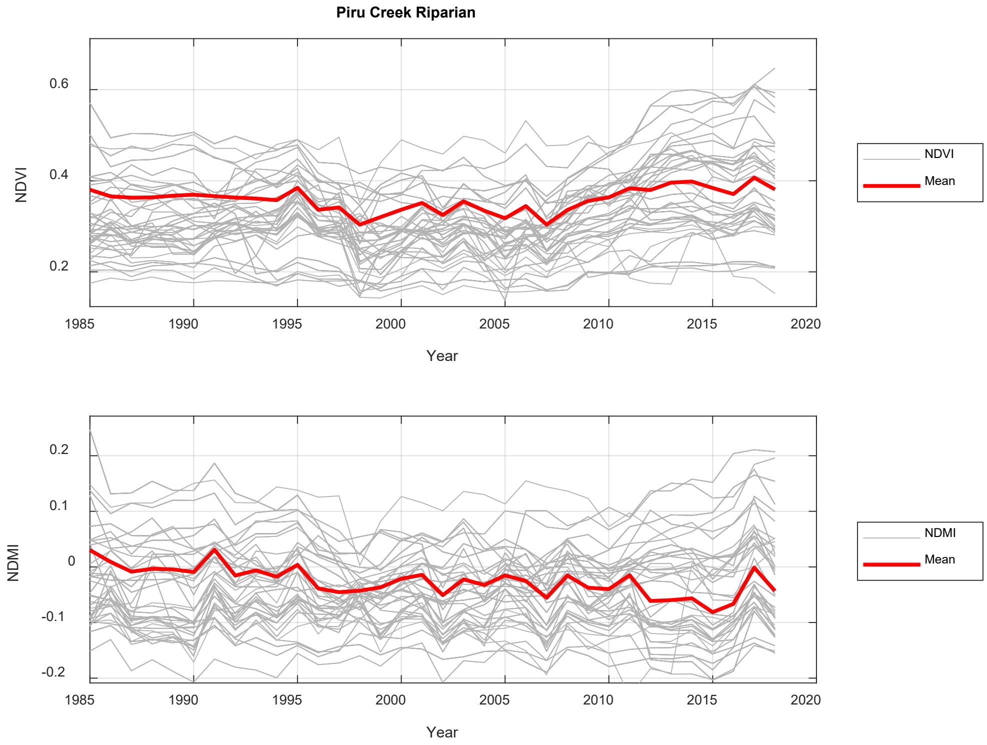

Figure 6.2-6. NDVI and NDMI for the Piru Creek Riparian GDE Unit.

Piru Basin Tributary Riparian GDE

The mean NDVI and NDMI for the Tributary Riparian GDE Unit in the Piru Groundwater Basin from 1985–2018 were 0.30 and -0.07, respectively. The NDVI was relatively steady from 1989–2007 before increasing in 2008 and remaining relatively steady through 2018 (Figure 6.2-7). NDVI was relatively steady during the 1989–1991 and 2012–2016 droughts. Drops in NDVI occurred in 1996 and 2002, but were small compared to changes in other GDE units. NDMI varied more than NDVI from 1989–2007, and had a similar increase in 2008, but declined from 2010–2018 to the mean value over the period of record.

Figure 6.2-7. NDVI and NDMI for the Piru Basin Tributary Riparian GDE Unit.

6.2.2 Fillmore Groundwater Basin

Fillmore Basin Santa Clara River Riparian Shrub

The mean NDVI and NDMI for the Santa Clara River Riparian Shrub GDE in the Fillmore Groundwater Basin from 1985–2018 were 0.29 and -0.046, respectively (Figure 6.2-8). The Santa Clara River Riparian Shrubland in the Fillmore Groundwater Basin has relatively low NDVI values typical of low-density vegetation in the GDE. The NDVI varies over 2- to 5-year cycles (Figure 6.2-8). The NDVI and NDMI values declined during the early 1990s and the 2012–2016 drought. NDVI and NDMI have not recovered from the most recent drought (Figure 6.2-8).

There is no apparent correlation between NDVI in the Santa Clara River Riparian Shrub (Fillmore Basin) unit and depth to water at Well 03N20W03N01S (Figure 6.2-9). NDVI declined when groundwater was lower, but there is considerable scatter. Summer depth to water data typically fall in a narrow range, between eight and 13 ft bgs.

Figure 6.2-8. NDVI and NDMI for the Santa Clara River Riparian Shrub GDE Unit in the Fillmore Groundwater Basin.

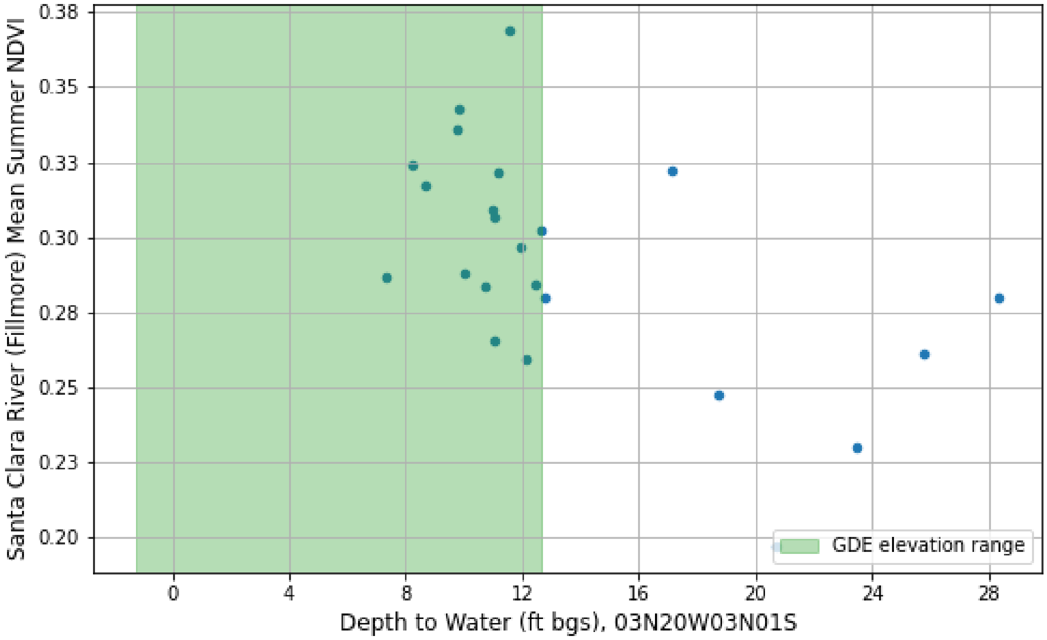

Figure 6.2-9. Mean Summer NDVI in the Fillmore Basin Santa Clara River GDE unit versus depth to water at Well 03N20W03N01S. Depth to water data selection method is outlined in Section 5.2.

Cienega

The NDVI analysis of the Cienega GDE Unit focuses on the Fillmore Basin where most of the mapped GDEs occur. The mean NDVI and NDMI values for the Cienega GDE Unit from 1985–2018 were 0.48 and 0.12, respectively. The mean NDVI in the Cienega GDE Unit was relatively consistent between 1995 and 2014 (Figure 6.2-10) but dropped by about half during the 1989–1991 and 2012–2016 droughts (Figure 6.2-10). Following the early 1990s drought, the NDVI recovered to its pre-drought value within two to three years. A similar recovery did not occur following the 2012– 2016 drought, and field observation confirms that much of the willow and cottonwood forest died during the drought (Figure 6.2-11). The 2005 flood was the only major flood during this period and resulted in a short-term increase in NDVI, likely because the wet water year supported extensive vegetation growth and new surfaces were rapidly colonized.

NDMI values declined slightly from 1995–2014 and had similar drops during the early 1990s and 2012–2016 droughts. The reason for the decline in NDMI from 1995–2014 is not known. A similar drop in vegetated health using a different remote sensing technique was observed by Kibler et al. (2019). Anecdotal evidence suggests that some of the arundo stands are recovering following the drought, but much of the willow and cottonwood forest in the GDE died during the drought.

The highest NDVI values (>0.4) in the Cienega (Fillmore Basin) unit are clustered between depth to water values of -1 and 5 ft bgs, within the elevation range of GDEs (Figure 6.2-12). When groundwater depth declines to 6-8 ft bgs, NDVI declines to below 0.40.

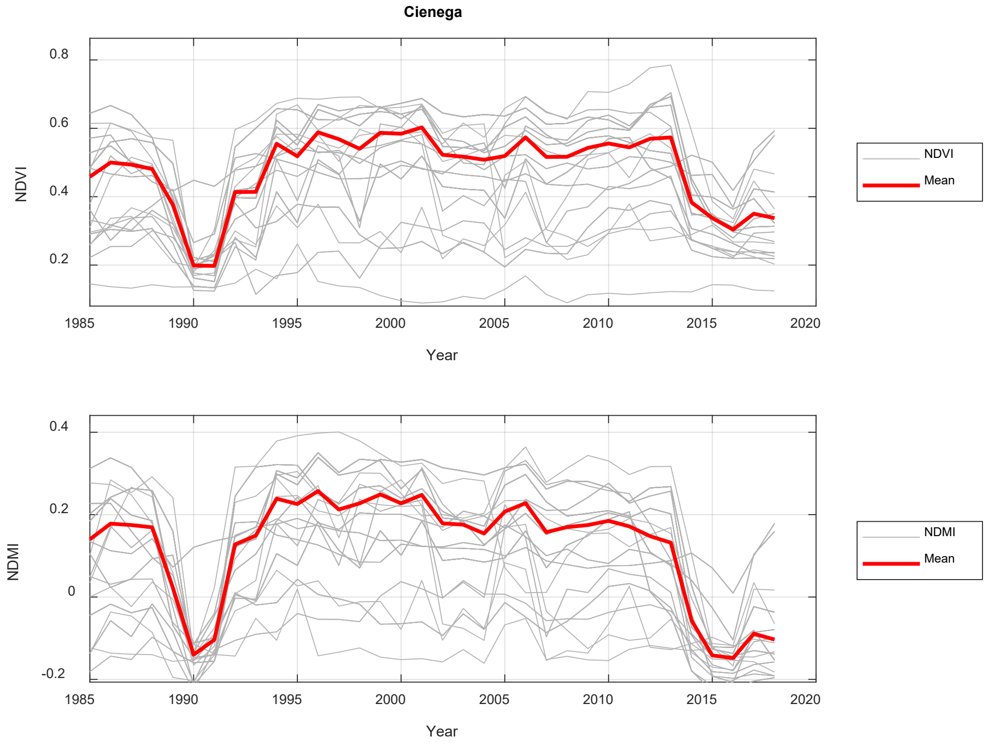

Figure 6.2-10. NDVI and NDMI for the Cienega GDE Unit.

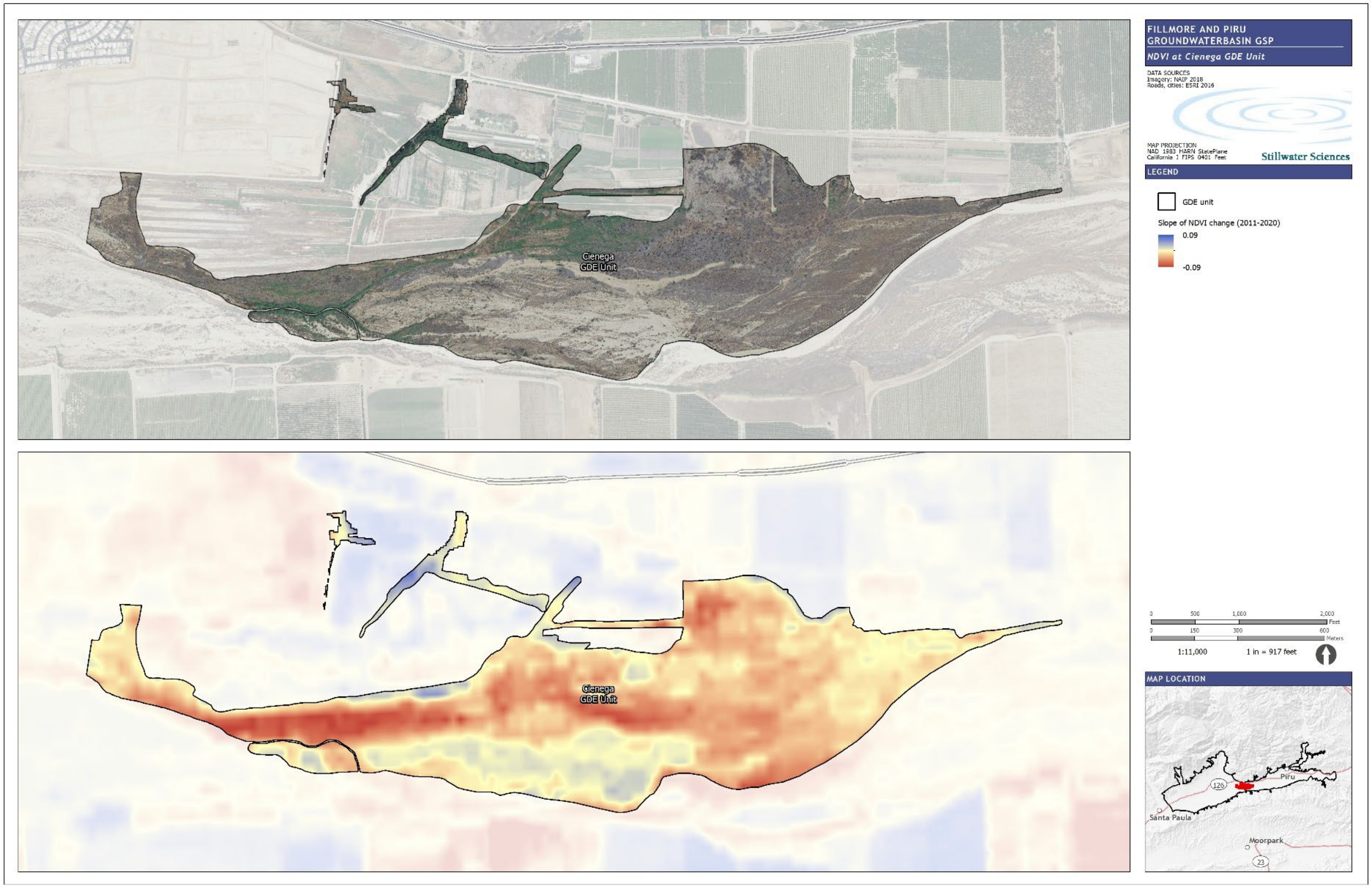

Figure 6.2-11. Slope of NDVI change in the Cienega GDE Unit in the Fillmore and Piru Basins from 2011–2020. Red areas have declining NDVI and blue areas have increasing NDVI.

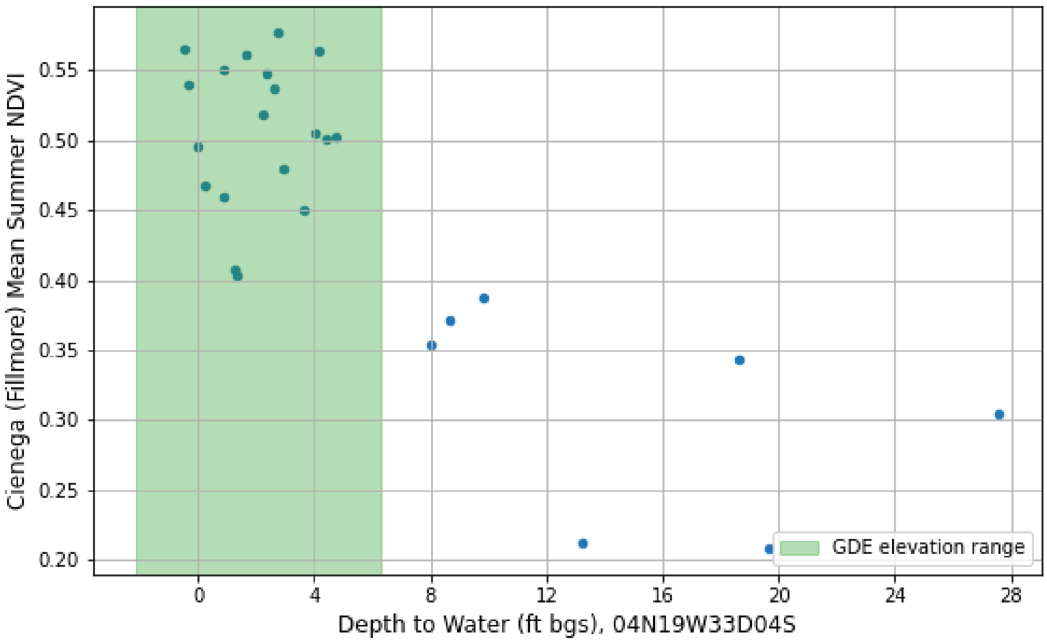

Figure 6.2-12. Mean Summer NDVI in the Fillmore Basin Cienega GDE unit versus depth to water at Well 04N19W33D04S. Depth to water data selection method is outlined in Section 5.2.

East Grove

The mean NDVI and NDMI for the East Grove GDE Unit from 1985–2018 were 0.52 and 0.16, respectively. NDVI values for the East Grove Riparian Complex were relatively steady through about 1997, with a small drop following the early 1990s drought (Figure 6.2-13).

Starting around 1998, the NDVI steadily increased until declining in 2013. There was a slight increase in NDVI following the 2005 flood. Mean NDMI was relatively constant until increasing in 2005. NDMI declined more than NDVI during the 2012–2016 drought (Figure 6.2-13).

Between 2011 and 2020, the slope of the NDVI through time was positive (i.e., NDVI increased), with decreases where the channel shifted (Figure 6.2-14). Decreases in NDVI occurred at the upstream portion of the East Grove GDE Unit, reflecting a change in the flow path of the Santa Clara River as well as a decline in vegetation health on the southeast portion of the GDE. In comparison with the Cienega GDE Unit, the increasing NDVI in the East Grove GDE Unit suggests that groundwater levels did not drop below the rooting zone of the riparian complex and hence the GDE was much more resilient.

There is no apparent correlation between NDVI at East Grove and depth to water at Well 03N20W09D01S (Figure 6.2-15).

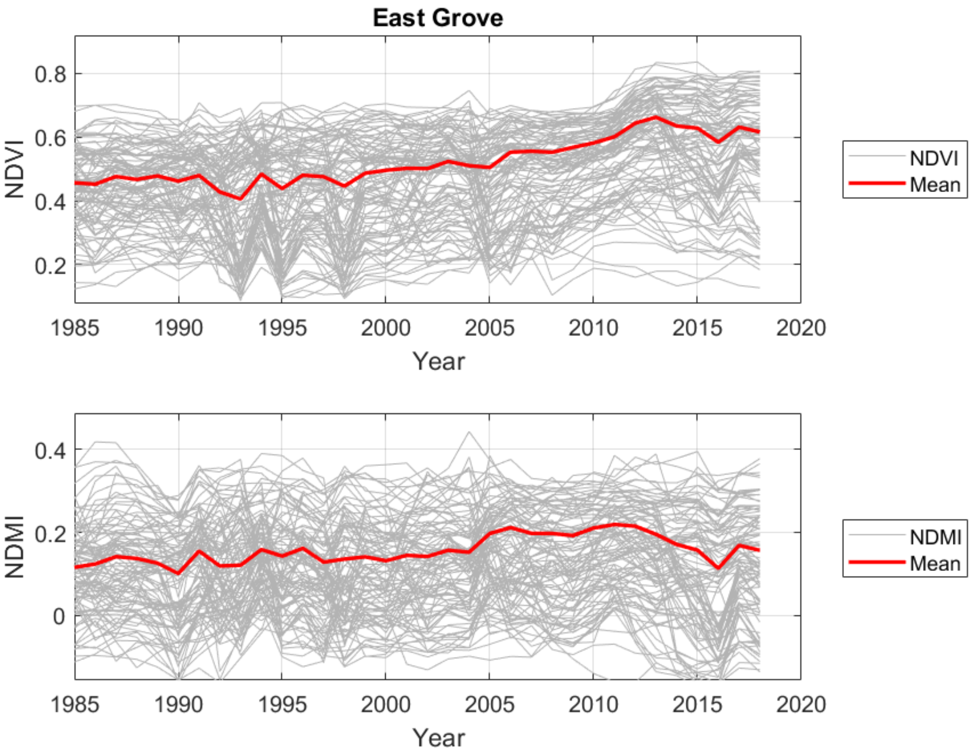

Figure 6.2-13. NDVI and NDMI for the East Grove GDE Unit.

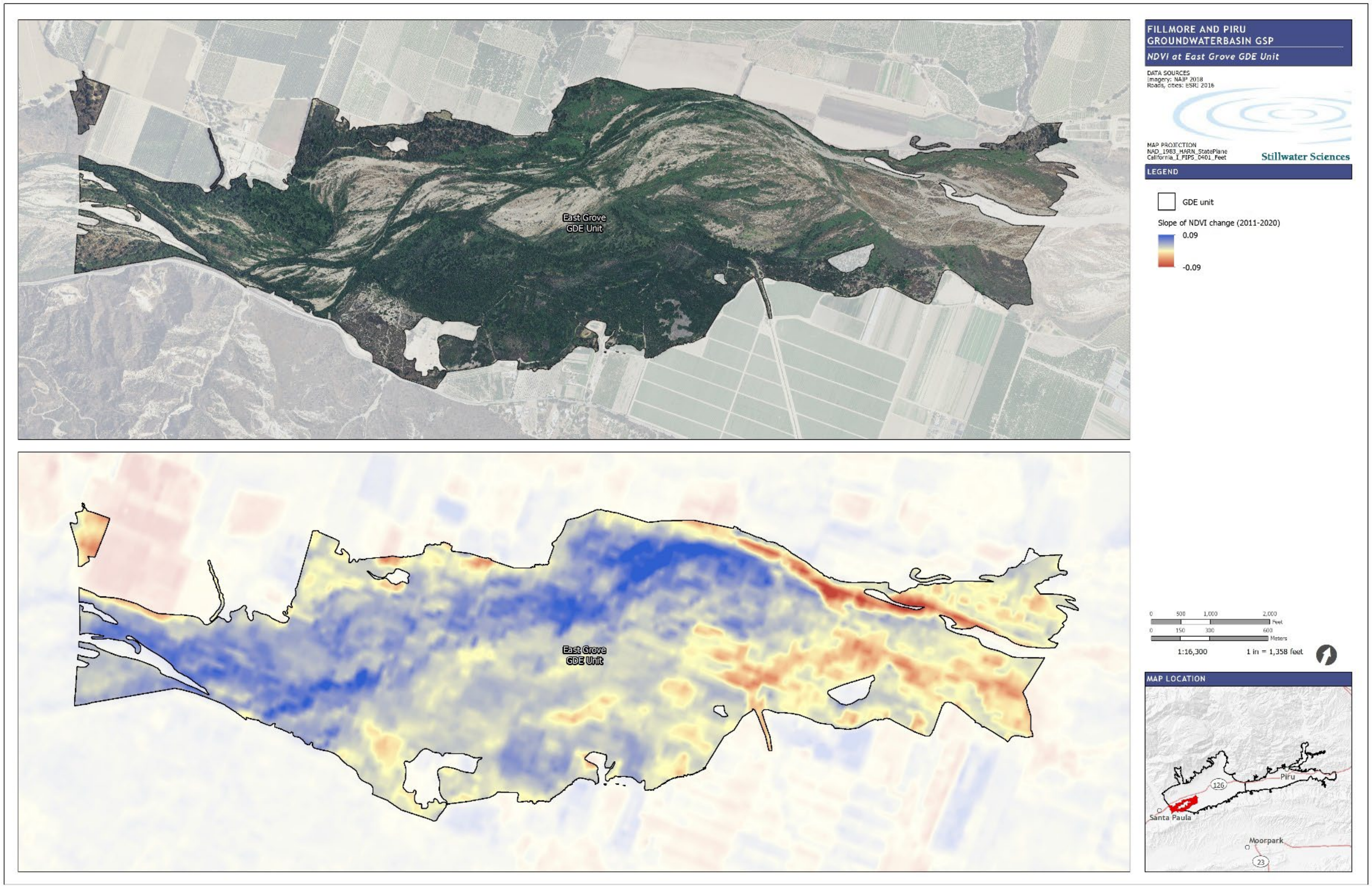

Figure 6.2-14. Slope of NDVI change in the East Grove GDE Unit in the Fillmore Basin from 2011-2020. Red areas have declining NDVI and blue areas have increasing NDVI.

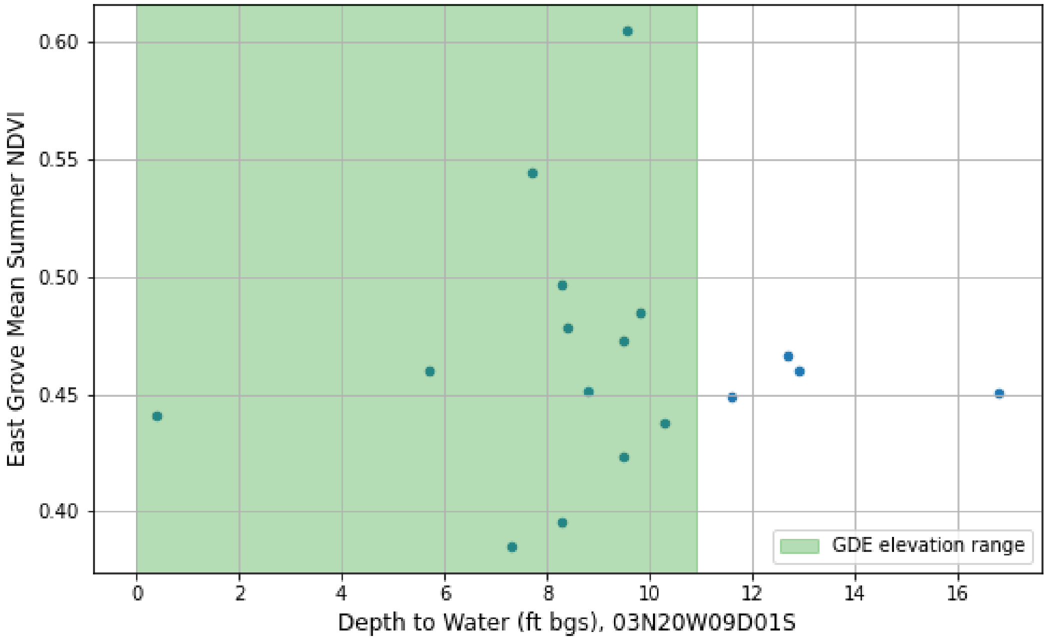

Figure 6.2-15. Mean Summer NDVI in the East Grove GDE unit versus depth to water at Well 03N20W09D01S. Depth to water data selection method is outlined in Section 5.2.

Fillmore Basin Tributary Riparian GDE Unit

The mean NDVI and NDMI for the Tributary Riparian GDE in the Fillmore Groundwater Basin from 1985–2018 were 0.50 and 0.058, respectively (Figure 6.2-16). The NDVI was relatively steady through the 1989–1991 drought and through 2017 before dropping in 2018, likely due to vegetation mortality due to the Thomas Fire. Short-term drops in NDVI occurred in 1996 and 2002, but were small compared to changes in other GDE units. NDMI declined in 2012 at the start of the 2012–2016 drought and has remained below the mean. In 2018 the NDMI further declined due to the Thomas Fire (Figure 6.2-16).

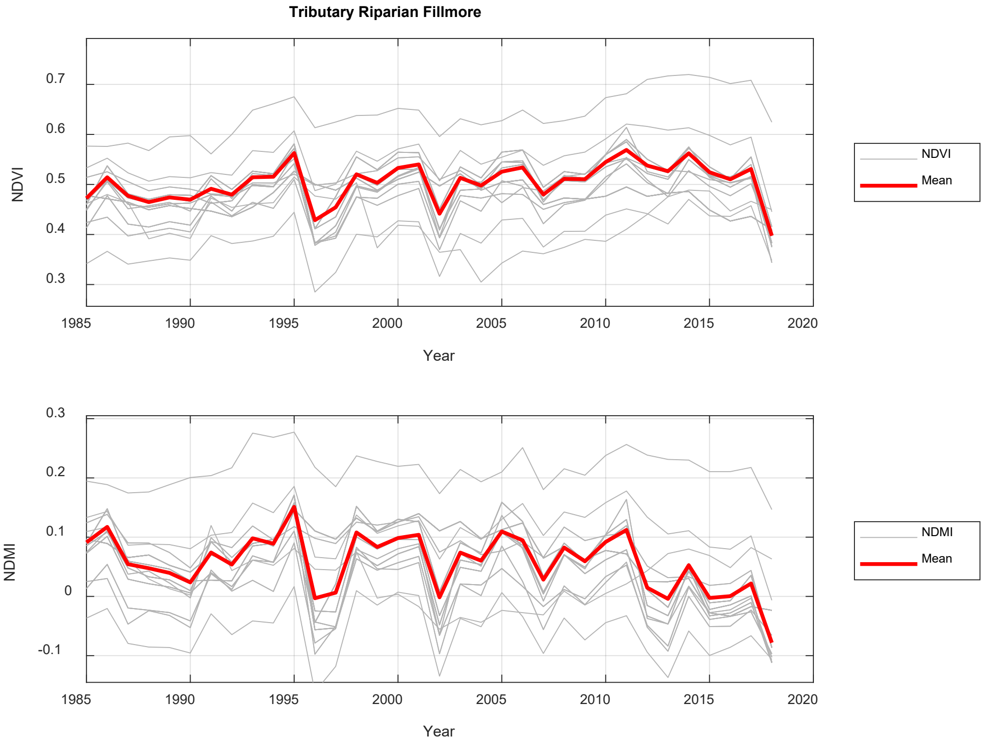

Figure 6.2-16. NDVI and NDMI for the Fillmore Basin Tributary Riparian GDE Unit.

Sespe Creek Riparian

The mean NDVI and NDMI for the Sespe Creek Riparian from 1985–2018 were 0.39 and 0.084, respectively. The Sespe Creek Riparian GDE has relatively steady intermediate NDVI of 0.3–0.4 prior to 2005, at which point NDVI dropped (Figure 6.2-17) as a result of the flood. Following the 2005 flood, NDVI gradually increased, as would be expected if the riparian forest were recovering following the flood. NDVI dropped from 2015–2018 (Figure 6.2-17). NDMI has been relatively consistent through time (Figure 6.2-17).

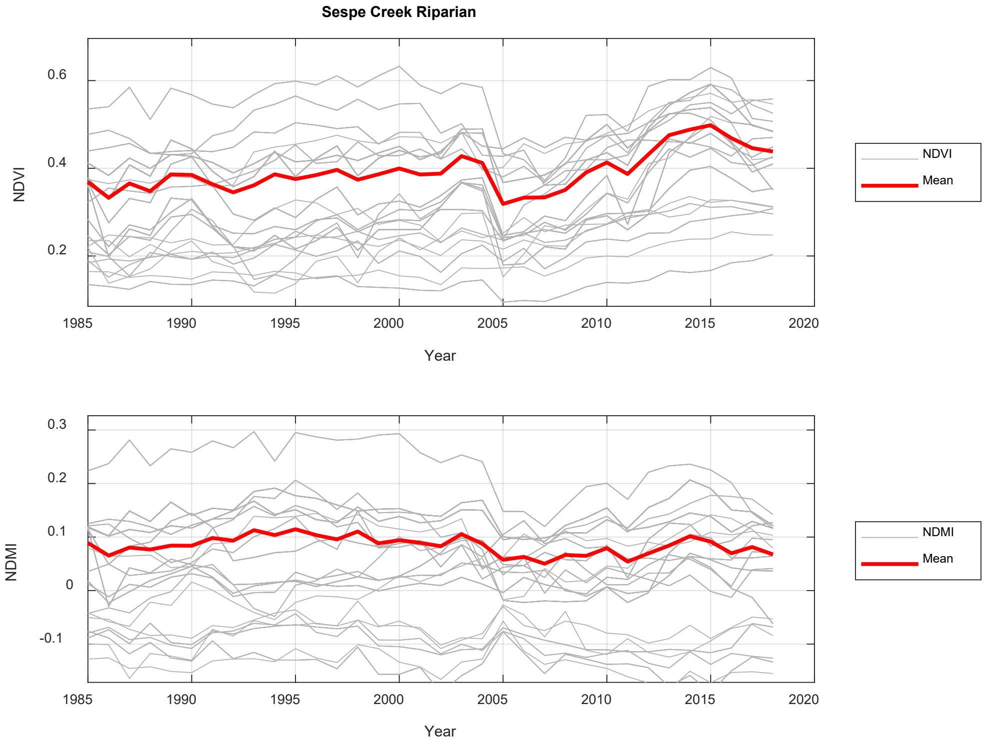

Figure 6.2-17. NDVI and NDMI for the Sespe Creek Riparian GDE Unit.

6.2.3 Summary of NDVI analysis

None of the GDE units showed a long-term decline in NDVI or NDMI, but some of the units had declines in NDVI and NDMI following floods and droughts. The largest declines in NDVI occurred following the 2012–2016 drought, where declines in vegetation health occurred in the Cienega, East Grove, and the Fillmore Basin Santa Clara River Riparian Shrubland. The largest declines in NDVI and NDMI were in the Cienega GDE unit where extensive die off of vegetation occurred during the drought and the area has yet to recover. NDVI was relatively constant through time in the Tributary Riparian GDE unit in the Fillmore and Piru Basins (outside of the effects of the Thomas Fire), and the Santa Clara River Riparian Shrubland in the Piru Basin. As expected NDVI dropped for many of the GDE units in 2005 following the 2005 flood which reworked large portions of the floodplain and uprooted vegetation.

6.3 Climate Change Effects

The effects of climate change on groundwater and interconnected surface water are discussed in DBS&A (2021). As an overview, the future groundwater levels forecast with assumed climate change factors (2070CF [climate change factor]) are not materially different from those recorded during the historical record (See GSP). The groundwater basin will continue to fill during wet years and decline during droughts. More frequent or severe droughts than those predicted by the model could affect groundwater levels and vegetation health. There is no suggestion of long-term chronic declines in groundwater levels, and models suggest that groundwater pumping has a small effect on rising groundwater flow.

Low water levels associated with major droughts (and accounting for future climate) are lower (typically 10–30 ft) than those of the historical time period (i.e., without the effects of climate change). Despite the lower, drought-induced water levels, the water levels return to historical high water level conditions during subsequent wet to normal precipitation periods. Statewide climate models suggest that there could be an increase in the duration, severity, and frequency of droughts and extreme floods through the remainder of 21st century (Swain et al. 2018) that could impact groundwater availability to GDEs but may also increase the frequency of flood events that are crucial for regrowth of the pioneer species that make up the GDEs along the Santa Clara River.

Climate change may alter the water demands of groundwater dependent vegetation, but the response is complex because decreased transpiration associated with increased carbon dioxide in the atmosphere may counter increased evaporation due to temperature increases (e.g., Klove et al. 2014). Monitoring of vegetation health (via NDVI) and components of the water balance in the Fillmore and Piru Basins (including rising groundwater) is therefore crucial for assessing the impacts of climate change.

6.4 Summary of Potential Effects

Potential effects on each GDE unit are summarized here based on four primary criteria:

1. The groundwater dependence of each unit (likely, uncertain, unlikely) based on hydrologic information and links with vegetation or interconnected surface water.
2. Ecological value (high, moderate, low), as described in Section 4.4.
3. Ecological condition of the GDEs within each unit (good, fair, poor), based on the information summarized in Section 4.1 and the NDVI/NDMI data presented in Section 5.2.
4. Susceptibility to changing groundwater conditions (high, moderate, low) based on available hydrologic data, climate change projections, and the GDE susceptibility classifications summarized in Table 6.1-1.

6.4.1 Piru

Del Valle GDE Unit

Groundwater Dependence: **Likely**

- Shallow groundwater measurements are rare in this unit but the historical persistence of the riparian forest and widespread willows and cottonwoods suggest that groundwater is likely within the rooting zone of plants.
- This GDE unit is a mixture of willows and cottonwoods that are likely connected to groundwater and facultative phreatophytes (e.g., mulefat and arrow-weed thickets) that may be connected to groundwater.
- Perennial surface water flows are likely connected with groundwater.

Ecological Value: **High**

- The Del Valle GDE Unit supports a relatively large number of special-status species and ecological communities, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for two federally listed species.

- The unit supports species and ecological communities that are vulnerable to changes in groundwater levels.

Ecological Condition: **Good**

- NDVI/ NDMI from 1985–2018 was relatively constant until a flood-related reduction in NDVI in 2005, followed by a gradual recovery until 2015, at which point NDVI began a gradual decline. As of 2018, NDVI had not declined below the long-term average. NDMI has declined slowly since 1995 and in 2018 was below the long-term average. These trends suggest that the structure and function of riparian vegetation in the unit may have experienced declines during the drought, particularly at the unit's downstream end. Although groundwater levels are relatively stable, and this reach receives wastewater effluent from upstream, the limited well data in this GDE unit are insufficient to determine whether groundwater pumping has contributed to the observed declining vegetation condition at the downstream end of the unit.
- Habitat suitability in the downstream portion of the unit may be somewhat compromised by the decline in vegetation condition for special-status species that rely on vegetation (e.g., riparian birds).
- Groundwater contributes to the ecological function and habitat value of the Santa Clara River, which supports native aquatic and semi-aquatic species and beneficial uses in and adjacent to the unit.

Susceptibility to Changing Groundwater Conditions: **Moderate**

- Shallow groundwater conditions in the unit since the 1930s have fluctuated considerably in response to drought and possibly other factors. An 80-ft decline with the 2012–2016 drought has been followed by a slow recovery, and by spring 2020 groundwater depth was again within the baseline range for non-drought conditions. The groundwater well is at the downstream end of the unit and therefore may not reflect groundwater elevation changes further upstream.
- Rooting depths of willows and cottonwoods in this unit range up to 6.9 ft while the average relative elevation is 10 ft for cottonwoods and 5.6 ft for red willow. The mulefat thickets are not likely connected to groundwater.
- The decline in groundwater at the downstream end of the unit exceeded the rooting depth of the vegetation. Groundwater declines in the rest of the unit were likely less based on the vegetation response to the drought, but there are no well data further upstream.
- Future changes in groundwater conditions in the unit related to increased groundwater pumping, declining effluent releases from upstream, or climate change could cause groundwater levels to fall below the baseline range and result in mortality of the trees that comprise the GDE. Projections of climate change and groundwater pumping in the future suggest that changes in groundwater elevation are unlikely.

The unit includes a perennial portion of the mainstem Santa Clara River that is considered an interconnected surface water. The degree to which interconnected surface waters in this reach are maintained by releases from upstream effluent sources is unknown, but is believed to be significant.

Potential for effects

Available data are insufficient to discern a clear effect on GDEs related to groundwater pumping in the Del Valle GDE Unit. Declines in vegetation health (as shown by NDVI decreases) at the downstream end of the reach suggest that GDEs in this unit are susceptible to drought conditions. However, the extent of GDEs in the unit is moderately susceptible to future decrease in groundwater elevation and surface water conditions and the synergistic effects of climate change (described in Section 5.3). In combination these changes could cause groundwater levels to fall below the baseline range and result in mortality of the trees that comprise the GDE and reduce the extent of the GDE. GDEs in this unit are not expected to experience future water levels that are lower than the historical period, but more frequent or longer duration droughts due to climate change could also affect the extent of vegetation-dominated GDEs.

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in the Santa Clara River using remote sensing is recommended and is further discussed in Section 6. Changes to upstream effluent releases may impact aquatic habitat and groundwater elevation in this GDE unit.

Santa Clara River Riparian Shrubland GDE Unit

Groundwater Dependence: **Possible**

- There are few shallow groundwater measurements in this unit. Spring 2019 water contours provided by United Water showed groundwater levels within 5–10 feet of the ground surface in parts of the unit.
- This GDE unit includes a large polygon of giant reed (arundo) at the downstream end of Piru Groundwater Basin, with patches of sandbar willows and large mulefat thickets. Given the shallow rooting depth of mulefat thickets (approximately 2 ft), they likely are connected to groundwater at shallower relative elevations, particularly near the downstream end of the GDE, where groundwater is closer to the surface. Other vegetation communities in the unit may be connected to groundwater. Small patches of sandbar willows are present in this unit and have average relative elevations in the Santa Clara River of 4.8 ft and the relative elevation ranges up to 9 ft (Appendix C).
- Intermittent surface water flows are not connected with groundwater.

Ecological Value: **Moderate**

- The Santa Clara River Riparian Shrubland GDE Unit supports a moderate number of special-status species and ecological communities, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for two federally listed species.
- This naturally intermittent reach supports regionally rare alluvial scrub habitat.
- The unit supports species and ecological communities that are somewhat vulnerable to changes in groundwater levels. Although the Santa Clara River in the unit provides migration habitat for southern California steelhead, the migration habitat has low vulnerability to groundwater reduction because most fish migration occurs during seasonal high surface water flow periods.

Ecological Condition: **Fair**

- NDVI/ NDMI values in the unit from 1985–2018 are low compared to other GDE units in the Fillmore and Piru groundwater basins, reflecting the relatively sparse vegetation. Mean NDVI and NDMI during this period increased in response to wet years and returned to long-term average values between the peaks. Mean NDVI or NDMI values in the unit do not appear responsive to drought. There is no evidence that groundwater pumping affects the ecological condition of this GDE unit.

- Current habitat suitability for those special-status species with likelihood to occur in the unit may have declined relative to historical conditions.
- Groundwater provides little or no contribution to the ecological function and habitat value of the Santa Clara River in the unit, which is intermittent and mainly supports seasonal migration habitat for anadromous fishes.

Susceptibility to Changing Groundwater Conditions: **Low**

- Shallow groundwater conditions in the unit since the 1970s have fluctuated in response to drought, with sharp drops followed by recovery to pre-drought levels. As of fall 2019, the shallow groundwater level recorded in the unit had apparently recovered from the large drop associated with the 2012–2016 drought and was again within the baseline range. So long as the duration and frequency of droughts does not change, the effects on this GDE unit are expected to be minimal. The sandbar willows and eucalyptus occur on the margin of the unit adjacent to agricultural lands and may subsist on agricultural runoff.
- Future changes in groundwater conditions in the unit related to increased groundwater production or climate change are not expected to cause groundwater levels to fall below the baseline range. As a result the potential effects on GDEs are deemed negligible.
- The unit includes an intermittent reach of the mainstem Santa Clara River that does not provide perennial aquatic habitat or beneficial uses.

Potential for effects
Modeling suggests that groundwater levels are likely to be stable in this reach. Moreover, the vegetation that makes up this unit may use groundwater when groundwater levels are high in the spring, but high groundwater levels are likely not persistent in this unit. The unit is therefore likely not strongly dependent upon groundwater and is comprised of sparse low water use species with relatively shallow rooting depths. Therefore, the potential for effects on this unit is low.

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in the Santa Clara River using remote sensing is recommended and is further discussed in Section 6.

Cienega GDE Unit

Groundwater Dependence: **Certain**

- Rising groundwater in this unit provides surface flows and keeps groundwater within the rooting zone (5–15 ft) of the vegetation.

Ecological Value: **High**

- The Cienega GDE Unit supports a moderate number of special-status species, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for two federally listed species.
- The unit supports species and ecological communities that are vulnerable to changes in groundwater levels.

Ecological Condition: **Poor**

- NDVI/ NDMI trends from 1985–2018 indicate vegetation responds mainly to precipitation and runoff (e.g., drought) but a decline in NDMI from 2005–2014 suggests other factors, potentially including groundwater pumping, may influence vegetation condition in the unit. As of 2018 the vegetation structure and functions in the Cienega GDE Unit are no longer intact or within the range of natural variability, due at least in part to vegetation mortality from the 2012–2016 drought. The degree to which groundwater pumping has exacerbated the decline in groundwater elevation during the recent and other droughts is not known.

- Habitat suitability in the unit for special-status species relying on vegetation (e.g., riparian birds) may be compromised by the decline in vegetation condition during droughts.
- Groundwater contributes to the ecological function and habitat value of the Santa Clara River, which supports native aquatic and semi-aquatic species and beneficial uses in and adjacent to the unit.

Susceptibility to Changing Groundwater Conditions: **High**

- Shallow groundwater conditions in the unit since the 1970s have fluctuated in response to drought, with sharp drops followed by recovery within about one year. By 2019–2020, shallow groundwater levels recorded at the single well in the unit were again within the baseline range for the period of record, but the native cottonwoods and willows died during the drought and have not yet recovered. Those species are anticipated to recover once a future flooding event(s) removes the debris and the land surface is better conditioned for repopulation. The recent expansion of arundo in this GDE unit may limit re-establishment of cottonwoods and willows, particularly if groundwater conditions decline below cottonwood and willow rooting depth. The time required for that recovery is unknown.
- Reported maximum rooting depths of willows and cottonwoods in this unit range up to 6.9 ft while the average relative elevation is 10 ft for cottonwoods and 5.6 ft for red willow. The mulefat thickets generally occur at higher relative elevations in this reach and are not likely connected to groundwater.
- Future changes in groundwater conditions in the unit related to increased groundwater production or climate change could cause groundwater levels to fall below the baseline range and result in potential mortality to vegetation that comprises the GDE. Projections of climate change and groundwater pumping in the future suggest that changes in groundwater elevation are unlikely. However, based on widespread tree mortality during the 2012–2016 drought, future changes in the frequency or duration of droughts similar to 2012–2016 could have a deleterious effect on the GDE.
- The unit includes a perennial portion of the mainstem Santa Clara River, which is considered an interconnected surface water.

Potential for effects

Modeling suggests that climate change is unlikely to cause groundwater levels to drop below the baseline range. However, changes to the duration or severity of droughts could impact the health of the GDE through increased tree mortality. Moreover, it is possible that arundo could replace the cottonwood and willow forests that died during the 2012–2016 drought, which would lead to a decrease in habitat for other species (i.e., riparian birds).

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in the Santa Clara River using remote sensing is recommended and is further discussed in Section 6. For this unit, coupling remote sensing and shallow groundwater elevation monitoring, particularly during and following droughts, is recommended.

Piru Creek Riparian GDE Unit

Groundwater Dependence: **Uncertain/Unlikely**

- Groundwater wells in the rooting zone of plants (<30 ft) are rare in this unit.
- Releases from Santa Felicia Dam sustain surface flows.

Ecological Value: **High**

- The Piru Creek Riparian Complex GDE Unit supports a relatively high number of special-status species and ecological communities, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for two federally listed species.
- The unit supports species and ecological communities whose habitat in the unit may be vulnerable to changes in groundwater levels.

Ecological Condition: **Good**

- NDVI/ NDMI from 1985–2018 was relatively constant and seemingly unresponsive to droughts and floods. These trends suggest that the structure and function of riparian vegetation in the unit are relatively intact and within the range of natural variability. Riparian vegetation in the unit may be sustained by releases from Santa Felicia Dam, which likely raise the groundwater level in this area. Available information indicates that adverse impacts are not likely occurring in the unit, at least partially as a result of current surface water releases that provide water to at least the near-channel portions of the GDE Unit even if groundwater is below the rooting depth of most riparian plants.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- Releases from Santa Felicia Dam likely raise groundwater levels and help maintain baseflows over some portion of the length of Piru Creek, thus contributing to the ecological function and habitat value of Piru Creek under current conditions. Piru Creek supports native aquatic and semi-aquatic species and beneficial uses in and adjacent to the unit.

Susceptibility to Changing Groundwater Conditions: **Undetermined, likely low**

- There are no monitoring wells in the unit and shallow groundwater conditions and trends in the unit are therefore unknown.
- Assuming continued releases from Santa Felicia Dam, it is unlikely that future changes in groundwater conditions in the unit related to increased groundwater production or climate change will cause groundwater levels to fall below the baseline range. As a result, the potential effects on GDEs are deemed negligible.
- Piru Creek in this GDE unit currently has perennial flow over most of its length due to releases from Santa Felicia Dam, but surface flow is not connected to groundwater. The lower portion of Piru Creek near the confluence with the Santa Clara River periodically lacks surface flow. As described previously, releases from Santa Felicia Dam likely raise groundwater levels and help maintain baseflows in Piru Creek.

Potential for effects

Available data are insufficient to discern a clear effect on GDEs related to groundwater pumping in the Piru Creek Riparian Complex GDE Unit. However, groundwater levels and baseflows in Piru Creek are likely maintained by releases from Santa Felicia Dam, thus the susceptibility of GDEs in the unit (i.e., vegetation mortality) to future changes in groundwater conditions and the synergistic effects of climate change is low. With continued dam releases, the potential for these combined effects to cause groundwater levels to fall below the baseline range and result in potential effects on GDEs is low.

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in Piru Creek using remote sensing is recommended and is further discussed in Section 6. Coupling remote sensing with a shallow groundwater monitoring well would help to assess the degree to which groundwater dynamics affect GDEs in this unit. In this GDE unit, changes to releases from Santa Felicia Dam may affect aquatic habitat and groundwater elevation.

Tributary Riparian GDE Unit

Groundwater Dependence: **Unlikely**

- There are no shallow groundwater measurements in this unit. Based on the position in the landscape, a connection to the regional aquifer is unlikely.
- This GDE unit contains a mixture of obligate and facultative phreatophytes that may be connected to groundwater (unlikely) or surviving on episodic surface water flows.
- Intermittent and ephemeral surface water flows are not connected with groundwater. Hopper Canyon Creek within the Piru Basin may be a passage corridor for *O. mykiss*, but is likely dependent on surface water flows rather than groundwater for passage.

Ecological Value: **Moderate**

- The Tributary Riparian GDE Unit supports a relatively low number of special-status species and ecological communities and the dependence of these species and communities on groundwater is uncertain.
- The unit includes designated critical habitat for one federally listed species.
- The species and ecological communities in the unit have low vulnerability to changes in groundwater levels. The tributary streams in this GDE unit are considered intermittent or ephemeral and are not connected to groundwater. The tributaries within the basin boundary currently provide little habitat value for fish and other aquatic species. Hopper Canyon Creek contains critical habitat for southern California steelhead, but it is not known if flows on Hopper Canyon Creek within the basin are dependent on groundwater. Hopper Canyon Creek and other tributaries support valuable riparian habitat and likely movement corridors for a variety of native wildlife species.

Ecological Condition: **Fair**

- NDVI/ NDMI trends in the unit from 1985–2018 show relatively little change in vegetation condition during most of this period, with little change in response to droughts or floods. It is unlikely that adverse impacts are occurring in the unit as a result of current groundwater pumping.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- Groundwater likely provides little or no contribution to the ecological function and habitat value of the ephemeral tributaries in the unit, which support vegetation but have little habitat value for fish or other aquatic species.

Susceptibility to Changing Groundwater Conditions: **Moderate**

- There are no monitoring wells in the unit and shallow groundwater conditions and trends in the unit are therefore unknown.
- Model results suggest that the groundwater elevations are unlikely to decline under climate change, unless droughts are more frequent or more severe. Moreover, because this GDE unit is disconnected from the aquifer, future changes in groundwater conditions in the unit related to increased groundwater production or climate change are unlikely to cause groundwater levels to fall below the baseline range and result in mortality to vegetation that comprises the GDE.
- Streams within the unit are ephemeral and do not provide perennial aquatic habitat or beneficial uses.

Potential for effects

Based on the position of this GDE unit in the watershed, it is unlikely that groundwater pumping will affect the health of the GDE. Model results suggest that the groundwater levels will remain constant in the Fillmore and Piru Basins under climate change (DBS&A 2021). If groundwater pumping were to increase in this GDE unit, monitoring of groundwater levels and GDE health (using remote sensing) would be necessary. GDEs in the unit likely have low susceptibility to future changes in groundwater conditions and the synergistic effects of climate change.

6.4.2 Fillmore

Santa Clara River Riparian Shrubland GDE Unit

Groundwater Dependence: **Possible**

- There are few shallow groundwater measurements in this unit. Spring 2019 water contours provided by United Water showed groundwater levels within 5–10 feet of the ground surface in parts of the unit, but these contours have a large uncertainty in this reach due to the paucity of shallow wells.
- The Santa Clara River Riparian Shrubland GDE unit is primarily made up of vegetation that may or may not rely on groundwater.
- Intermittent surface water flows are likely not interconnected with groundwater.

Ecological Value: **Moderate**

- The Santa Clara River Riparian Shrubland GDE Unit supports a relatively large number of special-status species and ecological communities, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for two federally listed species.
- This naturally intermittent reach supports regionally rare alluvial scrub habitat.
- The unit supports species and ecological communities that are vulnerable to changes in groundwater levels. Although the Santa Clara River in the unit provides migration habitat for southern California steelhead and Pacific lamprey, the migration habitat has low vulnerability to groundwater reduction because most fish migration occurs during seasonal high surface water flow periods, and flows in this reach are not connected to groundwater.

Ecological Condition: **Fair**

- NDVI/ NDMI trends in the Unit from 1985–2018 indicate a decline in vegetation condition since 2012 relative to the long-term average, likely in response to decreased precipitation and runoff (e.g., drought). The current vegetation structure and functions may be compromised and somewhat below the range of natural variability. Groundwater pumping is unlikely to have an adverse effect on this GDE unit because summer groundwater is typically deeper than the rooting depth of vegetation in the reach.

- Current habitat suitability for those special-status species with likelihood to occur in the unit may have declined relative to historical conditions.
- Because surface water in this reach is disconnected from groundwater, groundwater provides little or no contribution to the ecological function and habitat value of the Santa Clara River in the unit, which is intermittent and mainly supports seasonal migration habitat for anadromous fishes.

Susceptibility to Changing Groundwater Conditions: **Moderate**

- Since 2015, shallow groundwater conditions in the unit have fluctuated in response to drought, with a sharp drop in 2013 followed by slow recovery. By 2019, the shallow groundwater level recorded in the unit had nearly returned to the long-term average (i.e., just below the baseline range).
- Future changes in groundwater conditions in the Unit related to increased groundwater production or climate changes that differ from modeled predictions could cause groundwater levels to fall below the baseline range and result in mortality to vegetation that comprises the GDE. Projections of climate change and groundwater pumping in the future suggest that changes in groundwater elevation are unlikely. However, based on widespread tree mortality during the 2012–2016 drought, future changes in the frequency or duration of droughts similar to 2012–2016 could have a deleterious effect on the GDE, particularly at the downstream margin of the unit.
- The unit includes an intermittent reach of the mainstem Santa Clara River that does not provide perennial aquatic habitat or beneficial uses.

Potential for effects

Modeling suggests that groundwater levels near the Santa Clara River Riparian Shrubland GDE Unit are unlikely to change due to climate change or modest changes to groundwater pumping. However, GDEs in the unit are moderately susceptible to future changes in groundwater conditions and the synergistic effects of climate change, which in combination could cause groundwater levels to fall below the baseline range and result in potential effects on GDEs if climate change differs from modeled conditions.

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in the Santa Clara River using remote sensing is recommended and is further discussed in Section 6.

East Grove GDE Unit

Groundwater Dependence: **Certain**

- This GDE unit occurs at a site of rising groundwater.
- This GDE unit is primarily made up of cottonwoods and willows that rely on shallow groundwater.
- Perennial surface water flows are rising groundwater.

Ecological Value: **High**

- The East Grove GDE Unit supports a relatively large number of special-status species and ecological communities, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for two federally listed species.
- The unit supports species and ecological communities that are vulnerable to changes in groundwater levels.

Ecological Condition: **Good**

- NDVI/ NDMI trends from 1985–2018 show minimal change in the unit and indicate vegetation responds mainly to precipitation and runoff (e.g., drought). The vegetation structure and functions are relatively intact and within the range of natural variability, and adverse impacts are not likely occurring in the unit as a result of current groundwater pumping.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- With the exception of flow during storm events and water releases from Santa Felicia Dam, Santa Clara River surface flows in this unit are composed of rising groundwater. As a result, groundwater contributes to the ecological function and habitat value of the Santa Clara River, which supports native aquatic and semi-aquatic species and beneficial uses in and adjacent to the unit.

Susceptibility to Changing Groundwater Conditions: **Moderate**

- Shallow groundwater conditions in the unit since the 1960s have fluctuated considerably in response to drought and possibly other factors. By 2019–2020, shallow groundwater levels recorded at the two wells in the unit were again within the baseline range for each well.
- Recorded maximum rooting depths of willows and cottonwoods in this unit range up to 6.9 ft while the average relative elevation is 10 ft for cottonwoods and 5.6 ft for red willow. Mulefat has a rooting depth of 2 ft (Appendix C), and the mulefat thickets are not likely connected to groundwater.
- Future changes in groundwater conditions in the unit related to increased groundwater production or climate change could cause groundwater levels to fall below the baseline range and result in mortality to vegetation that comprises the GDE. Projections of climate change and groundwater pumping in the future suggest that changes in groundwater elevation are unlikely. However, because the extent of rising groundwater decreased and vegetation health declined at the upstream end of the unit during the 2012–2016 drought, changes in the frequency or duration of droughts to make 2012-2016 conditions more common could have a deleterious effect on the GDE.
- The unit includes a perennial portion of the mainstem Santa Clara River, which is an area of rising groundwater.

Potential for effects

Modeling suggests that groundwater levels are unlikely to drop below the baseline range due to climate change. However, changes to the duration or severity of droughts could impact the health of the GDE through increased tree mortality.

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in the Santa Clara River using remote sensing is recommended and is further discussed in Section 6.

Additionally, monitoring of surface water flows or groundwater elevations should be conducted to assess any changes to hydrology that might impact GDEs.

Cienega GDE Unit

Groundwater Dependence: **Certain**

- Rising groundwater in this unit provides surface flows and keeps groundwater within the rooting zone (5–15 ft) of the vegetation.

Ecological Value: **High**

- The Cienega GDE Unit supports a moderate number of special-status species, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for two federally listed species.
- The unit supports species and ecological communities that are vulnerable to changes in groundwater levels.

Ecological Condition: **Poor**

- NDVI/ NDMI trends from 1985–2018 indicate vegetation responds mainly to precipitation and runoff (e.g., drought) but a decline in NDMI from 2005–2014 suggests other factors, potentially including groundwater pumping, may influence vegetation condition in the Unit. As of 2018, the vegetation structure and functions in the Cienega GDE Unit are no longer intact or within the range of natural variability, due at least in part to vegetation mortality from the 2012–2016 drought. The degree to which groundwater pumping has exacerbated the decline in groundwater elevation during the recent and other droughts is not known.
- Habitat suitability in the unit may be compromised by the decline in vegetation condition during droughts for special-status species relying on vegetation (e.g., riparian birds).
- Groundwater contributes to the ecological function and habitat value of the Santa Clara River, which supports native aquatic and semi-aquatic species and beneficial uses in and adjacent to the unit.

Susceptibility to Changing Groundwater Conditions: **High**

- Shallow groundwater conditions in the unit have fluctuated in response to drought since the 1970s, with sharp drops followed by recovery within about one year. By 2019–2020, shallow groundwater levels recorded at the single well in the unit were again within the baseline range for the period of record, but the native cottonwoods and willows died during the drought and have not yet recovered. Those species are anticipated to recovery once a future flooding event(s) removes the debris and the land surface is better conditioned for repopulation. The time required for that recovery is unknown.
- Reported maximum rooting depths of willows and cottonwoods in this unit range up to 6.9 ft while the average relative elevation is 10 ft for cottonwoods and 5.6 ft for red willow. The mulefat thickets are not likely connected to groundwater.
- Future changes in groundwater conditions in the unit related to increased groundwater production or climate change could cause groundwater levels to fall below the baseline range and result in potential mortality to vegetation that comprises the GDE.
- Projections of climate change and groundwater pumping in the future suggest that changes in groundwater elevation are unlikely. However, based on widespread tree mortality during

the 2012–2016 drought, future changes in the frequency or duration of droughts similar to 2012–2016 could have a deleterious effect on the GDE.

- The unit includes a perennial portion of the mainstem Santa Clara River, which is considered an interconnected surface water.

Potential for effects
Modeling suggests that groundwater levels are unlikely to drop below the baseline ranged due to climate change. However, changes to the duration or severity of droughts could impact the health of the GDE through increased tree mortality. Moreover, it is possible that arundo could replace the cottonwood and willow forests that died during the 2012–2016 drought, which would lead to a decrease in habitat for other species, including two special-status riparian bird species (i.e., southwestern willow flycatcher and least Bell’s vireo). The expansion of arundo could increase evapotranspiration in this reach and reduce water availability for other beneficial users.

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in the Santa Clara River using remote sensing is recommended and is further discussed in Section 6. For this unit, coupling remote sensing and shallow groundwater elevation monitoring, particularly during and following droughts, is recommended.

Tributary Riparian GDE Unit

Groundwater Dependence: **Unlikely**

- There are no shallow groundwater measurements in this unit. Based on the position in the landscape a connection to the regional aquifer is unlikely.
- This potential GDE unit is primarily made up of coast live oaks, which are facultative phreatophytes that may be connected to groundwater or episodic surface water flows associated with storm events.
- Ephemeral surface water flows are not connected with groundwater.

Ecological Value: **Moderate**

- The Tributary Riparian GDE Unit supports a relatively low number of special-status species and ecological communities and the dependence of these species and communities on groundwater is uncertain.
- There is no designated critical habitat in the unit.
- The species and ecological communities in the unit have low vulnerability to changes in groundwater levels. The tributary streams in this GDE unit are considered ephemeral and are not connected to groundwater, thus they provide little habitat value for fish and other aquatic species. Pole Creek may have supported steelhead, but access to habitat upstream of the channelized portion of the channel is currently blocked. Currently, flows in Pole Creek within the basin are unlikely to be connected to groundwater. The tributaries support valuable riparian habitat and likely movement corridors for a variety of native wildlife species.

Ecological Condition: **Fair**

- NDVI/ NDMI trends in the unit from 1985–2018 indicate relatively little change in vegetation condition during most of this period, with a decline in response the most recent drought (2012–2016) and potential damage to vegetation in 2018 resulting from the Thomas Fire. As a result, the current vegetation structure and functions may be compromised and below the range of natural variability, but it is unlikely that adverse impacts are occurring in the unit as a result of current groundwater pumping.

- Current habitat suitability for those special-status species with likelihood to occur in the unit may have declined relative to historical conditions.
- Groundwater currently provides little or no contribution to the ecological function and habitat value of the ephemeral tributaries in the unit, which support vegetation but have little habitat value for fish or other aquatic species. Mapped habitat in Pole Creek is almost entirely upstream of the basin.

Susceptibility to Changing Groundwater Conditions: **Low**

- There are no monitoring wells in the unit and shallow groundwater conditions and trends in the unit are therefore unknown, but the position of the tributaries suggests they are unlikely to be linked to regional groundwater.
- Because this GDE unit is disconnected from the aquifer, future changes in groundwater conditions in the unit related to increased groundwater production or climate change are unlikely to cause groundwater levels to fall below the baseline range and result in mortality to vegetation that comprises the GDE.
- Streams within the unit are ephemeral and do not provide perennial aquatic habitat or beneficial uses.

Potential for effects

Based on the position of this GDE unit in the watershed, it is unlikely that groundwater pumping will affect the health of the GDE. If groundwater pumping were to increase in this GDE unit, monitoring of groundwater levels and GDE health (using remote sensing) would be necessary. GDEs in the unit likely have low susceptibility to future changes in groundwater conditions and the synergistic effects of climate change on groundwater levels.

Sespe Creek Riparian GDE Unit

Groundwater Dependence: **Possible**

- This GDE unit occurs downstream of the confined canyon reach of Sespe Creek.
- Groundwater depths are typically >30 ft bgs, but there are few wells within the shallow groundwater zone.
- This GDE unit is primarily made up of willows and cottonwoods that rely on shallow groundwater or surface water and some communities (e.g., mulefat) that may rely on groundwater for part of their water needs.
- Surface water flows are perennial for the upper portions of the reach and intermittent downstream. The connection to groundwater in the upper portion of Sespe Creek is likely, while the connection in the downstream reaches in uncertain.

Ecological Value: **Moderately High**

- The Sespe Creek Riparian GDE Unit supports a moderate number of special-status species and ecological communities, some of which are directly dependent on groundwater.
- The unit includes designated critical habitat for one federally listed species.
- The unit supports species and ecological communities whose habitat in the unit may be vulnerable to changes in groundwater levels.

Ecological Condition: **Good**

- NDVI/ NDMI from 1985–2018 was relatively constant until a sharp flood-related reduction in NDVI in 2005 followed by a gradual recovery until 2015, at which point NDVI began a gradual decline. As of 2018, NDVI was still within the historical range of variability. NDMI has fluctuated little during the period of record. These trends suggest that the structure and function of riparian vegetation in the unit are relatively intact and within the range of natural variability. Available information indicates that adverse impacts are not likely occurring in the unit as a result of current groundwater pumping. Invasive species, particularly arundo, are a continuing threat to existing GDEs in this unit.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- It is undetermined if or to what extent groundwater contributes to the ecological function and habitat value of Sespe Creek, which supports native aquatic and semi-aquatic species and beneficial uses in and adjacent to the unit.

Susceptibility to Changing Groundwater Conditions: **Low**

- There are no shallow monitoring wells in the unit and shallow groundwater conditions and trends in the unit are therefore unknown.
- Climate change effects on Sespe Creek are unknown. Changes to the duration or extent of droughts may cause tree mortality within the GDE unit.
- The upper 2 miles or so of Sespe Creek in this GDE unit are considered perennial, while the lower portion of Sespe Creek is likely intermittent. Sespe Creek's connection to groundwater is undetermined.

Potential for effects
Modeling suggests that groundwater elevations along the Santa Clara River are unlikely to change due to changes in climate or groundwater pumping in the future. The effects of climate change on groundwater levels further upstream on Sespe Creek are uncertain. However, changes in the duration or severity of droughts could impact the health of the GDE through increased physiological stress to riparian vegetation, leading to branch dieback or whole tree mortality.

Monitoring of ecological conditions and trends in vegetation-dominated GDEs and in Sespe Creek using remote sensing is recommended and is further discussed in Section 6. Additionally, monitoring of surface water flows or groundwater elevations should be conducted to assess any changes to hydrology that might impact GDEs. Further assessing the extent of interconnected surface water in the reach will help to determine potential groundwater impacts to aquatic habitat.

6.4.3 GDEs important to consider when establishing sustainable management criteria

The evaluations of the GDE units in the Fillmore and Piru basins suggests that the following units are the most important for inclusion in the GSP analyses and the development of Sustainable Management Criteria:

- Del Valle,
- Cienega, and
- East Grove.

These units encompass areas of rising groundwater (and hence aquatic habitat) and have historically supported large, tree-forested wetland complexes. For all of the units, impacts to aquatic and riparian habitat occur during droughts. The Del Valle GDE Unit is likely sensitive to upstream effluent releases, and decreases in effluent releases could impact habitat. Because the aquifer is thin in this GDE unit, there are few wells present.

The Cienega GDE Unit is the most sensitive to changes in groundwater associated with droughts. Prolonged droughts result in groundwater levels below the rooting depth of vegetation and caused extensive die-off during the 2012–2016 drought. During the 2012–2016 drought, the decreased elevation of groundwater stopped rising groundwater in this reach and caused the channel to go dry.

In the East Grove, impacts during the 2012–2016 drought resulted in decreased vegetation health at the upstream end of the unit, and decreased the extent of rising groundwater, but surface flows persisted over at least part of the reach for the duration of the drought. If droughts become more severe in magnitude or duration, the East Grove may be more susceptible to impacts from droughts.

7 GDE MONITORING

GDEs were considered as part of the groundwater Monitoring Program (DBS&A 2020). Remote sensing, particularly NDVI data derived from Landsat imagery, is recommended to monitor GDE vegetation health through time. 30-m resolution Landsat images are collected every 16 days. Pre-processed, atmospherically corrected Landsat data are available through the Google Earth Engine API, with new imagery added approximately every two weeks (see https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LC08_C02_T1_L2). Tools developed by The Nature Conservancy (see Klausmeyer et al. 2019 for further description of methods) may be applied to these data to calculate summer medoid NDVI for ongoing monitoring of GDEs.

It is expected that NDVI will exhibit some natural variability given the dynamic nature of this river system. For example, NDVI would be expected to initially decline following the large floods that tend to uproot vegetation and provide fresh bare mineral surfaces and appropriate hydrological conditions for seedling establishment of cottonwoods and willows, but then increase again as native cottonwood and willow vegetation becomes established and individual shrubs and trees develop and mature. As part of the GSP, additional groundwater monitoring wells are proposed in both basins. Groundwater wells near the basin boundaries (the Del Valle, Cienega, and East Grove GDE units) can be used to determine changes in groundwater levels. Such data on groundwater levels through time could then be examined to see if there are clear correlations with observed trends in NDVI or related indicators of GDE health. Continued monitoring of rising groundwater at the Cienega and East Grove sites will help to validate future models and help to assess the availability of aquatic habitat, while wells along Sespe Creek will help to better understand interconnected surface water in this important reach.

For aquatic GDEs, the largest data gap is whether *O. mykiss* use the interconnected surface water reaches of the Fillmore and Piru basins for summer rearing. Because the Santa Clara River at the East Grove maintained some flow during the 2012–2016 drought, stream channels in the East Grove (including threads of the Santa Clara River and its tributaries) are the most likely location to provide summer *O. mykiss* rearing habitat in the Fillmore and Piru basins.

To address the uncertainty regarding use of the Fillmore and Piru Subbasins by *O. mykiss* and other aquatic GDEs, a study plan to assess aquatic GDE use will be developed in 2024-2025. To develop the study plan, a reconnaissance field visit will be conducted in 2024 to determine the most appropriate study methods and define the study extent. In addition, up to two days of snorkel surveys potentially coupled with environmental DNA (eDNA) samples for *O. mykiss* and southwestern pond turtle will be used to assess potential use within the subbasins during the wet-year conditions present in 2024. Up to six stream temperature loggers will be deployed in summer 2024 to provide initial documentation of potential suitability for *O. mykiss* and other aquatic GDEs. Temperature loggers would be deployed in reaches with habitat most likely to be suitable for summer rearing *O. mykiss,* particularly in shaded areas along the mainstem and Lost Creek and other tributaries or springs within the GDE. It is expected that the study plan will outline a three-year study focusing on *O. mykiss*, but subsequent studies will be evaluated based on the previous year's results.

A key component of this study is to integrate ongoing work in the East Grove and elsewhere in the Santa Clara River basin. Ongoing and planned studies include eDNA studies by UC Santa Barbara throughout the Santa Clara River watershed, high-resolution light detection and ranging (LiDAR) data collection along the Santa Clara River planned for summer 2024 that will include higher-density point cloud data collection in the East Grove, and potential CDFW e-fishing surveys in the East Grove Reach.

8 Projects and Management Actions

Projects and management actions (PMAs) are discussed in Section 4 of the GSP. At time of the release of this technical memorandum, the FPBGSA had not determined that projects and/or management actions were needed to sustainably manage the groundwater resources in the Fillmore or Piru basins.

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Appendices

Appendix A

Vegetation Communities in the Fillmore and Piru Groundwater Basins

Table A-1. All vegetation communities mapped in the Fillmore and Piru groundwater basins and corresponding vegetation classification crosswalk.

CALVEG classification	Manual of California Vegetation (MCV)[1]	Acreage	
		Fillmore Groundwater Basin	Piru Groundwater Basin
Alkaline mixed grasses and forbs Alliance	*Cressa truxillensis* - *Distichlis spicata* Herbaceous Alliance	-	2.2
Annual grasses and forbs Alliance	*Brassica nigra* - *Raphanus* spp. Herbaceous Semi-Natural Alliance	1,291.1	377.4
Arrowweed Alliance	*Pluchea sericea* Shrubland Alliance	-	31.5
Baccharis (riparian) Alliance	*Baccharis salicifolia* Shrubland Alliance	1,216.1	952.2
Barren	Riverwash	138.5	84.9
	Riverwash herbaceous		
Black cottonwood Alliance	*Populus trichocarpa* Forest Alliance	320.6	-
Black walnut Alliance	*Juglans californica* Woodland Alliance	6.8	3.7
Big sagebrush Alliance	*Artemisia tridentata* Shrubland Alliance	4.0	54.1
Blue oak Alliance	n/a	4.0	-
Buckwheat	*Encelia californica* - *Eriogonum cinereum* Shrubland Alliance	113.8	27.3
	Eriogonum fasciculatum Shrubland Alliance		
California sagebrush Alliance	*Artemisia californica* Shrubland Alliance	1,727.4	639.8
	Salvia apiana Shrubland Alliance		
California sycamore Alliance	*Platanus racemosa* Woodland Alliance	-	4.6
Ceanothus chaparral Alliance	n/a	44.2	-
Chamise Alliance	n/a	2.8	-
Coast live oak Alliance	*Quercus agrifolia* Woodland Alliance	815.8	65.4
Coastal mixed hardwood Alliance	n/a	77.8	4.0
Coyote brush Alliance	*Baccharis pilularis* Shrubland Alliance	4.1	0.9
Eucalyptus Alliance	*Eucalyptus* spp. - *Ailanthus altissima* - *Robinia pseudoacacia* Woodland Semi-Natural Alliance	74.7	14.4
Fremont cottonwood Alliance	*Populus fremontii* Forest Alliance	0.7	244.8
Giant reed/pampas grass Alliance	*Phragmites australis* - *Arundo donax* Herbaceous Semi-Natural Alliance	271.6	183.0
Lower montane mixed chaparral Alliance	n/a	170.7	3.1
Manzanita chaparral Alliance	n/a	<0.1	-
Non-native/ornamental conifer/hardwood Alliance	n/a	13.0	2.6
Non-native/ornamental grass Alliance	Non-native Grass and Forb Mapping Unit	195.0	90.2
Non-native/ornamental hardwood Alliance	*Schinus* (*molle*, *terebinthifolius*) - *Myoporum laetum* Woodland Semi-Natural Alliance	75.7	20.2
Perennial grasses and forbs Alliance	*Corethrogyne filaginifolia* - *Eriogonum* (*elongatum*, *nudum*) Herbaceous Alliance	6.3	-
	Leymus cinereus - *Leymus triticoides* Herbaceous Alliance		

CALVEG classification	**Manual of California Vegetation (MCV)**[1]	**Acreage**	
		Fillmore Groundwater Basin	**Piru Groundwater Basin**
Riparian mixed hardwood Alliance	*Sambucus nigra* Shrubland Alliance	396.2	286.4
	Salix laevigata Woodland Alliance		
Riparian mixed shrub Alliance	*Heterotheca* (*oregona*, *sessiliflora*) Herbaceous Alliance	152.2	557.1
	Salix exigua Shrubland Alliance		
Riversidean alluvial scrub Alliance	n/a	52.5	3.6
Saltbrush Alliance	*Atriplex lentiformis* Shrubland Alliance	54.1	58.1
Scalebroom Alliance	*Lepidospartum squamatum* Shrubland Alliance	320.1	118.0
Scrub oak Alliance	n/a	1.1	-
Soft scrub-mixed chaparral Alliance	n/a	62.9	-
Sumac shrub Alliance	n/a	522.4	0.9
Tamarisk Alliance	*Tamarix* spp. Shrubland Semi-Natural Alliance	-	37.6
Tule-cattail Alliance	*Schoenoplectus* (*acutus*, *californicus*) Herbaceous Alliance	8.1	3.3
	Typha (*angustifolia*, *domingensis*, *latifolia*) Herbaceous Alliance		
Wet meadow	n/a	0.4	-
Willow/Willow (shrub) Alliance	*Salix lasiolepis* Shrubland Alliance	63.5	3.9
	Salix lucida Woodland Alliance		
No corresponding CalVeg type[2]	*Olea europaea* Woodland Semi-Natural Alliance [Provisional]	-	2.7
	Pseudognaphalium leucocephalum Herbaceous Alliance [Provisional]	-	0.2
	Ricinus communis Shrubland Semi-Natural Alliance [Provisional]	-	2.2
All agriculture		12,436.9	6,123.8
All water		6.7	14.6
All development		1,968.6	903.2
Total		**22,620.3**	**10,922.0**

[1] An n/a in this column signifies that no corresponding MCV type was mapped in the Vegetation Mapping of Santa Clara River dataset (Stillwater Sciences 2019).

[2] These are provisional MCV alliances and as such do not have a corresponding CalVeg alliance.

Appendix B

Special-status Terrestrial and Aquatic Wildlife Species from Database Queries with No Reliance on Fillmore or Piru Groundwater Dependent Ecosystem Units

Table. B-1. Special-status terrestrial and aquatic wildlife species from database queries that are not groundwater dependent and/or unlikely to occur in the Fillmore and Piru groundwater dependent ecosystem units.

Common name *Scientific name*	**Status[1] Federal/State**	**Potential to occur in GDE Basins[2]**	**Documented occurrence location**		**Query source[3]**	**GDE . association[4]**	**Habitat and documented occurrences in GDE Management Units**
			Fillmore GDE units	**Piru GDE units**			
Amphibian							
California red-legged frog *Rana draytonii*	FT/SSC	Unlikely	No documented occurrences	No documented occurrences	CAFSD	Direct	Breeds in still or slow-moving water with emergent and overhanging vegetation, including wetlands, wet meadows, ponds, lakes, and low-gradient, slow-moving stream reaches with permanent pools; uses adjacent uplands for dispersal and summer retreat. Relies on surface water that may be supported by groundwater (Rohde et al. 2019).
Foothill yellow-legged frog *Rana boylii*	FSS, BLMS/SE	None	Extirpated	Extirpated	CNDDB, CAFSD	Direct	Shallow tributaries and mainstems of perennial streams and rivers, typically associated with cobble or boulder substrate; occasionally found in isolated pools, vegetated backwaters, and deep, shaded, spring-fed pools. The frog is reliant on surface water that may be fed by groundwater. Population has been extirpated from the Santa Clara River Valley Basin (CDFW 2019).
Western spadefoot *Spea hammondii*	BLMS/SSC	Unlikely	No documented occurrences	No documented occurrences	CAFSD	No known reliance on groundwater	Areas with sparse vegetation and/or short grasses in sandy or gravelly soils; primarily in washes, river floodplains, alluvial fans, playas, alkali flats, among grasslands, chaparral, or pine-oak woodlands; breeds in ephemeral rain pools with no predators.

Common name ***Scientific name***	**Status[1] Federal/State**	**Potential to occur in GDE Basins[2]**	**Documented occurrence location**		**Query source[3]**	**GDE . association[4]**	**Habitat and documented occurrences in GDE Management Units**
			Fillmore GDE units	**Piru GDE units**			
Reptile							
California legless lizard *Anniella sp.*	–/SSC	Likely	Santa Clara River Riparian Shrubland	Tributary Riparian	CNDDB	No known reliance on groundwater	Occurs in moist, warm, loose soil with plant cover and in sparsely vegetated areas of chaparral, pine-oak woodlands, desert scrub, and stream terraces with sycamores, cottonwoods, or oaks. Forages in loose soil, sand, and leaf litter for larval insects, beetles, termites, and spiders. Historical observation in the vicinity of Sespe Creek and Santa Clara River confluence in 1981 (CDFW2019). Observations in the vicinity of Tributary Riparian GDE Unit include Hopper Canyon in 2008 (CDFW 2019).
Coast horned lizard *Phrynosoma blainvillii*	FSS, BLMS/SSC	Likely	East Grove Riparian Complex	Santa Clara River Riparian Shrubland	CNDDB	No known reliance on groundwater	Open areas with sandy soil and/or patches of loose soil and low/scattered vegetation in scrublands, grasslands, conifer forests, and woodlands; frequently found near ant hills. Feeds on ants and other small invertebrates (e.g., spiders, beetles, and grasshoppers).
Coast patch-nosed snake *Salvadora hexalepis virgultea*	–/SSC	Likely	No documented occurrences	No documented occurrence	CNDDB	No known reliance on groundwater	Coastal chaparral, desert scrub, washes, sandy flats and rocky areas. Predominately preys upon lizards. Documented outside of groundwater basins on Hopper Canyon Creek, 2 miles northwest of Piru (CDFW 2019).
San Diegan Coastal whiptail *Aspidoscelis tigris stejnegeri*	–/SSC	Likely	No documented occurrences	Piru Creek Riparian	CNDDB	No known reliance on groundwater	Habitat generalists found in desert, woodland, and riparian communities. Feeds on small invertebrates (e.g., spiders, scorpions, centipedes, and termites) and small lizards. Documented on Piru Creek in 2009 (CDFW 2019)

Common name ***Scientific name***	**Status[1] Federal/State**	**Potential to occur in GDE Basins[2]**	**Documented occurrence location**		**Query source[3]**	**GDE . association[4]**	**Habitat and documented occurrences in GDE Management Units**
			Fillmore GDE units	**Piru GDE units**			
Bird							
Bank swallow *Riparia riparia*	BLMS/ST	None	Extirpated	Extirpated	CNDDB, CAFSD	Indirect	Nests in vertical bluffs or banks, usually adjacent to water (i.e., rivers, streams, ocean coasts, and reservoirs), where the soil consists of sand or sandy loam. Feeds on caterpillars, insects, frog/lizards, and fruit/berries. Relies on surface water that may be supported by groundwater (Rohde et al. 2019). Historical population documented in the 1920s Santa Clara River is extirpated (CDFW 2019).
Black swift *Cypseloides niger*	FSS/SSC	Unlikely	No documented occurrences	No documented occurrences	CAFSD	No known reliance on groundwater	Nests in moist crevices behind or beside permanent or semipermanent waterfalls in deep canyons, on perpendicular sea cliffs above surf, and in sea caves; forages widely for insects over many habitats.
Burrowing owl *Athene cunicularia*	FSS/SSC	Likely	Santa Clara River Riparian Shrubland	Santa Clara River Riparian Shrubland	CNDDB	No known reliance on groundwater	Level, open, dry, heavily grazed or low-stature grassland or desert vegetation with available burrows. Preys on invertebrates and vertebrates. Occurrences along or near the bank of the Santa Clara River near Fillmore and one mile south of Buckhorn (CDFW 2019).

Common name ***Scientific name***	**Status[1] Federal/State**	**Potential to occur in GDE Basins[2]**	**Documented occurrence location**		**Query source[3]**	**GDE . association[4]**	**Habitat and documented occurrences in GDE Management Units**
			Fillmore GDE units	**Piru GDE units**			
California condor *Gymnogyps californianus*	FE/SE	Unlikely	Sespe Creek Riparian	Piru Creek Riparian	CNDDB	Indirect	Requires vast expanses of open savannah, grasslands, and foothill chaparral in mountain ranges of moderate altitude; deep canyons containing clefts in rocky walls and large trees provide nest sites; forages up to 100 miles from roost to nest. Forages in grasslands, oak savanna habitats; condors may rely on groundwater dependent vegetation for nesting in foothill grasslands, oak savanna habitats, and old-growth forest (Rohde et al. 2019). Habitat for condors in the basins is therefore unlikely to be groundwater dependent. Condors observed drinking water at a small perched pool near spillway canyon just west of the Santa Felicia Dam in the vicinity of the Piru Creek Riparian GDE Unit and within Piru Canyon (CDFW 2019, eBird 2021).

Common name ***Scientific name***	**Status[1] Federal/State**	**Potential to occur in GDE Basins[2]**	**Documented occurrence location**		**Query source[3]**	**GDE . association[4]**	**Habitat and documented occurrences in GDE Management Units**
			Fillmore GDE units	**Piru GDE units**			
Mammal							
Pallid bat *Antrozous pallidus*	FSS, BLMS/SSC	Likely	No documented occurrences	No documented occurrences	CNDDB	No known reliance on groundwater	Roosts in rock crevices, tree hollows, mines, caves, and a variety of vacant and occupied buildings; feeds in a variety of open woodland habitats. Habitat and prey (e.g., insects and arachnids) not associated with aquatic ecosystems. Commonly found roosting under the bark of dead riparian trees in the Santa Clara River Watershed (UWCD 2018). Historical observations in the vicinity of Fillmore documented in 1906 and 1942 (CDFW 2019).

[1] Status codes:

Federal		State	
FT	= Listed as threatened under the federal Endangered Species Act	SE	= Listed as Endangered under the California Endangered Species Act
FSS	= Forest Service Sensitive Species	ST	= Listed as Threatened under the California Endangered Species Act
BLMS	= Bureau of Land Management Sensitive Species	SSC	= CDFW species of special concern

[2] Potential to Occur:
Likely: the species *has* documented occurrences and the habitat is high quality or quantity
Possible: no documented occurrences and the species' required habitat is moderate to high quality or quantity
Unlikely: no documented occurrences and the species' required habitat is of low to moderate quality or quantity
None: no potential to occur due to lack of habitat and/or the population is assumed extirpated

[3] Query source:
CAFSD: California Freshwater Species Database (TNC 2020)
CNDDB: California Natural Diversity Database (CDFW 2019)
eBird: (eBird 2021)

[4] Groundwater Dependent Ecosystem (GDE) association:
Direct: Species directly dependent on groundwater for some or all water needs
Indirect: Species dependent upon other species that rely on groundwater for some or all water needs

Appendix C

Rooting Depths for Selected Species

Table C-1. Maximum rooting depth of dominant species.

Dominant species	Vegetation type (MCV)	Vegetation type (CalVeg)	GDE?	Maximum rooting depth (ft)	Data source
Adenostoma fasciculatum		Chamise	no	25.0	Hellmers et al. 1955 as cited in Fan et al. 2017
Artemisia tridentata	*Artemisia tridentata* Shrubland Alliance		yes	9.8	Link et al. 1995 as cited in Tumber-Davila 2017
Arundo donax	*Phragmites australis - Arundo donax* Herbaceous Semi-Natural Alliance	Giant reed/pampas grass	yes	16.1	Stromberg 2013
Baccharis pilularis	*Baccharis pilularis* Shrubland Alliance	Coyote brush	no	12.1	Naumovich 2017
Baccharis salicifolia	*Baccharis salicifolia* Shrubland Alliance	Baccharis (riparian)	yes	2.0	Stromberg 2013
Ceanothus crassifolius		Ceanothus chaparral	no	4.5	Hellmers et al. 1955 as cited in Fan et al. 2017
Elymus triticoides	*Leymus cinereus - Leymus triticoides* Herbaceous Alliance		yes	3.8	Weaver 1919 as cited in Fan et al. 2017
Eriogonum fasciculatum	*Eriogonum fasciculatum* Shrubland Alliance	Buckwheat	no	4.0	Hellmers et al. 1955 as cited in Fan et al. 2017
Eucalyptus globulus and other *Eucalyptus* species	*Eucalyptus* spp. - *Ailanthus altissima - Robinia pseudoacacia* Woodland Semi-Natural Alliance	Eucalyptus	yes	16.4	Dawson and Pate 1996 as cited in Fan et al. 2017
Juglans californica	*Juglans californica* Woodland Alliance	Black walnut	no	5.9	Faber 2017
Pluchea sericea	*Pluchea sericea* Shrubland Alliance		yes	4.3	Stromberg 2013
Populus fremontii	*Populus fremontii* Forest Alliance	Fremont cottonwood	yes	6.9	Stromberg 2013
Populus trichocarpa	*Populus trichocarpa* Forest Alliance		yes	4.1	Zhang et al. 1999 as cited in Fan et al. 2017
Quercus agrifolia	*Quercus agrifolia* Woodland Alliance	Coast live oak / Coastal mixed hardwood alliance	yes	35.1	Schenk and Jackson 2002

Dominant species	**Vegetation type (MCV)**	**Vegetation type (CalVeg)**	**GDE?**	**Maximum rooting depth (ft)**	**Data source**
Quercus douglasii		Blue oak	no	80.0	Schenk and Jackson 2002
Salix exigua	*Salix exigua* Shrubland Alliance	Willow (shrub)	yes	6.9[1]	Pulling 1918 as cited in Fan et al. 2017
Salix laevigata	*Salix laevigata* Woodland Alliance		yes	6.9[1]	Pulling 1918 as cited in Fan et al. 2017
Salix lasiolepis	*Salix lasiolepis* Shrubland Alliance		yes	6.9[1]	x
Salix lucida	*Salix lucida* Woodland Alliance		yes	6.9[1]	Pulling 1918 as cited in Fan et al. 2017
Salix spp		Riparian mixed shrub / Willow	yes	6.9	Pulling 1918 as cited in Fan et al. 2017
Salvia apiana	*Salvia apiana* Shrubland Alliance		no	5.0	Hellmers et al. 1955 as cited in Fan et al. 2017
Schoenoplectus spp	*Schoenoplectus* (*acutus*, *californicus*) Herbaceous Alliance		yes	2.1[1]	Stromberg 2013
Tamarix spp	*Tamarix* spp. Shrubland Semi-Natural Alliance		yes	16.1	Stromberg 2013
Typha spp	*Typha* (*angustifolia*, *domingensis*, *latifolia*) Herbaceous Alliance		yes	0.8[1]	Shaver and Billlings 1975 as cited in Fan et al. 2017

[1] Rooting depth assigned by genus or close species association.

Table C-2. Relative elevation of dominant species. Data from Stillwater Sciences (2007).

Dominant species	**Alliance**	**Relative elevation (ft)**			
		mean	**SE**	**min**	**max**
Artemisia tridentata	*Artemisia tridentata* Shrubland Alliance	5.2	0.5	1.0	11.0
Arundo donax	*Arundo donax* Semi-Natural Alliance	7.6	0.3	0.0	32.8
Baccharis pilularis	*Baccharis pilularis* Shrubland Alliance	15.9	1.2	2.5	26.7
Baccharis salicifolia	*Baccharis salicifolia* Shrubland Alliance	9.6	1.8	2.3	24.6
Eriogonum fasciculatum and *Artemisia californica*	*Artemisia californica- Eriogonum fasciculatum* Shrubland Alliance	18.2	2.2	7.7	27.4
Eucalyptus globulus and other *Eucalyptus* species	*Eucalyptus* spp. - *Ailanthus altissima* - *Robinia pseudoacacia* Woodland Semi-Natural Alliance	15.4	2.6	12.5	23.0
Populus fremontii	*Populus fremontii* Forest Alliance	9.7	0.8	0.0	25.0
Populus trichocarpa	*Populus balsamifera* ssp *trichocarpa* Forest Alliance	7.4	0.4	2.1	20.5
Salix exigua	*Salix exigua* Shrubland Alliance	4.8	0.4	1.0	9.4
Salix laevigata	*Salix laevigata* Woodland Alliance	5.6	0.5	0.0	20.6
Salix lasiolepis	*Salix lasiolepis* Shrubland Alliance	12.4	0.7	0.6	24.8
Salix lucida	*Salix lucida* Woodland Alliance	4.9	0.8	0.2	12.3
Tamarix spp	*Tamarix* spp. Semi-Natural Alliance	6.3	1.1	4.0	9.0

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Appendix E

United Water Conservation District Groundwater Model Documentation (United, 2021a, 2021b, and 2021e; Porcello et al., 2021)

Appendix E-1

Ventura Regional Groundwater Flow Model Expansion and Updated Hydrogeologic Conceptual Model for the Piru, Fillmore, and Santa Paula Groundwater Basins (United, 2021a)

VENTURA REGIONAL GROUNDWATER FLOW MODEL EXPANSION AND UPDATED HYDROGEOLOGIC CONCEPTUAL MODEL FOR THE PIRU, FILLMORE, AND SANTA PAULA GROUNDWATER BASINS

United Water Conservation District
Open-File Report 2021-01
June 2021

WATER RESOURCES DEPARTMENT
UNITED WATER CONSERVATION DISTRICT

THIS REPORT IS PRELIMINARY AND SUBJECT TO MODIFICATION BASED UPON FUTURE ANALYSIS AND EVALUATIONS

ERRATA

This document dated June 15, 2021 replaces the previous document dated June 9, 2021. Changes include:

- Figure 2-12: Legend text edits
- Figure 2-25: Legend text edits
- Figure 4-58: Title edit
- Figure 4-59: Piru basin scatter plots were updated to include additional wells with "unknown" screen interval depths used in calibration analysis.
- Figure 4-60: Fillmore basin scatter plots were updated to include additional wells with "unknown" screen interval depths used in calibration analysis.
- Figure 4-61: Santa Paula basin scatter plots were updated to include additional wells with "unknown" screen interval depths used in calibration analysis.

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VENTURA REGIONAL GROUNDWATER FLOW MODEL EXPANSION AND UPDATED HYDROGEOLOGIC CONCEPTUAL MODEL FOR THE PIRU, FILLMORE, AND SANTA PAULA GROUNDWATER BASINS

United Water Conservation District
Open-File Report 2021-01
June 2021

PREPARED BY
WATER RESOURCES DEPARTMENT
JUNE 2021

THIS REPORT IS PRELIMINARY AND SUBJECT TO MODIFICATION BASED UPON FUTURE ANALYSIS AND EVALUATIONS

Preferred Citation: United Water Conservation District, 2021, *Ventura Regional Groundwater Flow Model Expansion and Updated Hydrogeologic Conceptual Model for the Piru, Fillmore and Santa Paula Groundwater Basins*, United Water Conservation District Open-File Report 2021-01. June.

Principal Authors: Dr. Jason Sun, PE, Dr. Zachary Hanson, Dr. Bram Sercu, Eric Elliot, and
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SUMMARY

United Water Conservation District (UWCD or United), a public agency, serves as a steward for managing the surface water and groundwater resources in the Santa Clara River (SCR) Valley and much of the Oxnard Plain. In the late 1980s, United's Board of Directors (Board) recognized that a groundwater flow model capable of addressing specific aquifer issues was needed and helped sponsor the U.S. Geological Survey (USGS) to develop a regional groundwater flow model (the "USGS model") for the basins in the Ventura County portions of the SCR and Calleguas Creek watersheds (USGS, 2003). From 2003 to 2008, with the help of consultants, UWCD continued to calibrate and update the USGS model. In 2010 the UWCD staff and Board determined that a new model that explicitly simulated each aquifer would be required to improve understanding of groundwater occurrence and movement within United's service area, and to forecast the effects of potential groundwater management actions under consideration.

In 2018, UWCD completed construction and calibration of a numerical groundwater flow model for the Oxnard and Mound sub-basins of the Santa Clara River basin (referred to herein as the Oxnard and Mound basins), Pleasant Valley basin, and the western portion of the Las Posas Valley basins (referred to herein as the West Las Posas Valley basin) (UWCD, 2018). The primary objective for development of that model ("Coastal Plain Model") was to provide an improved tool (compared to a previous model of the region constructed in the 1990s by the U.S. Geological Survey [USGS]) for forecasting aquifer-specific effects of potential groundwater management actions under consideration. In 2018 and 2019 UWCD staff updated the hydrostratigraphic conceptual model for Santa Paula, Fillmore and Piru basins and expanded United's numerical groundwater flow model to include those basins. This report documents the model expansion and calibration efforts that were completed in August 2020.

The expanded regional groundwater flow model ("Regional Model") uses the same finite-difference model grid spacing (2,000 feet), MODFLOW packages, simulation period (1985 to 2015) and groundwater model software - MODFLOW-NWT (Niswonger, et al., 2011) - as United's Coastal Plain Model.

In addition to including the SCR Valley basins in the Regional Model, there are three areas of difference between the Regional Model and Coastal Plain Model:

- Unconfined basin conditions and non-marine sediments predominate in the model expansion area, and significant interaction exists between surface water and groundwater
- Expansion of the outcrop area of the Mound basin and minor recharge component refinement and updates were included.
- The Regional Model adopts a daily time step to better simulate the highly variable SCR streamflow, while the Coastal Plain model utilized a monthly time step.

The Regional Model is well calibrated to simulate the groundwater elevations throughout the seven basins (Piru, Fillmore, Santa Paula, Mound, Oxnard, Pleasant Valley, and West Las Posas Valley). The Regional Model is sufficiently calibrated and discretized to inform regional groundwater management decisions and can provide meaningful interpretation of the inter-basin flow budgets between the seven basins within United's District boundaries in southern Ventura County.

The Regional Model generally simulates the streamflow routing and interaction between streamflow in the SCR and groundwater well, based on calibration of monthly average streamflow and stream channel recharge. Daily model simulations were used to capture the variability within a month and were instrumental in achieving satisfactory calibration (based on monthly averages). The simulation of the SCR streamflow routing is somewhat limited by assumptions and functionalities available in the stream package, resulting in underestimated streamflow at the Freeman Diversion. Therefore, rather than using the Regional Model, an existing surface water model was used to calculate daily streamflow at the Freeman Diversion, and subsequently to calculate diversions, artificial recharge, and surface water deliveries to the Oxnard and Pleasant Valley basins.

In 2016 UWCD contracted with three nationally recognized experts (Dr. Sorab Panday, Mr. Jim Rumbaugh, and Mr. John Porcello) to form a model review panel (the Expert Panel) to provide objective and critical review of construction and calibration United's new groundwater flow model. The Expert Panel concluded that the Coastal Plain Model was well constructed and well calibrated, is consistent with the conceptual model for the hydrogeology of the basins and is a good tool for simulating the effects of various water supply projects and management strategies (GSI Water Solutions and others, 2018). The Expert Panel has continued to review and advise United as staff has worked to expand the model up the valley of the SCR. In 2020, the Expert Panel completed a detailed initial review of the Regional Model and concluded that "The model calibration to both heads and streamflows is very good".

The completion of the Regional Model marks an important milestone of UWCD's effort in securing a working, well calibrated, and thoroughly reviewed regional groundwater model covering the United's service area. The Regional Model as well as the Coastal Plain Model can simulate the aquifer-specific groundwater flow to support its groundwater conservation and management. The Coastal Plain Model and the Regional Model have been used to simulate and analyze future groundwater conditions for the Groundwater Sustainability Plans (GSPs) of local Groundwater Sustainability Agencies, including the Fox Canyon Groundwater Management Agency (FCGMA), the Fillmore and Piru Basins Groundwater Sustainability Agency, and the Mound Basin Groundwater Sustainability Agency. UWCD has also used the Coastal Plain Model and Regional Model for internal project assessments, as well as supporting projects by local city and agency.

Looking forward, when more and/or newer data become available, UWCD will periodically (likely every 5 years) update and improve the groundwater models. Similarly, when new versions of

MODFLOW become available, UWCD will consider adopting new versions of MODFLOW, e.g., MODFLOW-USG (Panday and others, 2013), to take advantage of the technological improvement in new versions of MODFLOW.

ACKNOWLEDGEMENTS

We want to acknowledge the importance of the U.S. Geological Survey effort in the 1990s and 2000s to establish a regional groundwater monitoring-well network and construct the first MODFLOW model for the basins underlying the entire Santa Clara River and Calleguas Creek watersheds; their model was a critical “jumping-off point” for the Coastal Plain Model. United would again like to acknowledge the financial support provided by the Fox Canyon Groundwater Management Agency (FCGMA) and the Santa Clara River Watershed Committee when the Coastal Plain model was being developed. United would also like to acknowledge the various water and sanitation districts (including Ventura County Watershed Protection District), municipalities, diverters, farmers and other individuals that provided data to support development of the expanded Regional Model. Without the rich datasets that have been developed with great effort and consistency over decades in Ventura County basins the calibration of a regional groundwater flow model such as the one detailed here would be impossible.

The authors would also like to recognize the foresight, support and patience of United’s Board of Directors, General Manager and management team while we have worked to develop this tool. Significant contributions were made by other Water Resources Department staff, both past and current, and all those contributions were helpful and are appreciated. In addition, we thank and acknowledge the participants of the Expert Panel (Dr. Sorab Panday, James Rumbaugh, and John Porcello) convened by United to review and provide guidance for improving the model. The critical review by the Expert Panel has helped us develop a better model with confidence.

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(Appendices are located following the “Figures” section of the document)

1 INTRODUCTION

United Water Conservation District (United) is a California special district (i.e., a public agency) with a service area of approximately 335 square miles (214,000 acres) of southern Ventura County. United's service area includes the Ventura County portion of the Santa Clara River (SCR) Valley and much of the Oxnard coastal plain, including the lower part of the Calleguas Creek watershed, as shown on Figure 1-1. United serves as a steward for managing the surface water and groundwater resources within all or part of seven groundwater basins. It is governed by a seven-person board of directors elected by region, and receives revenue from property taxes, pump charges, recreation fees, and water delivery charges. United is authorized under the California Water Code to conduct water resource investigations, acquire water rights, build facilities to store and recharge water, construct wells and pipelines for water deliveries, commence actions involving water rights and water use, prevent interference with or diminution of stream/river flows and their associated natural subterranean supply of water, and to acquire and operate recreational facilities (California Water Code, section 74500 et al).

1.1 PURPOSE

This report documents the expansion of United's active numerical groundwater flow model domain beyond the Oxnard coastal plain to include the remaining groundwater subbasins of the SCR Valley within Ventura County, California. The coastal basins are connected subbasins in the larger groundwater system of the SCR Valley (California Department of Water Resources [DWR] basin number 4-004), but the common vernacular is to refer to them as basins. United's expanded groundwater flow model now includes the following basins: Piru (DWR 4-004.06), Fillmore (DWR 4-004.05), and Santa Paula (DWR 4-004.04; Figure 1-2). The recent effort of extending the numerical groundwater modeling builds from United's prior model development effort (Figure 1-3; United, 2018) which included the coastal basins of the SCR Valley (Oxnard (DWR 4-004.02) and Mound (DWR 4-004.03)) as well as the Pleasant Valley groundwater basin (DWR 4-006) and the western portion of the Las Posas Valley basin (DWR 4-008). With completion of the model expansion described in this document, United's Regional Model includes all basins within the District boundaries, and the portions of these groundwater basins that exist outside the District boundaries.

1.2 LOCATION

The SCR is located in Southern California, running 83 miles from the north side of the San Gabriel Mountains in Los Angeles County and through Ventura County until it meets the Pacific Ocean near the cities of Ventura and Oxnard (Figure 1-1). The SCR is the largest river in the Southern California region that remains in a relatively natural state (Los Angeles Regional Water Quality Control Board, 2006). The SCR flows through the Santa Clarita Valley within Los Angeles County, then flows through a narrow and thin geologic constriction near the Ventura County line where the river and minor volumes of groundwater underflow enter the SCR Valley within Ventura County. The SCR flows west and southwest over the alluvial Piru, Fillmore, and Santa Paula groundwater basins before entering the coastal basins near the Pacific Ocean (Figure 1-2). Along the SCR Valley, recharge from the river is a major source of water supply for irrigation, municipal and domestic wells that rely on water stored in the underlying groundwater basins. The Piru, Fillmore, and Santa Paula groundwater basins constitute the majority of the portion of the study area that was added to the model as described in this model expansion report. However, additional areas outside the groundwater basin boundaries which are hydraulically connected to the basins were included in the model. The study area is described in further detail in Section 2.1, below.

1.3 PREVIOUS INVESTIGATIONS

Nearly all previous hydrologic investigations that have included the Piru, Fillmore, and Santa Paula groundwater basins have been part of broader regional studies. The first detailed hydrologic investigation that included these basins began in the late 1920s and was performed by predecessor agencies to the State of California's Department of Water Resources (DWR, 1933). This and other early investigations provided datasets and analysis of streamflow, groundwater elevations, and underlying geologic formations, and included estimates of water budget components for each of the groundwater basins (DWR, 1956; Mann and Associates, 1959). Beginning in the 1970s, investigations by the Department of Water Resources and Ventura County Public Works Agency began to refine the understanding of the basin settings through additional review and collection of data in order to support the first numerical modeling efforts related to water quantity and quality issues within the County (DWR, 1974 and 1975). Later, the United States Geological Survey (USGS) collected field data to contribute to and refine previous efforts for development of their numerical flow model (USGS, 1995); these efforts ultimately resulted in completion of a 2-layer MODFLOW model of groundwater and surface water flow within the SCR and Calleguas Creek watersheds (Figure 1-4; USGS, 2003). Local funding for development of the USGS model came from United, Calleguas Municipal Water District (CMWD), and the Fox Canyon Groundwater Management Agency (FCGMA).

The Santa Paula groundwater basin was adjudicated in 1996 (United Water Conservation District vs. City of San Buenaventura, original March 7, 1996, amended August 24, 2010). Members of the Santa Paula Basin Pumpers Association (SPBPA) and the City of San Buenaventura exercise rights to pump groundwater from the basin for reasonable and beneficial uses. Through this legal process, several investigations of hydrogeologic conditions were conducted, but numerical groundwater flow modeling was not applied (Law/Crandall, 1993; Bachman, 2015; DBS&A and RCS, 2017).

Following completion of the USGS (2003) model, United worked with consultants to attempt to refine and improve the 2-layer model for various regional planning activities (e.g. FCGMA and others, 2007), particularly related to overdraft issues on the Oxnard Plain and the resulting seawater intrusion concerns. United's efforts to refine of the USGS model ended by 2008. In 2012 United began initial development of a new numerical groundwater flow model for the basins of the Oxnard coastal plain in order to construct an "improved tool for simulating future occurrence and movement of groundwater within the study area" (United, 2018).

In addition to previous investigations related to the lower SCR Valley, several investigations took place during the 2000s focusing on the Santa Clarita Valley, located upstream of the Piru basin within the SCR watershed in Los Angeles County (CH2M HILL 2004, 2005; CH2M HILL/HGL, 2008). These efforts are relevant to development of the model described in this report, specifically the estimates of future streamflow and subsurface underflow entering the Piru groundwater basin from the SCR Valley East subbasin (Figure 1-2; this area is also referred to as the Santa Clarita Valley area). Currently, the Santa Clarita Valley Groundwater Sustainability Agency (SCVGSA) is working on an updated model for the East subbasin, based in part on the previous numerical groundwater flow models in the East subbasin, for GSP development. Coordination between SCVGSA, United, the Fillmore and Piru Basins Groundwater Sustainability Agency (FPBGSA) and the Mound Basin Groundwater Sustainability Agency (MBGSA) on developing assumptions for future land use, water use and hydrologic conditions has allowed for information from that updated modeling related to subsurface underflow from the East subbasin to be incorporated into United's modeling of the SCR Valley basins (Section 3.5.1.2).

The previous studies and estimated water budget component briefly described here are described in detail in United's Open-File Report 2020-02, titled *Summary of Past Groundwater Models and Water Budgets for the Piru, Fillmore, and Santa Paula Groundwater Basins* (UWCD, 2020). Water budget estimates from those prior studies are summarized in Section 2.6, below.

2 HYDROGEOLOGIC CONCEPTUAL MODEL

This section provides a summary of the hydrogeologic conceptual model for the area covered by United's expanded groundwater flow model. As previously mentioned, the Regional Model builds from the previous numerical model developed by United for the Oxnard coastal plain (UWCD, 2018) and incorporates the remaining groundwater basins along the SCR Valley within Ventura County (Figures 1-2 and 2-1). In order to construct the Regional Model in a manner that explicitly and accurately represents all major hydrostratigraphic units, United staff made a significant effort to review available geophysical well logs and lithologic data and build a hydrostratigraphic conceptual model for the study area. Section 2.5 of this report provides documentation of this updated Basin Conceptual Model (hereafter referred to as BCM 14), which incorporates some important changes in the understanding of the characteristics of aquifers and aquitards in the study area based on United's review of the data. The description of the hydrogeologic conceptual model generally follows the hydraulic gradient down the SCR Valley from Piru to Fillmore to Santa Paula.

2.1 STUDY AREA PHYSICAL SETTING AND LAND USE

The study area for this Regional Model report includes the Piru, Fillmore, and Santa Paula groundwater basins (Figures 1-2 and 2-1), which are now included in order to expand the Regional Model from the 2018 Coastal Plain Model (United, 2018). The SCR watershed has a total area of 1,625 square miles and a channel length of approximately 83 miles, and flows from headwaters on the north slope of the San Gabriel Mountains near Acton in the east to the Pacific Ocean in the west. The study area is oriented east to west and is bounded by the Topa Topa Mountains to the north and South Mountain to the south (Figure 2-1). The model domain contains about 29 miles of the main channel of the SCR and about 55,600 acres (86.9 mi^2) within the underlying alluvial groundwater basins (Piru: 10,900 acres (17.0 mi^2); Fillmore: 22,580 acres (35.3 mi^2); Santa Paula: 22,110 acres (34.5 mi^2)). The SCR watershed encompasses three significant tributary watersheds that flow into the groundwater basins of the study area—those of Piru, Sespe, and Santa Paula Creeks (Figures 2-1 and 2-2). Much of the flow in the SCR is derived from streamflow originating in the mountain regions drained by these tributaries.

In addition to expanding the model into the Piru, Fillmore, and Santa Paula basins, there were also minor changes made in the Mound basin. Specifically, the active model domain in Mound basin was expanded to correspond with DWR's 2019 groundwater basin boundary updates, and a general-head boundary used to simulate groundwater underflow between Santa Paula and Mound basins in United's 2018 model was eliminated (it became unnecessary when the model was extended to include Santa Paula, Piru, and Fillmore basins). In addition, some minor recharge component refinement and updates were implemented in the hydrogeologic conceptual model (described in Sections 2.3.7, 2.3.9 and 2.7, below). Implementation of these modifications in the numerical model is discussed in Section 3.

Compared to the basins of the Oxnard coastal plain, urban development within the model expansion area remains relatively modest, with the dominant land use being agricultural. Figure 2-3 shows the extent of farmland and “urban/built-up” (municipal and industrial) land within the SCR Valley in Ventura County as of 2016, based on data available online from the California Department of Conservation’s Farmland Mapping and Monitoring Program (http://www.conservation.ca.gov/dlrp/fmmp). Figure 2-3 shows the expansion of urban and built-up land since 1984, immediately prior to the beginning of the historical model calibration period, in 6- to 8-year increments. Inspection of Figure 2-3 indicates that the majority of urban/built-up land within the study area was developed before 1985, with relatively minor expansion since that time.

Population nearly doubled in the unincorporated town of Piru between the years 2000 and 2010, but its area of urban/built-up land remains small, and the rate of population increase appears to have slowed between 2010 and 2019 (Table 2-1). The population and area of the Cities of Fillmore and Santa Paula are both significantly larger than Piru, with Santa Paula having about twice the population of Fillmore. Both cities have experienced lesser population growth rates relative to Piru since 2000, with both Fillmore’s and Santa Paula’s population growth at about 15%. Urban development often represents a conversion from agricultural land to largely impervious surfaces and typically results in reduced recharge to groundwater basins in the areas of urban growth, although the increased runoff and discharge of treated wastewater to percolation ponds in unconfined alluvial basins does result in some opportunity for subsequent recharge in areas downstream.

Figure 2-3 also shows the extent of agricultural lands within Ventura County as of 2016, based on Ventura County Agriculture Commissioner datasets. Within the areas of the expanded model domain, open space along the SCR and other tributary channels, as well as agricultural land, occupy the majority of the land area. The Piru basin contains approximately 5,920 acres of agricultural land (54% of total basin area), the Fillmore basin contains approximately 12,430 acres of agricultural land (55% of total basin area), and the Santa Paula basin contains approximately 10,660 acres of agricultural land (54% of total basin area). Citrus and avocados remain the predominant crop for all three basins – with citrus having been more so historically. Over the past 20 years the Piru basin has seen a significant conversion from citrus to row crops. Over the same time-period, the Fillmore basin also saw a significant conversion from citrus to row crops, particularly in the Bardsdale area on the south side of the SCR. Although less significant than in the Piru basin within the past decade, both the Fillmore and Santa Paula basins have seen an increase in the conversion from citrus to avocados, as well as major expansion of avocado acreage up the hillsides adjacent the valley floor in recent years.

2.2 CLIMATE

According to the updated Köppen-Geiger climate classification system (Rubel et al., 2017), the climate type for the study area is classified as warm-summer Mediterranean (Csb), characterized by warm, dry summers and cool winters with variable precipitation (i.e. sometimes wet). Santa Paula air temperature data from 1951- 2008 (available record period for National Climatic Data Center site number 7957) had a mean daily minimum air temperature of 48 degrees Fahrenheit, mean daily maximum air temperature of 74 degrees Fahrenheit, record minimum daily air temperature of 25 degrees Fahrenheit, and record maximum daily air temperature of 109 degrees Fahrenheit. The Fillmore and Piru basins typically show similar temperature trends, but minimum and maximums do vary slightly compared to the Santa Paula basin due to the increased elevation and a more inland location up the SCR valley and away from the coast. Long-term precipitation datasets covering the extent of the three additional groundwater basins (Figure 2-2) show similar statistics representing overlapping periods (Table 2-2).

Figure 2-4 shows the time-seies for annual (Water Year) precipitation totals for Santa Paula Gage 245 from water years 1850 – 2019 as well as the 5-year moving average. This plot highlights the decadal variability that is present within the study area, with wet periods bracketed by dry periods that range from several years to a decade. Several major wet years within the 1985-2015 calibration period drive the 5-year moving average far above the long-term average of 16.8 inches for the Santa Paula Gage 245 (Table 2-2). The Regional Model used precipitation data from 70 rain gauges in the region, which were used to interpolate monthly precipitation across the study area. The monthly totals were then distributed evenly across the month for estimates of direct recharge from precipitation (see section 3.5.2.3).

2.3 SURFACE WATER HYDROLOGY

The interaction between surface water and the underlying groundwater basins in the study area plays a significant role in the occurrence, movement, and quality of groundwater. In particular, the SCR flows westward into Ventura County (and the study area) from Los Angeles County, and receives large volumes of water from several primary tributaries within the groundwater basins of the study area, including Piru Creek, Sespe Creek, and Santa Paula Creek (Figure 2-1). Two smaller tributaries to the SCR are also gaged (Hopper Creek and Pole Creek), however many smaller tributaries from the surrounding mountains and drainages are ungaged (Figure 2-5). Surface water flowing in the SCR can percolate downward and recharge the underlying groundwater basins within the study area. In addition to United’s Freeman Diversion Facility, there are several smaller active diversions for agricultural irrigation along the SCR. Availability and the quality of historical data on diversion rates for these smaller diversions is highly variable. Each of these subjects is discussed below in more detail.

2.3.1 SANTA CLARA RIVER

Downward percolation of surface flows in the SCR is the primary source of recharge to each of the groundwater basins within the study area. Its watershed extends well beyond the study area, draining a total area of 1,625 square miles (Figure 2-1). The primary source of surface water flows in the SCR within the study area is surface runoff from the largest tributaries discharging into the main channel (Piru Creek, Sespe Creek, and Santa Paula Creek) and surface flow entering the Piru Basin at the Los Angeles/Ventura County line (Figure 2-5). Flow in the SCR can be described as interrupted perennial flow, with certain reaches being predicably wet or dry in most years (SFEI, 2011).

At the eastern portion of the model domain, the Piru basin adjoins the SCR Valley East Subbasin (Eastern basin) at the Ventura/Los Angeles County Line. The USGS has maintained daily streamflow records near this location dating back to 1952. USGS streamflow gage 11108500 at Blue Cut ceased operation in 1996 after the USGS streamflow gage 11109000 was installed approximately 2.75 river-miles downstream at the Las Brisas Bridge. Streamflow in the reach between these two locations is observed to be fairly stable and the alluvial channel deposits are fairly thin, allowing for a reasonable assumption that flow consistency can be considered to exist between the two measurement locations. Daily data from these USGS gages was obtained from these gages and used as input for streamflow entering the eastern boundary of the Regional Model domain for daily simulations. Streamflow statistics for calendar years 1985 – 2015 are shown in Table 2-3.

United's Freeman Diversion is located 25 miles downstream (west-southwest) of the Los Angeles County line, approximately 1.5 river-miles upstream from where the SCR channel exits the Santa Paula groundwater basin, and approximately 11 miles inland from the Pacific Ocean. United maintains daily observations of streamflow and diversions at Freeman Diversion. The average annual discharge (water years 1950 to 2015) of the SCR at the Freeman Diversion is 266 cubic feet per second (192,400 acre-feet per year [AFY]). However, annual average discharge of the SCR, like most largely ephemeral streams in southern California, is highly variable, ranging from 6 cubic feet per second (4,100 AFY) in water year 1951 to 1,590 cubic feet per second (1,152,000 AFY) in water year 2005, as shown on Figure 2-6. Discharge also varies significantly on a monthly basis, generally peaking during the wet season (January to March), with lower and more consistent base flows occurring year-round in the Santa Paula basin during all but the driest years. More discussion on streamflow, diversions, and streamflow past Freeman Diversion in the model simulations is described in Sections 3.5.2.1 and 4.2.5 below. In addition to the stormflows that are present in the SCR flow regime, conservation releases that originate from Piru Creek are also present and discussed more in Section 2.3.2.

2.3.1.1 RISING GROUNDWATER AT BASIN BOUNDARIES ALONG THE SANTA CLARA RIVER

The Piru and Fillmore basins commonly discharge significant volumes of groundwater to the channel of the SCR when groundwater elevations near the basin boundaries are higher than the elevation of the river channel (DWR, 1956; Mann 1959; United, 2016). This “rising groundwater” commonly occurs near the boundaries between Piru and Fillmore basins, and between Fillmore and Santa Paula basins. These are locations where the groundwater basins are narrow, and geologic features at depth may also restrict regional groundwater flow down the valley. The water table may then intersect the ground surface elevation within the channel and the SCR, resulting in an increase in surface water flow (and a loss to the groundwater flow system). Measurements of rising groundwater at the Piru-Fillmore and Fillmore-Santa Paula basin boundaries are available for the period 2011-2019, which includes periods with high and low groundwater elevations. Observations were available for dry months only, as it is difficult to measure rising groundwater when streamflow is high and dynamic. For both basins, observed rising groundwater correlates well with groundwater elevations at selected wells, as shown on Figures 2-7 and 2-8. Locations of rising groundwater along the SCR in the study area are shown on Figure 2-9.

2.3.1.1.1 PIRU - FILLMORE BASIN BOUNDARY

The reach of the SCR within the “Piru narrows” is located about one mile upstream from the City of Fillmore (Figure 2-9), and displays perennial rising groundwater (a gaining stream reach) in most years. The gaining stream reach can extend upstream to the vicinity of Hopper Creek when the Piru basin is full, and the wetted channel reach retreats downstream towards the basin boundary as groundwater levels fall within in the basin. The channel of the SCR is commonly dry upstream of the boundary area in all but the wettest of years, and this area of the mid-Piru basin is sometimes called the “dry gap.” Streamflow at the western Piru basin boundary has been observed to go dry following a period of drought. The SCR channel at the basin boundary was dry in fall of 2014 and for much of calendar year 2015. This is a rare condition, directly related to drought conditions and resulting low groundwater levels in the Piru basin (Figure 2-7). Rising groundwater discharging from the Piru basin will often percolate back into the groundwater system within Fillmore basin, though during wet periods surface water may flow all the way to the confluence with Sespe Creek and on to the Santa Paula basin.

2.3.1.1.2 FILLMORE - SANTA PAULA BASIN BOUNDARY

Near the Fillmore - Santa Paula basin boundary exists another reach of the SCR that displays perennial rising groundwater (gaining stream conditions) even in dry years (Figure 2-9). The upstream extent of the gaining stream reach is greatest when water levels are high in the Fillmore and Santa Paula basins, and length of the wetted reach decreases as groundwater elevations fall in the Fillmore basin. This reach flowed continuously during the dry conditions experienced in calendar years 2014 and 2015. Available manual stream gaging data collected by United near the basin boundary suggest that surface water infiltration in this reach of the SCR is limited, and several variables (e.g., evapotranspiration, diversions for irrigation, interaction with the alluvial aquifer) remain difficult to quantify (UWCD, 2013). Additionally, river percolation under high-flow conditions remains undetermined, as channel conditions make high-flow measurements difficult to obtain. Higher percolation rates would be anticipated when flood flows inundate wider areas within the floodplain, although the duration of flood inundation is generally limited to a maximum of a few days per year (UWCD, 2013).

2.3.2 PIRU CREEK

Piru Creek is within the study area and flows over basin alluvial deposits just downstream from Santa Felicia Dam (SFD) (Figure 2-5). The USGS streamflow gage 11109800, with a drainage area of 425 square miles of the Piru Creek watershed, is located just downstream of the SFD penstocks. The gage is located upstream of the confluence from the SFD spillway channel, which receives flow only in the wettest conditions (the most recent spill event was in 2005). Daily data from the USGS gage at this location records releases from SFD and is used as input for streamflow entering into the Regional Model domain for daily simulations. Annual average discharges at this gage, with SFD spill data from an active USGS gage located just above Lake Piru, was added to the lower USGS gage data; therefore, annual SFD spill volumes are included in Tables 2-3 and 2-4.

2.3.2.1 LAKE PIRU CONSERVATION RELEASES

United’s conservation releases from Lake Piru are conducted to provide groundwater recharge to the Piru, Fillmore, Santa Paula and Oxnard basins at times when natural runoff in the SCR watershed is limited. United contracts with the USGS to maintain the gage and records for daily release discharge volumes from Lake Piru. The conservation releases also help to sustain groundwater underflow that exists between the downstream groundwater basins, including the Piru, Fillmore, and Santa Paula basins, as well as the Mound and Oxnard basins. Released water that does not percolate into the Piru and Fillmore basins flows downstream to the Santa Paula basin, and is diverted at the Freeman Diversion for subsequent surface water deliveries and managed aquifer recharge operations in the Oxnard basin. The conservation releases typically span over a month to several months in order to optimize the recharge in the downstream groundwater basins.

Table 2-5 shows the measured distribution of released water to each basin for United’s conservation releases from 1999 through 2015. Most of the released water is natural inflow from the Piru Creek watershed, but in many recent years a portion of the released water is imported State Water Project water (State Water) purchased by United and conveyed from storage in Pyramid Lake by way of middle Piru Creek (UWCD, 2014). Natural inflows originating from the portion of the watershed upstream of Pyramid Lake are mixed with State Water stored in Pyramid

Lake before being released to middle Piru Creek under the current inflow-outflow regime. Therefore, releases to middle Piru Creek often have a significant percentage of State Water, whether they consist of natural flows from the watershed or State Water purchased by United.

Due to drought conditions and low inflows into Lake Piru, United did not perform conservation releases between 2013 and 2015. The last time prior to 2013 that there was no conservation release was during drought conditions in 1990. United is, however, required to release water continuously to maintain fish habitat in lower Piru Creek. Current habitat water release requirements range between 7 and 20 cfs, depending on cumulative annual rainfall at the Piru-Temescal Guard Station rain gage at Lake Piru (Ventura County gage #160; see Figure 2-2) (UWCD, 2012). Most of the habitat water releases recharge to the Piru basin. Piru Mutual Water Company and Rancho Temescal operate diversions on lower Piru Creek that divert a portion of the creek flow for agricultural uses, as discussed in more detail in Section 2.3.8.

2.3.2.2 PIRU SPREADING GROUNDS

United's Piru Spreading Grounds are located just west of Piru Creek adjacent the town of Piru (Figure 2-5) and sometimes receive diversions from Piru Creek for recharge into the underlying groundwater flow system. Details regarding this United operation during the calibration period is detailed further is Section 2.3.8.1, below.

2.3.3 HOPPER CREEK

Hopper Creek is a tributary to the SCR within the Piru basin (Figure 2-5). USGS streamflow gage 11110500, with a drainage area of 23.6 square miles, drains a steep watershed directly into the SCR at a location about halfway between the confluence of Piru Creek with the SCR and the Piru basin's western boundary with Fillmore basin. Daily data from the USGS gage was obtained from this location and used as an input for streamflow entering into the Regional Model domain for daily simulations. Discharge statistics for calendar years 1985 – 2015 are shown in Table 2-3. Preliminary measurements indicate that percolation from Hopper Creek is minimal.

2.3.4 POLE CREEK

Pole Creek is a tributary to the SCR within the Fillmore basin (Figure 2-5). Ventura County Watershed Protection District (VCWPD; https://vcwatershed.net/hydrodata/) streamflow gage 713 is located northeast of the City of Fillmore and drains a small and steep watershed with an area of 8.09 square miles. Much of the eastern areas of the City of Fillmore are located on the Pole Creek alluvial fan. An engineered creek channel now turns southward once the creek emerges from the foothills and passes under Highway 126 and into a large sediment capture basin before flowing into the SCR main channel. Daily data from the VCWPD gage was obtained from this location and used as input for streamflow entering into the Regional Model domain for daily simulations. Discharge statistics for calendar years 1985 – 2015 are shown in Table 2-3.

2.3.5 SESPE CREEK

Sespe Creek drains a large (252 square mile) undeveloped watershed within the Los Padres National Forest, located north of the study area, and flows into the Fillmore groundwater basin from the north (Figures 2-1 and 2-5). Agricultural developments are located along the banks of Sespe Creek as it enters into Fillmore basin, and the City of Fillmore is located further downstream on its eastern banks. Infiltration of surface flows in Sespe Creek is a major source of recharge to the Fillmore basin on the Sespe Fan alluvium as well as within the SCR channel. Measured percolation rates along Sespe Creek range from approximately 2 cfs to 15 cfs, for observed discharges at the mouth of the canyon entering the Fillmore basin ranging from about 10 cfs to over 100 cfs (DWR, 1933). The USGS streamflow gage (USGS 11113000, “SESPE C NR FILLMORE”) is located near where Sespe Creek enters the Fillmore basin, with measurements dating back to 1911. Historically a diversion for the Fillmore Irrigation Company was located upstream of USGS streamflow gage and upstream of the Fillmore basin boundary. Water was diverted and delivered downstream to the agriculture fields within the Fillmore basin along the western banks along Sespe Creek. An old USGS stream gage was located in the diversion canal (USGS 11112500, “FILLMORE IRR CO CN NR FILLMORE CA”), and an additional gage recorded the combined streamflow and diversions (USGS 11113001, “SESPE C + FILLMORE IRR CO CN NR FILLMORE CA”). However, data gaps are present within all of these available records within the 1985-2015 simulation period, and these were filled as estimates by United on a daily basis as part of the Regional Model development using: 1) a correlation developed between Sespe Creek and Santa Paula Creek gages, or 2) USGS gages 11113001 and 11112500 records (Table 2-6). Diversions by the Fillmore Irrigation Company ceased in 2007. Diversion values and data gaps are further detailed in Section 2.3.8.2. Final discharge statistics for calendar years 1985 – 2015 are shown in Table 2-3.

2.3.6 SANTA PAULA CREEK

The watershed of Santa Paula Creek (Figure 2-5) drains approximately 45 square miles, and much of the area consists of steep, mountainous terrain. The steep terrain tends to produce significant runoff, and the erodible sedimentary rocks of the region produce high sediment loads during flood events (Stillwater Sciences, 2007a and 2007b). The alluvial fan at the mouth of Santa Paula Creek is completely developed, with agricultural land uses dominant (until recently) on the east bank and residential development in and adjacent the City of Santa Paula the dominant land use on the west bank. Industrial land use dominates in the areas south of the railroad bridge. The high flows and high sediment loads of Santa Paula Creek resulted in persistent flooding problems in the lower reach of the creek since the time the area was first developed (HDR CDM, 2012). Historically, percolation rates in lower Santa Paula Creek were similar to the Sespe Fan in the Fillmore basin; however, as a result of flood control projects constructed by the U.S. Army Corps of Engineers in the late 1990s, which included channelization and lining, little to no percolation now occurs in lower Santa Paula Creek (UWCD, 2013). Daily data from the USGS gage was obtained from upstream of this location and used as input for streamflow entering into the Regional Model domain for daily simulations. Discharge statistics for calendar years 1985 – 2015 are shown in Table 2-3. The USGS gauging station is located upstream from Canyon Irrigation's Harvey Diversion, so estimates of Santa Paula Creek flow reaching the SCR based on gage data are generally thought to be higher than the flows in the lower reach. Diversions from Santa Paula Creek are accounted for and described in Section 2.3.8, below.

2.3.7 MOUNTAIN FRONT RECHARGE AND UNGAGED WATERSHEDS

In addition to the SCR main channel and associated tributaries detailed above, there are additional watershed areas in the model expansion area representing 118.10 square miles of ungaged runoff and mountain front recharge from the mountain slopes bounding the study area to both the north and the south (Figure 2-5; not shown are 8.55 square miles of additional ungaged watershed that are related to Mound basin following the expansion to 2019 DWR groundwater basin boundaries). Ungaged runoff may percolate into the ground along the runoff channel or reach the SCR channel. The range for previous estimates for mountain front recharge is small compared to other major water budget components in the Piru, Fillmore, and Santa Paula basins, and values from previous studies for these basins are presented later in Section 2.6.1.

2.3.8 STREAMFLOW DIVERSIONS

The model expansion domain includes 14 surface water diversions based on water use records submitted to the State, in addition to United's Freeman Diversion (Figure 2-10). The reported active and historical diversions include:

- Camulos Ranch (SCR, Piru basin)
- Isola (SCR, Piru basin)
- Rancho Temescal 1 and 2 (Piru Creek, Piru basin),
- Piru Mutual (Piru Creek, Piru basin),
- UWCD Piru Spreading Grounds (Piru Creek, Piru basin)
- Fillmore Irrigation Company (Sespe Creek, Fillmore basin)
- Limoneira (minor; Boulder Creek, Filmore basin)
- Beans Ranch (Boulder Creek, Fillmore basin)
- Canyon and Farmer's Irrigation Companies (Santa Paula Creek, Santa Paula basin)
- Zaragosa (minor; SCR, Santa Paula basin)
- Diversions related to Hyde Ditch (SCR, Santa Paula basin)

- Southfork Ranch (SCR, Santa Paula basin)
- UWCD Freeman Diversion (SCR, Santa Paula basin).

This section will provide a brief description for each diversion relating to their source and water destination locations for each. Diversion data was obtained from:

- previous investigation reports in the area (CH2M HILL/HGL, 2008),
- reported monthly data to California's State Water Resources Control Board's California Integrated Water Quality System available to the public (https://ciwqs.waterboards.ca.gov/ciwqs/ewrims/EWMenuPublic.jsp),
- communication with diversion owners/operators, and from United's records for the diversions operated by United.

California's State Water Resources Control Board began requesting diversions to be reported in the 1980s and 1990s, but available records suggest early compliance was fairly sparse. However, the State required that mandatory monthly diversion totals to be provided on an annual basis beginning in 2009, which resulted in much more recent diversion information being reported on a regular basis. Monthly records were acquired or estimated for diversions within the model domain, and reported monthly totals were distributed equally across the month for the daily simulations in the model. Available records for diversions are fairly consistent since 2009, but data gaps were identified and diversions estimated in some instances. Those estimation methods are briefly described below.

2.3.8.1 PIRU BASIN

The Piru basin contains diversions from the SCR as well as Piru Creek below Santa Felicia Dam (Figure 2-10). Both Camulos Ranch and Isola currently have, or previously had, operating diversions located in the eastern portion of Piru basin, upstream from the confluence with Piru Creek. Camulos Ranch was active through 2015, but Isola has not diverted any water since 2005. The Camulos Ranch diversion has records available over the majority of the 1985 – 2015 simulation period (1985 – 2005, 2010 – 2013). In order to fill data gaps for the Camulos records (2006-2009, 2014-2015), a ratio of reported monthly diversions to observed streamflow in the SCR upstream of the diversion (USGS gages 11108500 and 11109000) was calculated for all months with data. The data gaps were filled with either individual average monthly diversions (i.e. January average, February average, …, December average) or the individual average monthly ratio was used to set as a limit for estimated diversions when compared to individual average monthly diversions. This method ensured that representative diversions were estimated and that diversions in excess of historical diversion to streamflow ratio were not applied. Camulos irrigates approximately 770 acres and supplements groundwater well use with the diverted water, with annual diversion rates, from 1985 – 2015 provided in Table 2-7. The Isola diversion ceased operating after 2005 and had monthly records available from 1985 – 2005 through the CH2M Hill/HGL (2008) documentation (Table 2-7). Isola irrigated approximately 210 acres and supplemented groundwater use with the diverted surface water.

Rancho Temescal has two diversions on Piru Creek which were not used prior to 2002 (no data reported to the State). The first diversion is located immediately downstream of Santa Felicia Dam and supplements groundwater use to irrigate approximately 242 acres to the west of Piru Creek. The second diversion is located further downstream, nearby Piru Mutual's diversion, and supplements groundwater well use to irrigate approximately 314 acres to the east of Piru Creek. The annual diversion rates from 2002 – 2015 for these two diversions are provided in Table 2-7. Piru Mutual Water Company's diversion is located on Piru Creek in the same location as Rancho Temescal's second (lower) diversion. Piru Mutual has records available over the majority of the 1985 – 2015 simulation period (1985 – 2005, 2011 – 2013). In order to fill data gaps for these Piru Mutual records (2006-2010, 2014-2015), the same method described above for Camulos Ranch was used for Piru Mutual data, but with the USGS gage 11109800 located on Piru Creek, and with Santa Felicia Dam Spills included as well (Tables 2-3 and 2-4). Piru Mutual irrigated approximately 546 acres with the diverted water.

United used to divert water from Piru Creek to spreading grounds in order to recharge groundwater supplies. United's Piru Spreading Grounds are located just west of Piru Creek (Figure 2-5) and received diversions from Piru Creek for recharge into the underlying groundwater system. United maintains records for daily diversions, and these records were used for implementation into the Regional Model. The Piru Spreading Grounds diversion was active from 1985 – 2008, with annual diversion rates provided in Table 2-7. On average, nearly half of the annual diversion flows by volume were diverted in April, May, and June, often during periods when Lake Piru was spilling. The Piru Spreading Grounds have not been used since 2008 due to permitting restrictions at the facility (the diversion structure lacks a fish screen).

2.3.8.2 FILLMORE BASIN

Fillmore basin has three diversions, with the largest being historically operated by the Fillmore Irrigation Company. The Fillmore Irrigation Company diversion is located outside of the groundwater basin boundary on Sespe Creek, and applies water for agricultural application along the northern portion of the basin west of Sespe Creek (Figure 2-10), with a service area around 1,105 acres. Since 2007 no water has been diverted by the Fillmore Irrigation Company, and the dataset of the annual records prior to 2007 are incomplete. Diversion values and data gaps for Fillmore Irrigation Company diversion are provided in Tables 2-7 and 2-8. As described in Section 2.3.5, above, there were several USGS gages available related to Sespe Creek and the Fillmore Irrigation Company's diversion. Similar to filling data gaps for Sespe Creek streamflow, data gaps for the Fillmore Irrigation Company's Diversion were filled on a daily basis using 1) a correlation developed between rainfall at VCWPD gage 171 (Figure 2-2) Sespe Creek and or 2) USGS gages 11113001 and 11112500 records. The remaining two diversions are located in the same area, where Boulder Creek drains a small watershed (5.57 square miles) into Fillmore basin from the north (Figures 2-5 and 2-10). Bean's Ranch is the larger of the two diversions over the simulation period (Table 2-7) and applies water for agriculture and livestock along the northern edges of the

Fillmore basin. Monthly records are fairly complete after 2002, and data gaps before that (1985-1993 and 1996-2001) were filled with average annual totals reported for 1994 and 1995. In the vicinity as the Bean's Ranch diversion, Limoneira is reported to also have historically had a diversion for application to about 126 acres for agricultural land application in the northern portion of Fillmore basin. Limoneira records show periodic diversions from 2000 – 2015 (Table 2-7). Records are limited prior to 2000 and it was assumed to no diversions occurred except for the years when Limoneira provided data to the State.

2.3.8.3 SANTA PAULA BASIN

Santa Paula basin includes diversions from the SCR as well as Santa Paula Creek (Figure 2-10). The Canyon Irrigation Company operates the Harvey Diversion, located on Santa Paula Creek downstream of the USGS streamflow gage and just upstream from the confluence of Santa Paula Creek and Mud Creek. Mud Creek drains a minor watershed east of the diversion location. Through United correspondence with Canyon Irrigation Company, a complete monthly record set was provided from the operators for the 1985 – 2015 time-period (Frank Brommenschenkel personal communication, January 2020). Canyon Irrigation Company diverted water to their service area (approximately 784 acres). Beginning in 2001, Canyon Irrigation Company began selling and distributing diverted water from the Harvey Diversion on Santa Paula Creek to the Farmer's Irrigation Company for conjunctive use across their service area (approximately 3,178 acres) located across much of the western portion of the Santa Paula basin. Annual diversion rates, from 1985 – 2015 are provided in Table 2-7 for both the Canyon Irrigation Company and the Farmer's Irrigation Company.

In addition to the Harvey Diversion on Santa Paula Creek, there are four known diversions located along the SCR in Santa Paula Basin, three of which are on the south side of the river where groundwater production is more limited (Figure 2-10). There is a minor diversion that reportedly applied water for agricultural land application on the north side of the SCR, beginning in 2011 (Zaragosa Diversion, Table 2-7). Downstream from that location, water is diverted from the SCR through what was historically known as the Hyde-Turner Ditch, for application to the agricultural land. The Hyde-Turner Ditch diversion more recently consisted of the parties of Carmichael, Furnas, Green Thought LLC, the Wishtoyo Foundation, and several predecessor land owners and diversion right holders related to the Hyde-Turner Ditch. Collectively, the Hyde-Turner Ditch diversions have historically applied diverted water for agriculture purposes to approximately 346 acres located along the south bank of the SCR within the Santa Paula basin. Annual diversion rates, from 1985 – 2015 are provided in Table 2-7.

Further downstream is the Southfork Ranch diversion, which diverts water out of the SCR and applies it mainly to agricultural land with some livestock use, but all application is located outside of the Santa Paula basin (Figure 2-10). Reported data was available from 2012-2015, but reporting was infrequent for years prior. Data gaps were filled with annual averages and linear interpolation using the years where reported data was present (1991-1992, 1994, 2008). Annual diversion rates, from 1985 – 2015 are provided in Table 2-7.

Lastly, United’s Freeman Diversion is located within Santa Paula basin, where diversions are directed downstream by canals to major artificial recharge facilities for replenishment of groundwater within the Oxnard groundwater basin (Figure 2-10). United has complete records for this diversion and annual diversion rates, from 1985 – 2015, are provided in Table 2-7.

2.3.9 IMPORTED SURFACE WATER

Wastewater discharges to the SCR in Los Angeles County, most notably from the Valencia Water Reclamation Plant located adjacent to the SCR near Interstate 5, have contributed to surface water flows in the SCR in the study area. A large percentage of these flows is comprised of State Water that is imported into the SCR Valley East basin within Los Angeles County (4-004.07; Figure 1-2). Urban development has continued since State Water was first imported into the basin beginning in 1980, and the community relies on local groundwater in addition to imported State Water supplies (CH2M HILL/HGL, 2006). Figure 2-11 shows historical annual surface water flows for the SCR near the Los Angeles/Ventura County Line plotted with historical precipitation from a Piru basin gage. Related to the increase in surface flows from upstream development, subsurface underflow into Piru basin has been estimated to have increased from around 240 AFY, representative of 1930s – 1970s (Mann, 1959; DWR, 1974 and 1975) to approximately 1,100 AFY after the 1980s (HydroMetric’s 2008 analysis performed from United of CH2M HILL/HGL [2008]). The basin boundaries related to this underflow comparison are similar; however, it is noted that significant basin boundary changes shifted the current 2019 DWR boundaries closer to the Los Angeles/Ventura County Line and result in substantial increase in underflow for the current effort because the aquifer thickness at the new boundary is thicker and capable of transmitting larger volumes of water downstream within the subsurface (UWCD, 2020). Continuous surface water flow sometimes extends across this “dry gap” (which commonly extends from near the historic Rancho Camulos to around Cavin Road) during the wet season when runoff from storms generates enough flow to overcome the significant infiltration capacity of this reach.

Additionally, United is party to a water conservation agreement between the California Department of Water Resources and the Downstream Water Users (DWUs), which dates back to 1978. The DWUs consist of United, Los Angeles County Waterworks District, Newhall Land and Farming (currently FivePoint), and Valencia Water Company (currently Santa Clarita Valley Water Agency). The program is designed to hold back flood flows in Castaic Lake (Figure 1-1) and release them at a later date (typically in the spring) in a manner that allows the flows to percolate in the basins downstream of the dam, benefiting the DWUs with water rights that predate construction of Castaic Lake (United, 2014). United represents the DWUs in coordinating the storage and release of water with DWR, which operates Castaic Lake, and by monitoring the associated releases to ensure that the flows are optimally benefiting the basins. In most years the majority of released water that makes it to the Ventura County line percolates in the SCR channel within the Piru basin, while in some years surface flow may make it to the Fillmore basin where the remainder percolates. Castaic Lake releases generally do not occur during dry years, for example during the recent drought from 2012-2016.

Near the western boundary of the model domain the City of Ventura's Water Department (Ventura Water) obtains approximately 5,000 AFY of surface water from the Ventura River watershed (sources include water from Casitas Municipal Water District and Ventura Water's facilities at Foster Park) for blending and distribution throughout its service area, which lies mostly within Mound basin, but also includes portions of northern Oxnard basin and western Santa Paula basin. The quantity of water reported above was averaged for the period from 1985 to 2015 (Ventura Water, 2020). This imported surface water was not included in United's Coastal Plain Model (UWCD, 2018); however, it is included in the current model. Only a small fraction of this imported water reaches the underlying aquifers in the Regional Model domain as municipal and industrial return flows (see Section 2.7 below).

2.3.10 WASTEWATER TREATMENT PLANT DISCHARGES

There are four water treatment plants located within the expanded study area; their locations are shown on Figure 2-12.

The Piru Wastewater Treatment Plant (WWTP) is located west of the town of Piru and on the east bank of Hopper Creek. Plant discharge flows through a pipeline that runs parallel with Hopper Creek toward the confluence with SCR. Plant effluent discharges into 2 percolation basins located adjacent the SCR main channel where the effluent percolates into the subsurface. Monthly reported data is provided to the State Water Resources Control Board (https://geotracker.waterboards.ca.gov/) on an annual reporting basis, but that reporting was not as complete prior to the 2000s. There were several data gaps in the Piru WWTP records (1985-1989, April 1993, October-December 2000, and 2005-2006). These data gaps were filled with representative monthly averages. Monthly records were acquired or estimated and monthly totals were equally distributed across the month for implementation into daily simulations. The average annual discharge for the Piru WWTP is provided in Table 2-9.

The Fillmore Water Reclamation Plant (WRP) was located along the SCR main channel near the southwestern edge of the city until 2008, when it was relocated about a half-mile northwest, near the Sespe Creek confluence with the SCR (Figure 2-12). Prior to 2008, the Fillmore plant discharged its effluent onsite into percolation basins adjacent to the SCR, and directly into the SCR at times. Following new plant construction and relocation in 2008, about one-third of the discharge is used to irrigate public space within the City of Fillmore through shallow drip lines. The remaining effluent is discharged into onsite percolation basins located near Sespe Creek at the west end of River Street. Similar to Piru WWTP records, there were some data gaps in the available Fillmore WRP reported records (1985 – 1997, 2000, 2005-2006, July 2007 – December 2008), and these also were filled with representative monthly averages. Because of the limited historical data regarding discharges to the SCR from the Fillmore WRP, it was assumed that discharge prior to 1998 went to the WRP percolation ponds only. The average annual discharge for the Fillmore WRP is provided in Table 2-9.

The Santa Paula Water Reclamation Facility (WRF) is located on the southwestern edge of Santa Paula about one-third of a mile north of the SCR main channel (Figure 2-12). Up until 2010, this WRF discharged treated wastewater directly into the SCR via the Peck Road drain. Due to discharge permit issues related to water quality, the City of Santa Paula worked to construct an improved facility that now percolates to discharge basins setback at least 0.15 miles away from the SCR. Average annual discharge records for the Santa Paula WRF are shown in Table 2-9.

The Todd Road Jail Wastewater Treatment Plant (Todd Rd. Jail WWTP) that is located north of the SCR near the southern end of Todd Road, downstream from the Santa Paula WRF in Santa Paula basin (Figure 2-12) and began operations in 1995. Reported records were not available prior to 2011 and representative monthly averages were used to fill the data gap. The average annual discharge for the Fillmore WRP is provided in Table 2-9.

2.3.11 RIPARIAN VEGETATION

The SCR and its tributaries contain riparian vegetation habitat for various classes of vegetation, including forest, woodland, shrubland, herbaceous, and *Arundo donax*, which together extend across the river corridor, as shown by Stillwater Science's 2016 (Stillwater Sciences, 2019) mapping of the SCR vegetation (Figure 2-9). Within the SCR, there with several expansive and distinct reaches that are wide sandy channel with minimal in-channel or bank vegetation. These "dry gaps" occur in areas where rising groundwater is absent. Specifically related to the hydrogeologic conceptual model, riparian vegetation consumes water through evapotranspiration (ET). Previous estimates for the range of ET rates within the SCR valley in Ventura County have ranged from 1.1 ft/yr (DWR, 1974 and 1975) to 5.2 ft/yr (Mann and Associates, 1959). Studies relating to mixed riparian communities of arid and Mediterranean-type climates have estimated ET rates ranging from 0.36 ft/yr to 5.2 ft/year (UCLA, 2011). Additionally, *Arundo donax* is a reed-like invasive species that is of special interest to natural resource and water managers because of the amount of habitat and potential amount of water that it utilizes. This invasive species has some presence within the entire expansion domain, with the largest infestations occurring in reaches with perennial surface water and shallow groundwater (Stillwater Sciences, 2019). Studies related to *Arundo donax* ET rates have reported estimates ranging from 0.8 ft/yr to as much as 58 ft/yr (The Nature Conservancy, 2019; UCLA, 2011), with the majority of the studies presenting average annual consumption of 10 ft/yr or less (The Nature Conservancy, 2019; Table 1).

2.4 GEOLOGY

Southern Ventura County is located in the Transverse Ranges geomorphic province of California. Within this province, the axes of mountain ranges and valleys are oriented east-west rather than northwest-southeast as is typical in the adjacent Peninsular and Coastal Ranges geomorphic provinces. Most of the study area overlies an elongate, structurally complex syncline that trends west-southwest to east-northeast, referred to as the Ventura structural basin (Yeats and others, 1981). Active thrust faults border the Ventura structural basin, causing uplift of the adjacent mountains while the basin continues to deepen.

The groundwater basins within the study area include the broad extent of the active floodplain of the SCR, located along the southern portion of the valley, with a generally west-southwest to east-northeast oriented axis from Ventura County line to the Saticoy area, where the SCR enters the Oxnard coastal plain and then at Highway 101 trends west to its mouth near Ventura Harbor. The Piru and Fillmore groundwater basins are considered unconfined basins with large extents of alluvium deposited above thick Pleistocene freshwater-bearing deposits of the Saugus and San Pedro Formations (United, 2017). The Saugus Formation is identified by Dibblee and other investigators, and constitutes the fluvial silt, sand, and gravel deposits of the upper San Pedro Formation (Dibblee, 1990 and 1991; USGS, 2003). Past investigations (Mann, 1959, USGS, 2003, 2011, CH2M HILL/HGL, 2006) have referred to both the Saugus Formation and the San Pedro Formation; this report will use the Saugus/San Pedro Formation naming convention. The Piru and Fillmore basins are largely the extent to which the Saugus/Upper San Pedro Formation is mostly composed of continental fluvial deposits, and lack marine environment deposition more common to the Santa Paula, Mound and Oxnard basins to the west.

Located to the west and downstream of the Piru and Fillmore basins, Santa Paula basin's stratigraphy is also mapped as alluvial deposits overlying the Saugus/San Pedro Formation (Mann, 1959, DBS&A and RCS, 2017). The alluvial deposits in all three basins facilitate interaction between the groundwater and surface water flow systems. However, the Santa Paula basin is believed to be semi-confined due to the presence of thick clay deposits below the alluvium in much of the eastern portion of the basin. Confining clay deposits are observed near the confluence of the SCR and Santa Paula Creek, and channel modifications for flood control purposes likely has reduced the amount of surface water that directly percolates as groundwater recharge along lower Santa Paula Creek (UWCD, 2011).

2.4.1 GEOLOGIC UNITS PRESENT IN STUDY AREA

Hydrostratigraphic units (strata) exposed at land surface within the study area are commonly classified as follows, from youngest (top) to oldest (bottom):

- Recent (active) stream-channel deposits along the present course of the SCR and its tributaries;
- Recent surficial and colluvium deposits along the flanks of the basins;
- Undifferentiated younger alluvium of Holocene age, covering much of the Piru and Fillmore basins and a portion of the Santa Paula basin;
- Undifferentiated older alluvium of Holocene to late Pleistocene age, underlying the undifferentiated younger alluvium of Holocene age across much of the Piru, Fillmore, and Santa Paula basins;
- Semi-consolidated alluvial gravel, sand, and clay deposits of the Saugus/San Pedro Formation

These exposed strata in the study area were classified based largely on their hydrogeologic characteristics, as these are the units that typically bear freshwater in usable quantities and are of primary interest for groundwater supply. Other researchers have divided these deposits in other, equally valid ways, based on their geomorphological or other characteristics (e.g., Mukae and Turner, 1975; USGS, 2003).

Older (lower) strata, which are regarded as hydrologic bedrock in the region, or non-water bearing, are also described. These strata include (following the descriptions of the USGS [2011]):

- Marine shales, mudstones, siltstones, and sandstones of the Santa Barbara Formation, of Late Pleistocene age;
- Marine siltstones, sandstones, and conglomerates of the Pico Formation, of Pliocene or early Pleistocene age;
- Shales and sandstones of the Monterey Formation, of late Miocene age
- Terrestrial sandstones and claystones of the Sespe Formation, of Oligocene age

It is important to distinguish the geologic strata from the hydrostratigraphic units which are described in subsequent sections. The strata described above, which are present in the study area, are classified by geologic characteristics including age and depositional setting. The hydrostratigraphic units were identified and classified by distinct hydrogeologic properties as discussed in Section 2.5 below, and do not always necessarily conform to the geologic strata classifications.

2.4.2 FAULTS

Geologic faults can be pathways or barriers for groundwater movement. In crystalline or cemented rocks, faults can create fractures that act as conduits to groundwater flow. However, the aquifers within the study area consist of semi-consolidated sedimentary formations, which tend to create fine-grained, low-permeability “smear zones” when faulted, effectively producing weak to strong barriers to groundwater flow, particularly in the deeper aquifers. Within the study area, the trend of many, but not all, of the faults is west-southwest to east-northeast, consistent with regional structural trends (Figure 2-13). The Oak Ridge, San Cayetano, and Country Club Faults have previously been identified as significantly limiting or diverting groundwater flow (Mann, 1959; Mukae and Turner, 1975). The study area is flanked to the south by the Oak Ridge fault, a steeply south-dipping reverse fault, and to the north by the San Cayetano fault, a north-dipping thrust/reverse fault (Mukae and Turner, 1975). The southern and western portion of the Santa Paula basin boundary is bounded by the Country Club fault, a steeply south-dipping reverse fault which acts as a barrier to groundwater flow (Mukae and Turner, 1975, USGS, 2003).

2.4.3 FOLDS

Similar to the faults in the study area, the axes of major anticlines and synclines in the sedimentary strata tend to be oriented approximately west-southwest to east-northeast. Related to the discussion of faulting, above, the works of Mann (1959), USGS (2003), and other previous investigators provide more details on the potential effects of folds on groundwater flow within the study area.

The Ventura-Santa Clara basin syncline is recognized as the major fold feature within the study area. This feature, a result of north-south compressional forces, extends from Los Angeles County east of Piru basin to offshore near Ventura, CA. The synclinal axis trends west-southwest to east-northeast, and is generally oriented parallel with the SCR channel (Figure 2-13). To the north, the San Pedro Formation crops out at land surface and may receive recharge through precipitation or streamflow percolation. To the south, the syncline is in contact with non-water bearing rocks at the Oak Ridge Fault (Mukae and Turner, 1975).

The limbs of the folds are gently dipping within most of the freshwater bearing strata in the study area; therefore, it is unlikely that the folds themselves have a notable direct impact on groundwater flow. However, it is recognized that changes in thickness (which affects transmissivity), outcrop area (which affects where recharge occurs), and other hydrogeologic properties of strata can be indirectly influenced by fold geometry.

2.4.4 PIRU BASIN

Piru basin is a westward sloping alluvial strip that consists of recent and older alluvium underlain by the Pleistocene Saugus/San Pedro formations. The basin is bounded on the north and south by mountains composed of non-water-bearing formations. Piru basin is approximately 9.75 miles long and 1.75 miles wide (excluding the Piru Creek limb of the basin). The recent and older alluvium exists nearly basin-wide and is made up primarily of coarse sand and gravel. The recent alluvium ranges in thickness from approximately 20 feet near Blue Cut at the east end of the basin (underlain by non-water bearing Pico formation at the most eastern extent) to over 120 feet near the SCR channel; the thickness varies in the remainder of the basin. The older alluvium crops out in some areas as terrace deposits, but mostly occurs as a layer of variable thickness (up to 150 feet) under the recent alluvium.

The Saugus/San Pedro Formations are folded into a syncline with a west-southwest to east-northeast-oriented axis. These formations underlie the older alluvium, except at the east end of the basin where the older alluvium is underlain by impermeable Pico Formation. The San Pedro Formation consists primarily of permeable sand and gravel and can extend to a depth of approximately 8,800 feet, as interpreted from oil well electrical logs (Mann, 1959). Few water wells deeper than 700 feet currently exist in the Piru basin.

Three principal faults bound the Piru basin: The Oak Ridge fault to the south, and the San Cayetano and Camulos Faults to the north (Figure 2-13). These faults largely define the north and south basin boundaries, separating the aquifers from the adjacent non-water-bearing rocks. Thin “shoestring” alluvial deposits of Holocene to recent age, deposited in minor drainages and tributaries from upland areas, commonly overlie older formations that are displaced by these faults (Figure 2-13).

The channel of the SCR is constrained at the southern margin of the Piru basin by the alluvial fans of the tributaries entering the basin from the north. Downstream of the Las Brisas Bridge, east of Camulos Ranch in the eastern portion of the basin, the river channel broadens significantly. The percolation of surface water in the channel of the SCR is the largest source of recharge to the Piru basin. There are no known structural or stratigraphic barriers impeding recharge from the SCR in the Piru basin downstream of this area.

2.4.5 FILLMORE BASIN

The Fillmore basin is a wider (than the Piru basin), westward-sloping alluvial basin that consists of recent and older alluvium underlain by the Saugus/San Pedro Formation. It is approximately 9.5 miles long and 4.25 miles wide. The northern portion of the Fillmore basin in the area west of Sespe Creek is called the Sespe Upland (Figure 2-14). The Sespe Upland is characterized by steep south-sloping alluvial fan material, including complex terrace deposits, older alluvial fan deposits and recent alluvial fan deposits, which unconformably overlie the Saugus/San Pedro formation (Mann, 1959).

The Pole Creek Fan is located between Sespe Creek and the SCR and forms the northeastern portion of the basin underlying much of the City of Fillmore. This area is primarily composed of fine-grained alluvial fan material.

The area of the Fillmore basin located south of the SCR is covered by recent sand and gravel deposits from the SCR. The recent sand and gravel of the SCR near the Fillmore Fish Hatchery at the eastern boundary of the basin extend to a depth of about 60 feet, and the older alluvial material extends from depths of approximately 60 to 100 feet. In the Bardsdale area, the combined thickness of this alluvial fill is as much as 250 feet. At the downstream basin boundary near Willard Road, the recent alluvium is approximately 80 feet thick. West of the City of Fillmore, the recent alluvium of Sespe Creek is approximately 80 feet thick. The recent sand and gravel deposits associated with Sespe Creek and the SCR are highly permeable.

The Saugus/San Pedro Formation underlies most of the Fillmore basin and is folded into a syncline with a west-southwest to east-northeast oriented axis. Along the main axis of the syncline near the center of the basin, the Saugus/San Pedro Formation reaches a depth of 8,430 feet (Mann, 1959). The depth from which groundwater production is suitable for agricultural and urban use and can be reasonably extracted is considerably shallower than 8,430 feet. Few wells in the basin are deeper than 800 feet in the Fillmore basin with one notable exception discussed in subsequent section 2.5.6. At the western basin boundary, the Saugus/San Pedro formation extends to a depth of 5,000 to 6,000 feet.

The two principal faults that bound the Fillmore basin are the Oak Ridge Fault to the south and the San Cayetano Fault to the northeast (Figure 2-13).

The SCR and Sespe Creek are major surface water features in Fillmore basin. Infiltration of surface water in their channels and underflow from Piru basin are recognized as the major sources of recharge to the Fillmore basin. Significant structural or stratigraphic barriers that might impede recharge from either the SCR or Sespe Creek have not been identified.

2.4.6 SANTA PAULA BASIN

The Santa Paula basin is located downstream of the Fillmore basin and is bounded by the Sulphur Mountain foothills on the northwest and South Mountain on the southeast. The basin is elongated in a northeast-southwest orientation and slopes generally westward. It is approximately 10 miles long and 3.5 miles wide. The elevations of the surface of the valley fill deposits range from 130 feet above sea level (near Saticoy) to 270 feet above sea level near the City of Santa Paula. The major fresh water-bearing strata utilized for groundwater production are the San Pedro Formation and younger overlying river deposits of the SCR; alluvial fan deposits; and recent river and stream deposits (DBS&A and RCS, 2017; Mann, 1959).

Similar to Piru and Fillmore basins, sediments in Santa Paula basin have been warped into a syncline that is oriented in a northeast-southwest direction. To the south, the Oak Ridge fault forms a barrier to groundwater movement. To the north, a portion of the aquifer represented by the San Pedro Formation is exposed in an outcrop along the Sulphur Mountain foothills (Figures 2-13). The Santa Paula basin borders the Oxnard basin (Forebay area) to the southwest and the Mound basin to the west. To the east, the Santa Paula basin is in hydraulic connection with the Fillmore basin; underflow from Fillmore basin provides the largest portion of groundwater inflow to Santa Paula basin (DBS&A and RCS, 2017). Rising groundwater in the western Fillmore basin produces perennial surface flows in the SCR. However, during periods of extended drought, dry season flow may not extend downstream to the Freeman Diversion.

Hydrogen and oxygen isotope data, and other recorded data, indicate that the Santa Paula basin receives recharge from the SCR (USGS, 1999). However, thick clay deposits exist in the eastern portions of the Santa Paula basin. Other sources of recharge to the Santa Paula basin include: rainfall percolation through the San Pedro Formation outcrops that are exposed along the foothills to the north, percolation of streams crossing these sediments, and underflow from the Fillmore Basin (UWCD, 2013).

2.5 UPDATE OF HYDROSTRATIGRAPHIC CONCEPTUAL MODEL

Strata with distinct hydrogeologic characteristics are commonly referred to as hydrostratigraphic units (HSUs). United’s previously published groundwater flow model for the Oxnard coastal plain included 13 layers, which included seven aquifers and 6 aquitards (UWCD, 2018). In the coastal basins, the basal Fox Canyon Aquifer and Grimes Canyon Aquifer were designated as Layers 11 and 13, respectively. However, these aquifers do not extend into the Piru, Fillmore, and Santa Paula basins, and layering in the expanded model domain reflects these changes in the conceptual model, with United identifying and mapping just ten HSUs (six aquifers and four aquitards) in the expanded model domain. The revised model layering for the upper basins is compared the coastal basins model layering (for reference) in Tables 2-10 and 2-11. Figures 2-15 to 2-17 show the locations and areal coverage of the stratigraphic sections. Representative schematic cross sections are shown in Figures 2-18 to 2-22 that illustrate the relationships between the mapped hydrostratigraphic units within Piru, Fillmore, and Santa Paula basins.

The hydrostratigraphic model forms the basic framework required to define the geometry and layering of the aquifers and aquitards for the numerical groundwater flow model. Available borehole e-logs were reviewed to determine the depth and quality of the logs, and that locations of the wells were plotted appropriately. A subset of available e-logs (~575) was selected based on quality, depth and location/distribution; this subset was then digitized. The digitized logs were imported to RockWorks® (ver. 15), the software used to record aquifer picks, record relevant comments and construct cross-sections. Lines for cross-sections were identified in GIS, where shapefiles of oil well and water well locations, faults, basin boundaries, surface geology and other pertinent features were available to aid in selection of optimal section lines. Alignments were selected to intersect locations of known structural and stratigraphic change in the subsurface while utilizing as many e-logs as practical. Land surface elevations for the well heads with e-logs were determined based on the USGS National Elevation Data Set digital elevation model. E-logs from selected wells along the various sections were printed on plotter paper for identification of HSUs ("aquifer picks") and correlation of those units. Vertical exaggeration of the various plotted sections was determined by the depths of the well logs and the length of the section. Lithologic descriptions from additional wells along and near the lines of section were commonly noted on the working sections to help identify aquitards and aquifer units. Upon finalization of picks for a given section, depths of the various HSUs were entered into a RockWorks® database, along with notes supporting the unit picks, as necessary.

For the Piru, Fillmore, and Santa Paula basins, over 200 wells and control points were included in updating and refining the conceptual model. These well data were used to identify and determine the geometries of the HSUs within the basins. Elevations of the tops and bottoms of HSUs were then used to create digitally-interpolated elevation surfaces using Kriging methods. These elevation surfaces define the thickness and extent of the model layers within the model domain, as described in Section 3.

Additionally, 12 control points were manually added in specific areas to better define the geometry of known geologic structures. Generally, these control points were added near the basin boundaries or geologic features (such as faults) in order to accurately represent the boundary feature and terminate thinning stratigraphic units. Ten of the control points were added to the north of the basins, where faulting and folding result in units "pinching-out." A basal model layer was designated with one foot of thickness. Two control points in Piru basin located near the southern basin boundary also serve as basal layer points. Figures 2-15 to 2-17 show the locations and areal coverage of the stratigraphic sections.

The following subsections describe areas of importance and refinements in understanding of the hydrogeology in the upper basins as a result of United's effort in developing BCM 14.

2.5.1 EXTENT AND MERGENCE OF ALLUVIAL AQUIFERS

Throughout much of the Piru and Fillmore basins, thick sequences of alluvial sediments have been deposited as a result of differential stream erosion along the Ventura-Santa Clara basin syncline (Mann, 1959). The younger and older alluvial aquifer units are mapped as being continuous over much of the valley floor area of the basins and are understood to provide little impediment to vertical flow. The Piru and Fillmore basins are considered to be unconfined and these permeable alluvial deposits allow for water to move downward from recharge sources unimpeded. Layers 3 and 5, typically representing the younger and older alluvium respectively, are often merged (Layer 4 aquitard is absent) within the vicinity of the SCR channel and are generally laterally continuous east to west across all the basins of the SCR valley. These unconsolidated alluvial sediments unconformably overlie the Saugus/San Pedro Formation.

Alluvial sediments consist primarily of coarse sands and gravels, with some occasional finer-grained sediments. The older alluvium of late Holocene to Pleistocene age typically shows a greater occurrence of finer-grained lenses and more interbedding in the Piru and Fillmore basins, and somewhat less permeable sediments overall compared to the younger alluvium. Hydraulic conductivities and aquifer properties are described in subsequent sections.

Thickness of the alluvial aquifers vary throughout the basin (see Figures 2-18 through 2-22). Within the vicinity of the SCR channel, Layer 1 and 2 deposits are generally absent, and Layer 3 is mapped to ground surface. In the Santa Paula basin, Layer 3 is mapped to the surface within the active SCR channel, and northward to approximately Highway 126. North of the highway, Layer 1, alluvial fan and surficial colluvium deposits are commonly present to the base of the foothills, and often forms a surficial deposit on top of San Pedro formation outcrop in the foothills. However, in some areas of the upper basins, aquitards of various thickness and extent are mapped to exist between these young alluvial aquifers.

2.5.2 EAST PIRU ALLUVIUM

The eastern portion of Piru basin, near the Ventura and Los Angeles County line, has a scarcity of subsurface data compared with the rest of the basin. The limited well data in this area shows that the alluvium is thin and overlies the non-water bearing Pico Formation. United relied on geophysical log data and exploratory borings drilled by Geomatrix Inc. in 2006 and 2007 (Geomatrix, 2006, 2007). These data show the alluvium is just tens of feet thick at and near the County Line, with saturated thickness estimated to be around 5 feet just upstream of Blue Cut and thickening to around 25 feet east of the County Line. In this area, east of Piru Creek, Layer 1 is mapped as the terrace features and slopes near the basin boundary, and Layer 3 was designated as the active stream channel deposits. This allows for underflow into the basin and percolation of streamflow within the shallow sediments. Downstream of this area, the Pico Formation steeply plunges along the synclinal axis, and the alluvium that overlies the Saugus/San Pedro Formation becomes significantly thicker and wider in the main portion of the basin (USGS, 2003).

2.5.3 PIRU CREEK ALLUVIUM

Downstream of Santa Felicia Dam (Lake Piru), thin alluvial sediments overlie the Monterey and Pico Formations along lower Piru Creek to the mouth of Piru canyon, approximately where the

San Cayetano fault is mapped and overturned beds of the Saugus/Sand Pedro and Pico Formations are mapped in outcrop. The terraces and upslope deposits outside of the active stream channel were mapped as Layer 1, surficial colluvium and slope fill. The active stream channel was mapped as a thin alluvial Layer 3 to a depth of 20 to 30 feet below ground surface, based on lithologic data from wells 04N18W10C02S and 04N18W15M01S. An underlying Lower Saugus/San Pedro (Layer 9) was mapped where aquifer materials became more indurated, as indicated from lithologic records.

2.5.4 POLE CREEK FAN DEPOSITS

Near the mouth of Pole Creek, a thick deposit of interbedded and poorly-sorted clay and cobbles was observed in the lithologic log of well 04N19W30H01S. This assemblage of poorly stratified material is interpreted to be alluvial fan and fanglomerate deposits of significant thickness (up to 480 feet), but relatively limited extent. The deposit thins radially and was not identified in wells to the west or northwest, approximately a mile away. This deposit was mapped as an aquitard (Layer 2).

2.5.5 SESPE UPLAND RECENT STRUCTURAL UPLIFT

In the Fillmore basin there is an area of relatively recent structural uplift, designated as the Sespe Upland (Mann, 1959). This area is located west of the Sespe Creek channel and north of the current SCR channel and the associated recent SCR alluvial deposits (Figure 2-14). Here, at the base of slope of the upland, the alluvial deposits of Sespe Creek and the SCR are interfingered and transition to finer-grained sediments and interbedded minor clays deposited by tributaries and minor drainages, most notably the Timber Canyon and Boulder Canyon drainages (Figure 2-5). Well data show that recent alluvial deposits and colluvium (Layer 1), derived from the steep northern tributaries is over 350 feet thick in some areas (Chevron S 15, API: 1110046). These sediments overlie an aquitard of variable thickness (Layer 6), and the Upper Saugus/San Pedro Formation. Layers 3 and 5 are notably not present, a result of deposition of fan deposits from Timber and Boulder Canyons and the uplift creating a barrier restricting the river channel to the southern portion of the basin.

2.5.6 04N20W24R02S - FILLMORE MUNICIPAL WELL #4

The City of Fillmore drilled well 04N20W24R02S in 1963; United pumping records show usage from 1979 (when United first required reporting of pumping) until 2005, with the majority of pumping occurring prior to 1998. The well was drilled to a total depth of 2,018 ft and was screened at various intervals to a depth of 1,820 ft. This well is the deepest known production well in the Piru and Fillmore basins, and represents the deepest pumping from Layer 10. To accommodate this historical pumping, Layer 10 was mapped from 1,140 ft to 1,827 ft. at this location, resulting in a significant increase in Layer 10 thickness in this vicinity. At these depths the Saugus/San

Pedro Formation is not likely to be a significant source of future water production, but Layer 10 was assigned to this production zone and represents the thickest mapped portion of the Saugus/ San Pedro Formation.

2.5.7 AREAS OF RISING GROUNDWATER/BASIN BOUNDARIES

There are two important areas of rising groundwater within the expanded model domain; the boundary between Piru and Fillmore basins and the boundary between the Fillmore and Santa Paula basins. In these areas, the water table intersects the SCR channel invert elevation, resulting in surface flows. Topographic narrowing of the basins by older and more indurated rock also constricts groundwater flow down the valley in these areas.

At the Piru-Fillmore basin boundary, the basin narrows in the area upstream of the Fillmore Fish Hatchery. A deposit of finer-grained material of relatively limited extent, mapped as Layer 6, separates the alluvial aquifers from the underlying Upper Saugus/San Pedro Formation (Figure 2-21), as identified in log signatures from wells 04N19W33M08S, 04N19W33F01S, and 04N19W33D05S. This change in stratigraphy, as well as the constriction of the basin, contributes to groundwater being discharged in the SCR as surface flow. A thinner, less extensive deposit of finer-grained material (Layer 4) was also identified in the resistivity log of well 04N19W32L02S, separating the alluvial aquifers.

Near the mapped boundary between the Fillmore and Santa Paula basins, the valley again narrows, and finer-grained deposits of varying thickness and extent were identified between both the alluvial aquifers and the Upper Saugus/San Pedro Formation. A shallow clay layer (Layer 2) of limited extent was identified to the east-northeast of the Fillmore/Santa Paula basin boundary. Aquitard material designated as Layer 4, which is observed to be thickest in the central portion of the Santa Paula basin, is mapped as extending upstream across the boundary and into the western portion of the Fillmore basin. The aquitard material separating the older alluvium aquifer from the Saugus/San Pedro Formation (Layer 6) has a similar depositional extent near the active river channel, but extends northeast to Sespe Creek, underlying the Sespe Upland area (Figures 2-19 and 2-20).

These clay deposits, which are particularly prevalent in the eastern portion of the basin near the confluence of Santa Paula Creek and the SCR, reduce infiltration of surface water resulting in semi-confined groundwater conditions. These deposits are penetrated by wells 03N21W12F06S, 03N21W12F07S, and 03N21W12B04S, located near the basin boundary and north of the active river channel. Artesian conditions have been observed in a number of wells near this basin boundary, indicating some degree of confinement. The Oakridge fault mentioned previously in this report, roughly parallels the southern basin boundaries at this location.

2.5.8 EXTENT OF SANTA PAULA BASIN CONFINING UNITS

As previously mentioned, the alluvial aquifers of Santa Paula basin are separated by a relatively extensive and laterally continuous aquitard, mapped as Layer 4. This aquitard is primarily composed of clay, sandy clay, and fine sand. The USGS-drilled well 03N21W15G01S has been instrumented with transducers and monitored by United since the mid-1990s. Wells screened above and below Layer 4 here commonly record head differences of 20 feet or more, indicating that the clay layers at least partially isolate the aquifers and restrict the vertical movement of water. In the Piru and Fillmore basins the mapping of HSU Layer 5 is generally comparable to the mapped extent of the Older Alluvium of Mann (1959) and others. In the Santa Paula basin Layer 5 is mapped deeper and below the extensive confining layer 4, and as such deviates from the traditional geologic description of Older Alluvium in the SCR Valley.

Another extensive aquitard, Layer 6, extends upstream beyond the Fillmore/Santa Paula basin boundary and is generally laterally continuous across the Sespe Upland area. Layer 6 is also mapped across the majority of the Santa Paula basin, and is interpreted to be present up to the base of slope of the Sulphur Mountain foothills to the north. These interpretations are largely consistent with previous investigations (DBSA and RCA, 2017)

2.5.9 HYDRAULIC PROPERTIES

As discussed in Section 2.5 above, the study area contains water-bearing formations which include the recent and older alluvial deposits and those of the underlying Saugus/San Pedro Formations. In relation to the numerical modeling that is detailed further in Section 3, Figure 2-23 relates the HSU layering of the Basin Conceptual Model to Aquifer System units (A, B, and C) that are used in the model calibration and results sections. These Aquifer System designations have combined various stratigraphic units in similar fashion to the historically used aquifer system designations used in the basins of the Oxnard coastal plain. Aquifer System A represents the Surficial Deposits and Colluvium (Layer 1), Aquitard (Layer 2), and Recent (younger) Alluvium (Layer 3). Aquifer System B represents an Aquitard (Layer 4), Older Alluvium (Layer 5), another Aquitard (Layer 6), and the Upper Saugus/San Pedro (Layer 7). Aquifer System C represents an Aquitard (Layer 8), Lower Saugus/San Pedro (Layer 9), and the Undifferentiated Sedimentary Deposits (Layer 10). This section provides estimates of horizontal hydraulic conductivity for each of these Aquifer Systems, or when wells are screened across multiple systems, the combinations of Aquifer Systems within each of the groundwater basins, where data are available. Estimates of horizontal hydraulic conductivity in Santa Paula basin were obtained from the Daniel B. Stephens & Associates (DBS&A) and Richard C. Slade & Associates (RCS) (DBS&A and RCS, 2017 report. The methods regarding calculation of horizontal hydraulic conductivity estimates, which pertain to the Santa Paula Basin and adjacent areas only, are presented here:

> *The UWCD GIS well database lists specific capacity values for a number of wells in the Basin. As reported by UWCD, the database was originally constructed by the USGS and has been only minimally updated. Specific capacity values were primarily derived from water level and pumping data listed on drillers' logs, and therefore the dataset is subject to the typical uncertainty associated with such logs.*
>
> *Based on these data, transmissivity values (T) were calculated using the empirical relationship:*
>
> $$T = X * [\text{Specific Capacity}]$$
>
> *The value of X is dependent on the type of aquifer: 1,500 for unconfined aquifers, 1,750 for semiconfined aquifers, and 2,000 for confined aquifers (Driscoll, 1986). For this equation, specific capacity must be reported in gallons per minute per foot of water level drawdown (gpm/ft ddn) and the resultant T is in units of gallons per day per foot (gpd/ft). RCS assigned each well a value for X based on the perforation intervals in the data set compared to RCS's subsurface hydrogeologic interpretations. Wells perforated only in undifferentiated alluvium were assumed to be unconfined (X=1,500), whereas wells perforated in both the undifferentiated alluvium and the San Pedro Formation were assumed to be semiconfined (X=1,750), and wells perforated within the San Pedro Formation only were assumed to be confined (X = 2,000). After transmissivity was determined, the transmissivity was divided by the total listed perforated length for each well (assumed to be continuous between the reported top and bottom of perforation information) to provide an estimate of lateral [horizontal] hydraulic conductivity. By dividing the transmissivity equally among the perforated sections in a well, this method of estimation assumes that each of the water-bearing zones perforated by the well have equal hydraulic conductivities.*

The DBS&A and RCS (2017) report presented estimated horizontal hydraulic conductivity values (in units of gpd/ft^2) for 48 wells within the Santa Paula Basin and adjacent areas (see Table D-1 in DBS&A and RCS, 2017). The same method was then applied to wells located within the Piru and Fillmore groundwater basin boundaries, assuming unconfined conditions within all formations. Location of well screen within the Aquifer Systems (A, B, C) were based on United's wells database (Section 2.7, above, and Section 3.5.2.5, below). From the data provided in the sections below, it is clear that many wells in the Piru, Fillmore, and Santa Paula basins are screened in Aquifer Systems A and B or a combination of the two. The pump test data presented in the following section can help serve as a starting point for aquifer properties in the calibration exercise. However, from the following sections, the variability for estimated hydraulic conductivity based on available well pump test data and well construction data within a given Aquifer System and a given basin is large (see estimated minimum and maximum values reported in Tables 2-12 to 2-14). This variability in the available pump test data emphasizes the high uncertainty of the hydraulic conductivity estimated primarily from specific-capacity data and the importance of estimating the basin-scale hydraulic conductivity through the numerical model calibration process based on the extensive observed water level data that are available.

2.5.9.1 PIRU BASIN

The Piru groundwater basin had a total of 13 wells within United's GIS database which had both the necessary specific capacity and well screen perforation data available (Figure 2-24). From these data the horizontal hydraulic conductivity statistics were calculated for wells screened in Aquifer Systems A and B (AB), Aquifer System B (wells only screened in B), and for wells screened in Aquifer Systems B and C (BC) within Piru basin (Table 2-12). The sample size available is relatively small, with no data available along Piru Creek or the area south of the SCR. From the estimated values, Piru basin has an average horizontal hydraulic conductivity estimated at about 197 ft/day for wells screened within both A and B (Layers 1-7), 236 ft/day for wells screened in B only (Layers 4-7), and 87 ft/day for wells screened in both B and C systems (Layers 4-10).

2.5.9.2 FILLMORE BASIN

The Fillmore basin had a total of 30 wells within United's GIS database which had both the necessary specific capacity and well screen perforation data available (Figure 2-24). From these data the horizontal hydraulic conductivity statistics were calculated for wells screened in Aquifer Systems: A only, A and B (AB), A, B, and C (ABC), B only, and C only within Fillmore basin (Table 2-13). Wells with pump test data are distributed across the Fillmore basin. For the Fillmore basin, an average horizontal hydraulic conductivity is estimated at about 149 ft/day for wells screened within A (Layers 1-3), 134 ft/day for A and B (Layers 1-7), 3 ft/day for wells screened across A, B, and C (Layers 1-10), 79 ft/day for B only (Layers 4-7), and 5 ft/day for wells screened in Aquifer System C systems (Layers 8-10).

2.5.9.3 SANTA PAULA BASIN

United's GIS database had a total of 31 wells located within Santa Paula basin which had both the necessary specific capacity and well screen perforation data available (Figure 2-24). From these data the horizontal hydraulic conductivity statistics were calculated for wells screened in Aquifer Systems A only, A and B (AB), and B only within Santa Paula basin (Table 2-14). For Santa Paula basin, an average horizontal hydraulic conductivity is estimated at about 152 ft/day for wells screened within A (Layers 1-3), 72 ft/day for A and B (Layers 1-7), and 100 ft/day for B only (Layers 4-7).

2.6 GROUNDWATER INFLOW AND OUTFLOW COMPONENTS

As described in Section 1.3, there have been several major hydrologic investigations that have taken place within Ventura County and surrounding areas over the past century which have included the current Regional Model expansion area. This section will first summarize the range of various water budget described in previous investigations, as presented in United's Open-File Report 2020-02, titled *Summary of Past Groundwater Models and Water Budgets for the Piru, Fillmore, and Santa Paula Groundwater Basins* (UWCD, 2020) This section will then discuss various inflows and outflows considered in the conceptual model, many of which have already been detailed in the conceptual model sections above.

2.6.1 PREVIOUS ESTIMATES OF MAJOR WATER BUDGET COMPONENTS

United previously summarized the water budgets of the Piru, Fillmore, and Santa Paula basins based on major hydrologic investigations that have been published over the past century (UWCD, 2020), and that effort supported expansion of the numerical groundwater flow model based on review of previous knowledge and hydrologic component accounting. Table 2-15 summarizes the hydrologic investigations which contributed information regarding water budget components in the Piru, Fillmore, and Santa Paula basins. Table 2-16 summarizes the *range* of reported water budget component values for each of the groundwater basins which were presented in the previous hydrologic studies that are listed in Table 2-15. The majority of the values presented in Table 2-16 were extracted from a California Department of Water Resources (DWR, 1956) or Mann (1959), with other primary sources being CH2M HILL (2004, 2005), CH2M HILL and HydroGeoLogic (CH2M HILL/HGL, 2008), LWA and others (2015) and DBS&A and RCS (2017). It is noted here that there were several predecessor agencies to California's current Department of Water Resources (DWR). DWR was formed in 1956 with legislation that simultaneously dissolved the Water Project Authority and Division of Water Resources within the Department of Public Works as well as took over duties of a reconstituted State Water Resources Board (DWR, 2020). Values for the lower and upper ranges were sourced from the cited investigations. Each of the reports used for this review are representative of varying, sometimes overlapping, climatic periods and conditions (Table 2-15). The values reported from DWR (1956) and Mann (1959) provided the most complete summaries of basin water budgets in the previous investigations and both included time-periods with wet and dry periods. Because of this, most of the lower and upper bounds of the reported range for many of the components, presenting the results in this way is considered appropriate, and helpful, for comparison purposes.

Based on United's review (UWCD, 2020), the following conclusions based on the previous studies and reported water budgets for the Piru, Fillmore, and Santa Paula groundwater basins were made:

- The most significant inflows to each basin consist of recharge from streamflow (SCR) percolation, areal recharge from precipitation and applied water from groundwater and surface water sources, and incoming subsurface underflow from upstream groundwater basins.
- The most significant outflows to each basin consist of groundwater extractions for beneficial use and outgoing subsurface underflow to downstream groundwater basins.
- With the SCR being the largest source of recharge for the Piru and Fillmore basins, the annual water budgets for these basins are highly variable due to the dependence on local rainfall within the SCR watershed. This variability and dependence on surface water inflows leads to the large range observed in the previously reported water budget components (Table 2-16). This dependence on surface water flows is expected to continue in the future, resulting in variable water budgets of similar ranges.
- Basin boundary modifications have recently been adopted that have altered the extent of the Piru, Fillmore, and Santa Paula groundwater basins. The majority of the studies reviewed for this document utilized boundaries that captured most of the water-bearing and productive alluvial deposits and underlying aquifers along the valley floor, and the overall effect on the ranges for many of the water budget components is not expected to be significant. Changes to the upstream extent of the Piru basin will however result in an increase in the subsurface underflow into Piru basin from the east. This value is expected to increase using the Department of Water Resources (DWR, 2019) boundary moving forward due to the relative increase in saturated aquifer thickness near the Los Angeles County line compared to the downstream locations used in previous studies, with saturated thickness estimated to be around 5 feet just upstream of Blue Cut and thickening to around 25 feet near the County Line. The increased basin area from the 2019 DWR updated boundaries will also result in increased direct recharge to the underlying aquifers due to precipitation.

2.6.2 GROUNDWATER INFLOWS

Multiple sources of groundwater recharge (water that enters an underlying groundwater system from land surface) occur in the study area. Those that have been previously been described in the surface water sections, include:

- “Artificial” recharge (or “spreading”); See section 2.3.2 above.
- Stream-channel recharge; See section 2.3 above.
- Mountain-front recharge; See section 2.3.7 above.
- Percolation of treated wastewater; See section 2.3.10 above.

The hydrologic conceptual model for each of these inflows is similar to that of the previously documented Coastal Plain Model (UWCD, 2018), and each surface water inflow source has been presented within Section 2.3, above as noted. Additional sources of groundwater recharge that have not been discussed in this report, but conceptually are extended in a similar manner to what was used within the within the Coastal basins (UWCD, 2018) include:

- Deep infiltration of precipitation
- Agricultural return flows
- Municipal and industrial return flows

Locations where the various types of groundwater recharge are understood to occur in the study area are shown on Figure 2-25. In addition to the types of recharge (from land surface) listed above, groundwater underflow to and from adjacent basins also occurs the study area. Groundwater underflow to and from other basins is discussed in Section 2.8.

2.6.3 GROUNDWATER OUTFLOWS

Within the study area, groundwater discharges to water-supply wells, the SCR and to the atmosphere (via ET). Like groundwater inflows, the conceptual model for each of these outflows is similar to that of the previously documented Coastal Plain Model (UWCD, 2018). Each of these components of groundwater outflow from the study area is described in some detail below.

2.6.3.1 PUMPING FROM WATER SUPPLY WELLS

Groundwater extraction from water-supply wells is a large component of estimated groundwater discharges (or outflows) from the groundwater system in the study area, with subsurface underflow and rising groundwater in the SCR, and to a smaller degree, riparian vegetation ET, also having been previously estimated to be significant (Table 2-16).

Since 1980, United has required semi-annual reporting of pumping by well operators within United's service area, vastly improving the accuracy of pumping estimates in the study area. Reported locations and the relative magnitude of groundwater pumping for the period 1985 - 2015 in the study area are shown on Figures 2-26 and 2-27. Many of the water-supply wells that exist in the study area are screened across multiple aquifers, as the objective of drilling a supply well is typically to yield a specified production rate of acceptable-quality groundwater, preferably without drilling any deeper than necessary in order to minimize costs. Few wells are screened only in the Aquifer System A (Table 2-12 to 2-14) ,and those that at are screened in Aquifer System A are located near the SCR or major tributaries where water levels are nearest to the ground surface. Most of the wells are screened within Aquifer System B, and few are screened in Aquifer System C.

A small portion of the groundwater extracted by water-supply wells in the Piru, Fillmore, and Santa Paula basins is conveyed and used outside of the Piru, Fillmore, and Santa Paula basins to other basins within the Regional Model Domain. Additionally, some groundwater extracted by water-supply wells in the Piru, Fillmore, and Santa Paula basins is conveyed and used within the Piru, Fillmore, and Santa Paula basins but used outside of the groundwater basin of origin.

No exports from the Piru basin were documented over the calibration period, however, there is an ongoing import of water through the Newhall south bank pipeline that totals approximately 3,500 AFY of water, sourcing from wells located in Los Angeles County. This water irrigates agricultural land located south of the SCR in the eastern portion of the Piru basin (Dirk Marks of SCV Water, personal communication, December 2020).

In the Fillmore basin there have been two wells historically exporting water from the Fillmore basin into the Santa Paula basin during the 1985-2015 study period. Farmers Irrigation Company installed a well approximately 150 feet east of the basin boundary in Fillmore basin in 2012. This well has pumped about 4,050 AFY in years 2013-2015 and it is assumed that this water is distributed across their service area (Figure 2-10) within Santa Paula basin (90%) and Mound basin (10%). In addition to this well, Limoneira Company has historically pumped from a well located just east of the Santa Paula boundary within Fillmore basin as well and distributed across their land that covered Fillmore basin (40%) and Santa Paula basin (60%). This well was destroyed in 2019 with the development of Santa Paula’s East Area 1, but pumped an average of about 360 AFY from 1988 – 2015.

Related to exports from the Piru, Fillmore, and Santa Paula basins to Mound basin, a long-term average of approximately 1,300 AFY of groundwater has been pumped from two water-supply wells operated by the Alta Mutual Water Company in the Oxnard basin (north of SCR) since the mid-1980s, and approximately 1,100 AFY has been exported to agricultural lands in and north of the Santa Paula basin and another 200 AFY has been exported to agricultural lands in eastern Mound basin. Further related to Mound basin, Farmers Irrigation Company has exported approximately 815 AFY from Santa Paula basin to eastern Mound basin since 1992. Lastly, related to exports to Mound basin from the Piru, Fillmore, and Santa Paula basins, Ventura Water pumped approximately 1,070 AFY of groundwater from its Saticoy wells in the Santa Paula Basin and supplies that water to portions of the city overlying the Mound and Santa Paula, and Oxnard basins (the quantity of water reported above was averaged for the period from 1985 to 2015 [Ventura Water, 2020]). Ventura Water has stated that the specific quantity of imported water from this source distributed to each basin is variable and cannot be precisely determined and so Ventura Water’s imports have been assumed for modeling purposes to be evenly blended and distributed across their service area.

2.6.3.2 RISING GROUNDWATER

As described in Section 2.3.1.1 and related to rising groundwater at the basin boundaries of the Piru-Fillmore basins and Fillmore-Santa Paula basins, significant amounts of water are discharged from the shallow aquifers as the groundwater elevations intersect the invert of the SCR channel. Previous studies have estimated these discharges to range from 0 – 37,800 AFY for Piru to Fillmore, 6,030 – 48,200 AFY from Fillmore to Santa Paula, and historically it was reported that 2,040 – 17,340 AFY related to rising groundwater outflowing from Santa Paula basin

(Tables 2-15 and 2-16), however, the previously reported rising groundwater estimates exiting Santa Paula basin “do not accurately indicate the volume of rising water as it is apparent that even relatively low flows consist in part of through-flowing surface water [from Santa Paula Creek, rising groundwater existing Fillmore basin, and SCR flows and] the estimates…are considered ‘excessively high’” (Mann, 1959).

2.6.3.3 EVAPOTRANSPIRATION

ET removes significant volumes of water from soil moisture before it can infiltrate to the water table. Much of this soil moisture originates as precipitation. The majority of ET occurs at land surface or within the root zone of the soil horizon, in the unsaturated zone. This near-surface ET does not directly affect groundwater elevations or flow in the saturated zone, and thus is not explicitly included in most groundwater flow models. However, near-surface ET is included implicitly as part of net recharge calculations applied as input to the Regional Model (see further details in UWCD [2018] Sections 2.7.1.3 and 2.7.2.4). Additionally, ET may occur in the form of groundwater uptake by phreatophytes in the riparian corridors of stream channels with shallow groundwater, and this form of ET is included in the modeling (see Section 3.5.2.6). Background related to ET rates for riparian vegetation is discussed in Section 2.3.11.

2.7 GROUNDWATER OCCURRENCE AND MOVEMENT

This section provides overviews of the groundwater flow system for each groundwater basin, displaying and discussing long-term hydrographs at key wells for each basin (key well locations shown on Figure 2-28) as well as groundwater elevation maps for various representative wet and dry periods.

United’s groundwater elevation database includes historical groundwater-level data for 1,369 wells within the Regional Model domain (as of May 2020), with 502 wells being in the model expansion area. The groundwater elevation database is a compilation of information supplied by several cooperating entities. Each of these entities has their own protocol for measuring water levels, and these protocols may vary over time. Other entities that may contribute water-level data within the model expansion include the Cites of Fillmore and Santa Paula, Farmers Irrigation Company (FICO), Alta Mutual Water Company, the City of Ventura, and VCWPD. United and other entities coordinate these groundwater elevation measurements to be taken within a specific calendar period, in an effort to accurately capture basin conditions during annual climatic cycles (wet and dry periods).

Groundwater elevations are normally measured in wells that are not pumping; these measurements are referred to as “static.” When evaluating trends in long-term groundwater elevations, static groundwater level measurements are preferred. However, the water level in a non-pumping well may remain depressed for some time due to residual drawdown in the well being monitored, or because of pumping interference from a nearby well. Although it is not possible to eliminate all effects of pumping when manually measuring groundwater elevations in a developed groundwater basin, UWCD and other parties take care to measure wells when residual drawdown is not expected, and no nearby wells are known to be pumping. When groundwater elevations are measured during the low-irrigation season (winter and early spring), potential pumping effects on the measurements are typically reduced. Some area wells are equipped with pressure transducers that collect frequent measurements and seasonal high and low groundwater elevations can be assessed with greater confidence. The groundwater level database records were further used in the Regional Model development for model calibration (Section 4) with all water levels available for wells within the active model domain used. The time dependent water level measurements from each well were used in hydrographs comparing with the simulated water levels. All water level measurements were also paired with the simulated water levels in scatter plots.

2.7.1 PIRU BASIN

Groundwater flow in the alluvium (Layers 3 and 5) of the Piru basin tends to be westerly, parallel to the river channel. Near the eastern basin boundary, groundwater elevations decrease over a relatively short distance as a result of the deepening and thickening of water bearing units where the Saugus/San Pedro Formation steeply plunges (Figure 2-29). Groundwater flow is westerly in this area, however recharge associated with the major tributaries along the northern margins of the basin can however create areas of southerly flow. Groundwater flow in the Saugus/San Pedro Formation is generally westerly with a relatively minor northerly and southerly components during wetter (2010) and drier (2015) years (Figures 2-29 to 2-31). The basin is considered to be an unconfined basin (UWCD, 2016). Figures 2-32 and 2-33 show hydrographs for key wells 04N18W29M02S (29M) and 04N19W25M01S (25M1) located within Piru basin, which highlight the decadal variability in groundwater elevations in Piru basin.

2.7.2 FILLMORE BASIN

Groundwater flow in the Fillmore basin generally moves east-to-west through the alluvium (Layers 3 and 5). Near the Piru/Fillmore basin boundary, groundwater flow is westerly, and in this area the water table elevation intersects the invert of the SCR channel resulting in surface flow. Groundwater flows generally westerly in the basin from the Piru/Fillmore basin boundary to the area of Sespe Creek. Gradients are steeper in this area, near the eastern boundary, than elsewhere in Fillmore basin. Groundwater recharge from Sespe Creek generally flows towards the southwest during wetter (2010) and drier (2015) years (Figures 2-29 to 2-31). Groundwater flow beneath the Sespe Upland area is generally southwest in the Saugus/San Pedro Formation. The basin is considered to be an unconfined basin (UWCD, 2016). Figures 2-34 and 2-35 show hydrographs for key wells 04N20W23Q02S, 04N20W23N01S (23N1), and 03N20W02A01S (2A1), located within Fillmore basin. Similar to Piru Basin, these wells highlight the decadal variability in groundwater elevations in Fillmore basin due to wetter and drier climate patterns that have occurred over the past century.

2.7.3 SANTA PAULA BASIN

Groundwater flow in the Santa Paula basin is generally northeast-to-southwest (Figure 2-36), following the SCR Valley gradient seen in the upstream basins, with localized groundwater depressions appearing in fall near groups of water-supply wells (Figure 2-37). Groundwater recharge from Santa Paula Creek has a relatively minor influence on groundwater gradients, and groundwater flow in this area is generally westerly. There are thick clay deposits in much of the eastern Santa Paula basin, near the confluence of the SCR and Santa Paula Creek that likely reduces the amount of water that infiltrates to the deeper aquifers (UWCD, 2013). Portions of Santa Paula basin are confined by this deposit, but the river corridor is largely sand and gravel. Similar to the Fillmore basin, groundwater flow beneath the northern flanks of the basin is generally southerly in the deeper Aquifer Zones B and C, where the Saugus/San Pedro Formation outcrops. Flow however becomes westerly in the central and southern portions of the basin. Near the western basin boundary, there is an abrupt shift in groundwater elevations, indicating the presence of the concealed barrier of the Country Club Fault, which is observed in both wet (spring) and dry (fall) periods. Recharge is observed in groundwater level hydrographs, as groundwater elevations in the majority of wells throughout the basin show significant seasonal variability (UWCD, 2011). Figure 2-38 shows a hydrograph for well 03N21W16K01S (16K1) located within Santa Paula basin. This well shows seasonal variability and an overall declining trend. Well 02N22W02C01S (2C1), located further west within the basin follows a similar trend.

3 NUMERICAL MODEL CONSTRUCTION

This section is focused on detailing the expansion of United's (2018) Coastal Plain Model into the Piru, Fillmore, and Santa Paula basins, but will also review model construction across the remainder of the model domain for completeness regarding the expansion and connection with the downstream basins (Mound, Oxnard, Pleasant Valley, and west Las Posas Valley basins) where the numerical model grid was unchanged during the model expansion. Readers are referred to the Coastal Plain Model Report (UWCD, 2018) for details on the Oxnard, Pleasant Valley, west Las Posas Valley and Mound basins.

The groundwater flow system within the Regional Model domain (Coastal Plain Model and the expansion area into the Piru, Fillmore, and Santa Paula basins) is influenced by cycles of extended drought and wet years. Observed groundwater elevations fluctuate over hundreds of feet during these cycles. This highly fluctuating groundwater level condition requires a numerical model capable of simulating the wetting and drying of aquifers. Since the 1980s, the USGS has been developing a finite difference-based groundwater model, MODFLOW. The MODFLOW numerical model has been applied in the United States and worldwide in the past 30 years. The popularity and transparency of MODFLOW attributed to its open-source policy, has led to a thorough critique of MODFLOW and numerous research papers, further cementing MODFLOW as the leading groundwater model. Among the different versions of MODFLOW available at present, some versions perform better than others under certain conditions. One version of MODFLOW, MODFLOW-NWT (Niswonger, et al., 2011), was developed to improve simulation of the drying and rewetting of aquifers, and is particularly well suited for conditions in the Regional Model. Therefore, MODFLOW-NWT was chosen as the preferred software for the Regional Model, as it was for the Coastal Plain Model (UWCD, 2018).

3.1 MODEL DOMAIN AND BOUNDARY CONDITIONS

The active domain of the Regional Model includes the Oxnard, Pleasant Valley, West Las Posas, Mound, Santa Paula, Fillmore, Piru groundwater basins, and the submarine (offshore) outcrop areas of the principal aquifers that underlie these basins. The active domain for each of the 13 model layers varies depending on the underlying geological units expanding or pinching out (see Figures 3-1 to 3-13). The active model domain spans approximately 245,821 acres (384 square miles), of which 72% (178,144 acres or 278 square miles) is onshore and 28% (67,677 acres or 106 square miles) is offshore. With the expansion of the model domain into the SCR Valley to include the Santa Paula, Fillmore, and Piru basins, the GHB that previously represented underflow in the western portion of the Santa Paula has been removed. All other boundary conditions in the area representing the Coastal Plain Model domain are identical in the Regional Model, with several additional modifications in Mound Basin, including changes related to mountain front recharge following the expansion of the DWR basin boundaries to include more outcrops to the north as well as changes in the implementation of stream channels for Harmon Barranca (i.e. Harmon Barranca was not previously simulated in the Coastal Plain Model).

The subsurface boundary conditions vary around the active model domain, as follows:

- The eastern edge of the active model domain in west Las Posas Valley basin adopts a no-flow boundary coincident with the East Las Posas basin boundary and the Central Las Posas Fault.
- The northeastern corner in Pleasant Valley basin is assigned a groundwater flux along Arroyo Las Posas based on the groundwater model developed by Calleguas Municipal Water District (CMWD, 2018). When the flux is unavailable from CMWD, an estimate based on precipitation is made.
- The eastern edge of the active model domain in Piru basin at the Los Angeles County line is assigned a groundwater flux along the SCR to represent the groundwater flow from Los Angeles County through model calibration. Details regarding the model calibration and implementation are discussed in Section 3.5.1.2.
- The western edge of the model in the ocean is assigned with general head boundary condition based on the seawater density and the depth of the submarine outcrop of each model layer.
- All other boundary conditions are assigned no flow boundary conditions.

The surface water boundary conditions are based on the streamflow measurements along the Santa Clara River and its tributaries (Piru Creek, Hopper Creek, Pole Creek, Sespe Creek, and Santa Paula Creek), as well as Conejo Creek and Arroyo Las Posas/Calleguas Creek in the coastal basins. Several minor tributaries were implemented with no surface inflow because they are ungaged. The implementation of streamflow boundary conditions is shown on Figures 3-14 to 3-26, with observed data presented in Section 2.3. See Section 3.3 below related to the simulation period and the timescales associated with the boundary conditions in the Regional Model. Figures 3-14 to 3-26 show other boundary conditions implemented in the model expansion, apart from pumping wells, which are shown in Figures 2-26 and 2-27. Further details regarding the various boundary conditions and inputs are described in Section 3.5.

3.2 MODEL LAYERS AND NUMERICAL GRID

As noted in Section 2.5, there are ten principal hydrostratigraphic units in the expanded model domain, including six aquifers and four aquitards. In Mound basin, there are nine principal hydrostratigraphic units, including five aquifers and four aquitards. As mentioned in the Coastal Plain Model report, there are 13 principal hydrostratigraphic units in the other coastal basins, including seven aquifers and six aquitards. Correlation of these hydrostratigraphic units to model layers is shown on Figure 2-23 and Tables 2-10 and 2-11. The layer thickness for each model layer is shown on Figures 3-1 to 3-13.

The model grid is oriented at North 26° West to align the dominant groundwater flow directions (southwest and southeast) with the primary axes of the model grid, as recommended by the USGS (McDonald and Harbaugh, 1988). The coordinate offsets are 6,151,000 and 1,790,000 ft, in the NAD 1983 State Plane Zone 5 system. A uniform grid size of 2,000 was adopted, consisting of 137 columns by 75 rows (Figure 1-2). There are 26,922 active cells out of total 133,575 cells.

3.3 SIMULATION PERIOD

The simulation period of the model calibration is from January 1985 through December 2015, same as the Coastal Plain Model. The time step is daily with 12,783 total stress periods (01/01/1985 – 12/31/2015), while the Coastal Plain Model is temporally discretized into monthly time steps with 372 total stress periods. The adoption of daily time steps is to better simulate the “flashy” streamflow observed along SCR and its tributaries. The SCR streamflow varies significantly on a daily or weekly basis during winter storms. The streamflow may rise from a few or tens of cubic feet per second (CFS) to thousands or tens of thousands CFS in a day. Following each winter storm, the streamflow may decrease to hundreds of CFS in a few days or in a week. The daily time step is more appropriate to simulate the highly flashy SCR streamflow.

All boundary conditions are implemented on a monthly basis except for streamflows. Although the Regional Model is simulated using daily stress-periods, the only input condition that is varied each day in streamflow. The computation time for the 2,000-foot-grid model increased considerably with the Regional Model expansion, requiring several hours per simulation (in comparison to less than 30 minutes for the 2018 model).

3.4 AQUIFER PARAMETERS

The aquifer parameters required for the Regional Model are horizontal hydraulic conductivity, vertical hydraulic conductivity, specific yield, storage coefficient, and streambed conductance. Further discussion about how streambed conductance is defined and adjusted in calibration is available in Section 3.5.1.1, below. Sections 2.5.9.1 to 2.5.9.3 describe the estimated hydraulic conductivity for the various Aquifer System and combinations, estimated with available specific capacity data well construction data. During the initial model calibration, it was noted that the hydraulic conductivity needed to be higher than the estimated values based on the aquifer tests, which aligns with the understanding that specific capacity data tends to underestimate conductivity values due to the well losses occurring inside the pumping well where drawdown measurements are being taken. The pattern of hydraulic conductivity highest in Piru basin, and decreasing toward Fillmore and Santa Paula basins do align with those similar trends in the estimated values, especially in Aquifer Systems A and B, where the available data are concentrated.

The horizontal hydraulic conductivities ultimately applied to the calibrated model are provided for each of the model layers (Figures 3-27 through 3-39). Additionally, the horizontal hydraulic conductivities and vertical anisotropy (ratio of horizontal to vertical hydraulic conductivity) ultimately applied to the calibrated model are also presented by Zone Number for each of the model layers within the model domain (Tables 3-1 and 3-2) which map to figures representing all Zone Numbers used within the Regional Model (Figures 3-40 through 3-52). The Regional Model retains all the faults used in the Coastal Plain Model. The modeled extents of the Country Club Fault and Oak Ridge Fault were extended up the SCR Valley as the Regional Model expanded into the Santa Paula, Fillmore and Piru basins. The locations of faults in each model layer that act as horizontal flow barriers, together with the conductance across those faults, are provided (Figures 3-14 through 3-39; Table 3-3).

The default values for specific yield (dimensionless) in the A, B, and C aquifer systems are 0.15, 0.15 and 0.1, respectively. The default value for specific yield in all aquitards is 0.05. The default values for storage coefficient (dimensionless) values in all aquifers and aquitards is 0.001. For MODFLOW-NWT input, the specific storage (unit: 1/ft) is used through dividing the dimensionless storage coefficient by cell thickness. Similar to hydraulic conductivity values above, the specific yield and storage coefficient values ultimately applied to the calibrated model are also presented by Zone Number for each of the model layers within the model domain (Tables 3-4 and 3-5) which map to figures representing all Zone Numbers used within the Regional Model (Figures 3-40 through 3-52).

3.5 MODEL INPUT CONDITIONS

The Regional Model is an expansion from the Coastal Plain Model; therefore, there are input conditions common to both the Coastal Plain Model and Regional Model. However, in the Piru, Fillmore, and Santa Paula basins, the SCR plays a dominant and unique role in the groundwater systems by recharging the aquifers and gaining groundwater from the aquifers. This is in contrast with the coastal basins where artificial recharge by UWCD within the Forebay area of the Oxnard basin is the dominant input condition in the groundwater system. In the following sections, the model input conditions unique in the Piru, Fillmore, and Santa Paula basins are detailed while the input conditions common in the Coastal Plain Model and Regional Model are summarized. Readers are referred to the Coastal Plain Model report (UWCD, 2018) for further detail on the input conditions common to the Coastal Plain Model.

3.5.1 INPUT CONDITIONS UNIQUE IN SANTA CLARA RIVER BASINS MODEL EXPANSION

Several important input conditions in the Piru, Fillmore, and Santa Paula basins are detailed in the following sections, including: (1) in the Piru, Fillmore, and Santa Paula basins, the SCR plays a unique role providing recharge to and receiving discharge from the groundwater flow system through the complex interaction between surface water and groundwater, including the various streamflow conditions and diversion activities; (2) subsurface underflow entering into the Piru basin along the SCR at the Los Angeles County line; (3) the operations of the Fillmore Fish Hatchery by the California Department of Fish and Wildlife, located near the Fillmore and Piru basin boundary creates a unique local recharge process; (4) through 2008, UWCD provided artificial recharge from Piru Creek streamflow into spreading basins located within Piru basin.

3.5.1.1 SANTA CLARA RIVER STREAMFLOW AND INTERACTION WITH GROUNDWATER

The SCR, with streamflow inputs from its tributaries (Piru Creek, Hopper Creek, Pole Creek, Sespe Creek, and Santa Paula Creek) has significant interaction with groundwater in the basins of the SCR Valley. The interaction of streamflow and groundwater is implemented in the stream (STR) package, with observed daily streamflow (Table 2-3) at the model boundaries for the SCR mainstem and tributaries. Along the SCR and its tributaries, there are several public and private diversions that operated during the 1985-2015 calibration period. The STR package accounts for these diversions, and reported diversion locations and rates are detailed in Section 2.3.8. The SCR mainstem, its tributaries, and diversions are tabulated in Table 3-6 and shown on Figure 3-53.

The SCR streamflow interaction with groundwater is more complex than the Conejo Creek or Calleguas Creek, which were implemented in the Coastal Plain Model, because the SCR streamflow is flashier (Conejo Creek and Calleguas are both predominately sourced by upstream wastewater discharges), has significantly higher flowrates, and has different types of streamflow events. The SCR within the Regional Model, from Piru basin to Oxnard/Mound basins, experiences two types of major streamflow events: (1) the conservation releases from Santa Felicia Dam determined by United and (2) naturally occurring storm flows. As discussed in Section 2.3, the conservation releases typically occur over a month to several months in order to optimize the recharge in the downstream groundwater basins. This is significantly different from the storm events that can bring large quantities of water to pass through the Regional Model domain over a period of several days or less. Because of the different timescales associated with the two streamflow types, the interaction with the groundwater system is implemented in the Regional Model differently in order to capture the physical variability.

The streambed conductance used in the STR package is the product of the streambed material hydraulic conductivity, stream channel width and stream channel length and then divided by the thickness of the streambed material. The STR input conditions for Calleguas Creek were calibrated in the Coastal Plain Model and are retained in the Regional Model. The STR input condition for SCR was simplified to the product of the streambed material hydraulic conductivity and the channel length. The streambed material thickness and the stream channel width were merged into the streambed material hydraulic conductivity. This assumption simplifies the model calibration by adjusting only the streambed hydraulic conductivity. The stream channel length was calculated based on the available SCR shapefile file (based from National Hydrography Dataset, which is available at from The National Map: https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map). The default vertical hydraulic conductivity of the streambed is 50 ft/day. The stream segment within Santa Paula basin is calibrated to be 10 ft/day, including Santa Paula Creek. There is a correction to the hydraulic conductivity based on the streamflow rates and the nature of streamflow detailed in the following.

(1) For the UWCD conservation releases, the interaction between the release flow and groundwater changes over the release time. The release flow is steady for several weeks to several months. During the initial days of releases, the release flow is widely distributed across the stream channel leading to higher percolation. As the release continues, a narrow channel is typically formed through the cutting by the release flow into the streambed sediments. The percolation is then reduced when the narrow stream channel is formed, and the streamflow rate is increased. In summary, the percolation of the UWCD releases is generally high in the initial 10 to 20 days and the percolation decreases after 20 days when a narrow channel is formed. Accordingly, the SCR conductance in the Piru and Fillmore basins is calibrated to be 200% of default conductance in the first 10 days of release and 150% of default conductance from the 11th to 20th days of releases. The conductance in Santa Paula basin was not affected by the UWCD releases. Overall, the conductance gradually decreases as the releases travel downstream from Piru to Fillmore and Santa Paula.

(2) For the naturally occurring streamflows that are mostly related to storms and base flows from LA County, the stream percolation is affected by the magnitude of streamflow. Generally higher streamflow leads to lower percolation because higher streamflows are more turbulent and muddy impeding the percolation. When the streamflow rate is low, the stream velocity is slow and the percolation is expected to be higher. The SCR conductance is corrected by multiplying the default SCR conductance value by the streamflow correction factor The streamflow correction factor developed through model calibration is tabulated int Table 3-7.

Table 3-7. Santa Clara River Streamflow Correction Factor

Monthly SCR streamflow (acre-ft)	Streamflow Correction Factor
< 500	3.0
500 - 3000	3.0 - 2.0
3000 - 5000	2.0 - 0.5
5000 - 10000	0.5 - 0.2
> 10000	0.2

3.5.1.2 SUBSURFACE UNDERFLOW

In addition to the surface water streamflows entering into the Piru, Fillmore, and Santa Paula basins related to the SCR and its tributaries, there is also a significant amount of subsurface underflow entering into the model domain along the SCR at the county line with Los Angeles County into the Piru groundwater basin. The literature review summary presented in Section 2.7.1 showed that previous studies have estimated the subsurface underflow into Piru Basin to range from 240 to 18,800 acre-ft annually. However, that total range represents estimates for various Piru basin boundary locations and time-periods. The current Piru basin boundary is located near the Los Angeles County line compared to the downstream locations used in serval of the previous studies, and the current boundary location results in substantial increase in saturated aquifer thickness. The initial subsurface underflow estimate is based on a recently calibrated numerical groundwater flow model developed for the SCVGSA. SCVGSA's groundwater model was developed without explicitly including the surface streamflow, however the calibrated model did estimate the subsurface underflow at the Piru basin boundaries to average 7,500 acre-ft on an annual basis, with a range of 7,000 to 8,100 AF annually during that model's 40-year calibration period (calendar years 1980 through 2019). To account for both the observed surface flows and estimated subsurface underflows near the Piru basin boundary appropriately, the Regional Model estimates the subsurface underflow at 5,000 acre-ft in addition to the observed surface streamflow that is implemented at the boundary within the stream package. The subsurface underflows are implemented in MODFLOW's well (WEL) package.

3.5.1.3 FILLMORE FISH HATCHERY

The Fillmore Fish Hatchery is located near the basin boundary between Piru and Fillmore, and the California Department of Fish and Wildlife has been using groundwater for as part of its mission since 1942 (Figure 2-9; https://wildlife.ca.gov/Fishing/Hatcheries/Fillmore/History). The discharge from the Fish Hatchery was used by neighboring watercress farms or released back to the SCR. To account for this unique operation, the pumped water for the Fillmore Fish Hatchery operation was assigned a higher groundwater return rate at 0.50, resulting in 50% of the hatchery's groundwater extraction use returning to the underlying groundwater system. To better simulate the watercress farm operations and the Fillmore Fish Hatchery operations, MODFLOW's drain return (DRT) package is used in Layer 1 (Figure 3-14) with a conductance of $1x10^7$ square feet and elevation at ground surface to simulate the water movement from the watercress farms and Fish Hatchery to the aquifer below the SCR stream channel.

3.5.1.4 UWCD PIRU SPREADING GROUNDS

Within the Regional Model expansion study area, monthly artificial recharge rates (measured and recorded by United) at the Piru spreading basins during the model calibration period (January 1985 through December 2015) were implemented. As noted in Section 2, the Piru Spreading

Grounds have not been operated since 2008. Annual totals implemented into the Regional Model were previously provided relating to diversions and applications within the expansion study area (Table 2-7).

3.5.2 COMMONLY USED INPUT CONDITIONS

The streamflow and subsurface underflow outside of the Piru, Fillmore, and Santa Paula basins are described here. Additionally, the input conditions commonly used in the Coastal Plain Model and Regional Models are described and include: areal recharge, mountain front recharge, pumping, evapotranspiration, tile drains, and the interaction with sea water.

3.5.2.1 STREAMFLOW

The major streamflow inputs outside of the SCR watershed include Calleguas Creek and its tributaries, Arroyo Las Posas and Conejo Creek. These surface water features were unchanged from the Coastal Plain Model, and like the SCR, the interaction of streamflow and groundwater is implemented in the stream (STR) package within MODFLOW. Calleguas Creek, its tributaries, and single diversion are numbered and tabulated in Table 3-6 and Figure 3-53.

3.5.2.2 SUBSURFACE UNDERFLOW

The significant subsurface underflow entering into the model domain outside of the Piru, Fillmore, and Santa Paula basins is the subsurface underflow along Arroyo Las Posas to Pleasant Valley from Las Posas basin that was implemented in the Coastal Plain Model. The Arroyo Las Posas underflow from 1985 to 2015 was simulated by a groundwater model by CMWD (CMWD, 2018) and was used in both the Coastal Plain Model and Regional Model.

3.5.2.3 AREAL RECHARGE

The 2020 Model adopts the same assumptions used in the Coastal Plain Model, implementing areal recharge using MODFLOW’s recharge (RCH) package. Readers are referred to Sections 3.5.1.3 to 3.5.1.5 in the Coastal Plain Model Report (UWCD, 2018) for further detail.

The recharge rate from precipitation depends upon the precipitation intensity. The precipitation recharge rate is as follows (Table 3-8):

Table 3-8. Areal Precipitation Recharge Rates

Monthly Precipitation (inches)	Precipitation Recharge Rate (%)
0 to 0.75	0
0.75 to 1.0	0 to 10
1 to 3	10 to 30
> 3	30

The recharge rate from agricultural use is based on the salt-leaching requirement (LR). The ITRC (2010) lists LRs for various crops in Ventura; using these LRs, United calculated the average LR for the Coastal Plain Model (based on crop acreage and the distribution uniformity factor of 0.8) to be 0.14. The Coastal Plain Model calibration concluded that a LR value of 0.20 is more appropriate for all basins except that the LR value in Oxnard Basin (Oxnard Plain and Oxnard Forebay) is 0.25. During the expansion of the Regional Model, the LR value of 0.20 is applied to Piru, Fillmore, and Santa Paula basins. During wet months, the soil condition is moister than the typical months leading to higher recharge rate. Therefore, in the wet months when the precipitation recharge rates are higher than the LR values, the higher recharge rates for precipitation are used for agricultural use instead of the LR value. If the precipitation recharge rates are lower than the LR value, the LR value is used. The recharge rate from domestic (municipal and industrial) use is assumed to be constant at 5%.

Other recharges included in the groundwater model are the United artificial recharge, and the percolation ponds at wastewater treatment plants (WWTP). The percolation rate of artificial recharge is assumed to be 1.0, or 100% of artificial recharge enters the groundwater system. Similarly, percolation rates within WWTP percolation ponds are also assumed to be 1.0.

3.5.2.4 MOUNTAIN FRONT RECHARGE

During rainfall events, a portion of precipitation falling in the neighboring mountains outside of the active model domain, and resulting surface flows, may recharge the shallow alluvial aquifer and/or the deep aquifer through the San Pedro outcrop or volcanic outcrop as mountain front recharge. The recharge rate is calculated based on the area of watershed outside of the active model domain receiving the precipitation (Figure 2-5) and uses the precipitation recharge rate to determine the mountain front recharge. The mountain front recharge is implemented in the

MODFLOW's well (WEL) package (see Figures 3-14 to 3-26 for well cells within the applicable model layers). For more detail of implementation outside of the Regional Model expansion, readers are referred to Section 3.5.1.6 in the Coastal Plain Model documentation (UWCD, 2018).

3.5.2.5 PUMPING

There are 1,610 extraction wells within the model domain that were active at some point during the calibration period, with 668 within the model expansion basins: 180, 363, and 125 extraction wells in Santa Paula, Fillmore and Piru basins, respectively (Table 3-9; Figures 2-26 and 2-27). The extraction wells tend to have long screen intervals to maximize the extraction capacity. To better handle the internal flow dynamics within the multi-layer extraction, groundwater withdrawals from wells in the study area were implemented using multi-node well (MNW2) package as the MNW2 package can handle the multi-layer extraction internally without user intervention. The extraction records in these basins are mostly reported every six months directly to United. To allocate the six-month reported pumpage into monthly usage, a precipitation-weighed formula was used. If the monthly precipitation was higher than 0.6 inch, the pumping allocation for that month was reduced. If there was no precipitation, the pumping allocation was increased. Therefore, the monthly allocation is inversely proportional to the monthly precipitation, and sums to the reported 6-month total pumpage. The Regional Model uses the monthly allocated rates for the daily extraction rates during the month. The default well conductance is assumed to be 2000 square feet. Some extraction wells are also the water level monitoring wells providing the water level measurements. For these extraction wells with water level measurements, the conductance may be adjusted to better fit the water level measurements during the model calibration.

The extraction wells in Oxnard, Pleasant Valley, West Las Posas, and Mound basin implemented in the Coastal Plain Model were kept unchanged in the Regional Model.

3.5.2.6 EVAPOTRANSPIRATION

The plants and vegetation on the ground surface can withdraw groundwater in the semi-perched or the shallowest aquifer. The Regional Model assumes the same ET parameters as the Coastal Plain Model for evapotranspiration (ET) in the coastal basins. Within the coastal basins, the maximum ET flux is 0.01 feet per day over the area of stream channel and wetland. The ET surface elevation is assumed at 3 feet below ground surface, and the ET extinction depth is set at 5 feet. In the Piru, Fillmore, and Santa Paula basins, the maximum ET flux was increased to 0.014 feet per day (5.2 feet per year) in order to account for higher estimated water use with the presence of *Arundo donax* within the SCR corridor along with other vegetation species (Section 2.3.10). To account for seasonal variation in ET, the maximum ET rates were adjusted according to percentages for each month shown in Table 3-10 below. These percentages were calculated based on monthly average reference ET data obtained from the California's Department of Water

Resource's California Irrigation Management Information System (CIMIS) Santa Paula station (ID 198), with data representing April 2005 to December 2019 conditions.

Table 3-10 Monthly Variation in ET Rates

Month	Variation Percentage
January	61%
February	67%
March	95%
April	114%
May	132%
June	135%
July	139%
August	135%
September	109%
October	92%
November	67%
December	54%

3.5.2.7 TILE DRAINS

The tile drains used in the Oxnard and Mound basin in the Coastal Plain Model were retained without changes. Readers are referred to Section 3.5.2.2 in the Coastal Plain Model documentation (UWCD, 2018).

3.5.2.8 GROUNDWATER/SEAWATER INTERFACE PARAMETERS

The Regional Model adopts the same assumptions regarding the groundwater and seawater interface used in the Coastal Plain Model. Readers are referred to Section 3.5.3 in the Coastal Plain Model documentation (UWCD, 2018).

3.6 ASSIGNMENT OF INITIAL HEADS

The initial head for a groundwater model simulation starting on January 1st, 1985 should be the water level at the end of 1984. To re-create the water level on December 31st, 1984, the available water level data from fall 1984 was collected for kriging. The kriged water level was evaluated manually and edited for any unreasonable water level values. The initial head may contain certain degree of uncertainty, but it is expected to have minimal effect on the overall model simulation from 1985 to 2015 as the effect of initial head uncertainty is diminished after a short period of time, e.g. the first few months of model simulation. The initial heads for all model layers used in the Regional Model are shown on Figures 3-54 through 3-66. For context of the initial heads, the hydrologic conditions at the end of 1984 were fairly wet, with water years 1982-1984 being a brief wet period between critically dry periods (see Figures 2-4, 2-6, 2-11, 2-32, 2-33, 2-34, 2-35, and 2-38 for long-term surface and subsurface records; water year classification based on DWR's Water Year Type Dataset [DWR, 2021]).

4 MODEL CALIBRATION AND RESULTS

For groundwater models with little or no streamflow interaction, the groundwater level is typically the only physical quantity for evaluating the model calibration. In the Coastal Plain Model, the SCR flows through northern Oxnard Plain where there is a clay top layer impeding the areal recharge into the Upper Aquifer System and the streamflow along Calleguas Creek is relatively less than the SCR streamflow. The interaction of streamflow and groundwater was relatively limited in the Coastal Plain Model compared to the Regional Model, and the targets of the Coastal Plain Model calibration were the transient water level measurements from 1985 to 2015. Therefore, the Coastal Plain Model calibration was completed mainly through the adjustment of hydraulic conductivity parameters.

In the Regional Model, where the interaction of the SCR flow and groundwater is a dominant process in the Piru, Fillmore, and Santa Paula basins, the calibration was sensitive to the simulation of SCR flow interaction with the groundwater. Therefore, the calibration of the Regional Model is performed simultaneously in both the groundwater and streamflow components and related parameters. The calibration focus for the groundwater component, like the Coastal Plain Model and other groundwater models, was to compare the simulated groundwater level with the available groundwater level measurements at monitoring and extraction wells. The calibration focus for the streamflow component was to evaluate the interaction between streamflow and groundwater by comparing the simulated and observed streamflow, streamflow percolation, rising groundwater flows as well as spatial and temporal trends in the extent of gaining and losing reaches.

4.1 GROUNDWATER CALIBRATION

For the groundwater component, the hydraulic conductivities in the Piru, Fillmore, and Santa Paula basins were adjusted to minimize the differences between the water level measurements (see Section 2.7 for water level database background) and the simulated water levels through the statistical analysis (Section 4.1.1 Residuals), temporal variation (Section 4.1.2 Hydrographs), and spatial variation (Section 4.1.3 Scatter Plots and Residual Plots). The calibrated hydraulic conductivity for each of 13 model layers in the Regional Model are shown on Figures 3-27 through 3-39. The hydraulic conductivity in Oxnard, Pleasant Valley, West Las Posas, and Mound are the same as the Coastal Plain Model. In the expanded area covering the Piru, Fillmore, and Santa Paula basins, the conductivity along the SCR riverbed is relatively high and decreases in the northern hillslopes and uppermost reaches of the northern tributaries to the SCR. The conductivity also gradually decreases from Piru to Fillmore, and to Santa Paula. The vertical anisotropy ratio (horizontal conductivity to vertical conductivity) remains constant at 10.0 (Table 3-2), except in West Las Posas basin. The specific yield and the storage coefficient are mostly uniform in space across a given model layer, but do have some variation between zones (Tables 3-4 and 3-5). To avoid confusion, it is emphasized that the dimensionless storage coefficient is divided by cell thickness to become specific storage (unit: 1/ft) for input parameters used in MODFLOW-NWT. The hydraulic parameters in Oxnard, Pleasant Valley, West Las Posas were the same as the Coastal Plain Model. The hydraulic conductivity in Mound basin were slightly adjusted in the Regional Model to account for the model expansion.

4.1.1 RESIDUALS

The residual is defined as the difference between the water level measurement and the simulated water level as defined below

$$Residual\ =\ Water\ level\ measurement - Simulated\ water\ level$$

The simulated water level at each water level observation well was calculated based on the screen interval and its location in the model grid. If the screen interval spans multiple model layers, the maximum of the simulated water levels over the spanned model layers were used to represent the simulated water level. Further, the water level wells are not always at the center of model grid. The simulated water level was interpolated from the four neighboring grid cells closest to the water level well.

Four residual statistical parameters are computed:

- Residual Mean (RM): The RM is the average (arithmetic mean) of the residuals from the model simulation. The RM is expected to be close to zero. If the RM deviates from zero too much, it may be considered that there may be bias in the model.
- Absolute Residual Mean (ARM): The ARM is the average (arithmetic mean) of the absolute value of the residuals. The ARM is used to evaluate the discrepancy between the water level measurement and the simulated water level without positive and negative residuals canceling each other out like RM.
- Root Mean Square (RMS): The RMS is the square root of the mean of the squared values of the residuals. The RMS is similar to the ARM.
- Standard Deviation (Std Dev): The Std Dev is the standard deviation of residuals. The Std Dev is similar to the RM and the RMS.

Generally, only one of the ARM, RMS, or Std Dev is used in the evaluation of model calibration. This report includes all three statistics for completeness. The model is considered well calibrated if the ARM, RMS or Std Dev value is less than 10% of the range of measurements.

The residual statistics of the entire Regional Model are listed in Tables 4-1 and 4-2. The residual statistics were calculated over the whole model and for each basin. During the model calibration, it was observed that there were wells with water level measurements inconsistent with the conceptual model. For example, the well is screened in the deep model layers but the water level measurements from the well were fluctuating like the nearby wells screened in the shallow model layers. To better evaluate the model calibration, the residual statistics were prepared for all water level data and for the water level data excluding the outlier wells and wells with less than 10 available data points.

From Tables 4-1 and 4-2, it is noted that the RM is close to zero with all basins included, highlighting that the model has very little bias. For individual basin, most of RM are within ± 5 feet. More importantly the percentage of ARM, RMS, or Std Dev are all much less than 10% leading to the conclusion that the Regional Model is calibrated. Residual plots are also available (Figures 4-1 through 4-8) and are discussed in 4.1.4.

4.1.2 HYDROGRAPHS

During the model calibration, many wells in each basin were checked to ensure the simulated transient water level mimics the historical water level. The hydrographs of a selection of these wells are shown on Figure 4-9 through 4-11, and it is noted that the simulated water levels over time closely resemble the fluctuating water level measurements over wet and dry years in many of these wells.

For Piru basin, the simulated water levels in wells screened in Systems A, B, and C closely mimic the water level measurements (Figure 4-9). For Fillmore basin, the majority of wells screened in Systems A and B are close to the water level measurement. A number of wells show a higher deviation from the water level measurements (Figure 4-10). For Santa Paula basin, the water level is relatively flat compared with the wells in Fillmore and Piru. The simulated water levels in Santa Paula basin from wells in Systems A, B, and C are generally in agreement with the water level measurements (Figure 4-11).

In addition to the selection of wells presented, Figures 4-12 through 4-18 show the locations of additional wells within the Piru, Fillmore, and Santa Paula basins as well as several areas within the Oxnard basin. Hydrographs for these additional wells are provided in Appendix A. For the Oxnard basin, the simulated water level is essentially the same as the simulated water level in the Coastal Plain Model. Therefore, the calibration holds for Oxnard, Pleasant Valley, West Las Posas, and Mound basin following the Regional Model expansion.

4.1.3 SIMULATED WATER LEVEL CONTOURS

Simulated groundwater elevations were also contoured for each of the model layers in the Regional Model for the same three dates that simulated water level contours were presented in the Coastal Plain Model documentation (UWCD, 2018). These dates included two key historical times—October 1991 (near the end of previous major drought in the region) and October 2006 (a year of high groundwater elevations following record-setting rainfall in 2005 and associated recharge in 2005 and 2006), as well as for December 2015, which is the most recent month in the model-calibration period and falls in another major drought period. These groundwater-elevation contours are shown on Figures 4-19 through 4-57, with layers 11 through 13 not present in the model expansion basins along the SCR as there is no active layer below Layer 10.

From inspection of these figures, simulated water levels in all applicable layers (1 through 10) of the Piru, Fillmore, and Santa Paula basins reasonably simulate the westerly groundwater flow down the SCR Valley, following the elevation change along the valley as well as the gradients down the hillslopes and tributaries discharging into SCR from the north. The model does capture the variation in water levels between the dry and wet periods, most notably along the valley floor and elevations near the basin boundaries, where rising water typically occurs.

4.1.4 SCATTER PLOTS AND RESIDUAL MAPS

Scatter plots pair the simulated water level with the water level measurement on X-Y plots for inspecting any bias that is not easily identified from residual statistics or well hydrographs. Figure 4-58 shows the scatter plot with all water level measurements throughout the Regional Model. Figures 4-59 through 4-66 show the scatter plots for each basin. Residual plots put the residual means (RM) based on well location in a figure for identifying any regional bias. Figures 4-1 through 4-8 show the RMs for river basins and coastal plain basins. For Aquifer System A shown on Figure 4-1, there is a positive bias (about 10 ft) in Fillmore basin and a slight negative bias (about 10 ft) in Santa Paula basin. These biases are relatively small, much less than 10% of water level data range. For Aquifer System B shown in Figure 4-3, there are significant biases along the foothill area north to the SCR valley floor influenced by the local fault lines. Overall, these biases do not present as a significant regional bias given that the water level data ranges around 500 feet.

4.1.5 SUMMARY ON THE CALIBRATION OF GROUNDWATER COMPONENT

Three criteria are generally used to evaluate the calibration of a groundwater model. They are residual statistics (in Section 4.1.1), well hydrographs (in Section 4.1.2), and residual bias globally or spatially (in Section 4.1.3). From the results shown in Sections 4.1.1 to 4.1.3, it is summarized in the following,

- Residual statistics: The RMs are close to zero and the ARMs are less than 10% of the data range. The residual statistics meet the requirement of the model calibration.
- Hydrographs: The simulated transient water levels from most wells were able to mimic the 1985-2015 water level measurements. Given the fact that the Regional Model simulates a large, complex system with the interaction of a highly flashy streamflow (SCR) with groundwater, the hydrographs are considered well calibrated.
- Residual bias: The scatter plots from Figures 4-58 through 4-66 show no systematic bias and the residual plots show only locally isolated high residuals.

The model calibration for the Piru, Fillmore, Santa Paula basins is summarized below:

- Piru basin: The simulated water level is well calibrated to the observed water level measurements. It is noted that the simulated water levels during a number of droughts are slightly higher than the data.
- Fillmore basin: The simulated water level is well calibrated to the observed water level measurements. There are a number of wells in System B with simulated water level consistently lower than the water level data by less than 10 to 20 feet (less than 10% of the water level range in Fillmore basin, 44.9 ft).
- Santa Paula basin: The simulated water level is well calibrated to the observed water level measurements. There are a number of wells in System B with simulated water level consistently higher than the water level data by less than 10 to 20 feet (less than 10% of the water level range in Santa Paula basin, 25.8 ft).

Based on the above summary, the Regional Model is considered to be a well calibrated regional model that simulates a complex groundwater system covering seven basins from Piru, Fillmore, Santa Paula, Mound, Oxnard, Pleasant Valley, and West Las Posas.

4.2 STREAMFLOW CALIBRATION

Streamflow in the SCR exhibits high spatial and temporal variability. Streamflow is significantly influenced by rainfall and rises rapidly throughout the watershed during rain events. On the other hand, large parts of the watershed are dry during most of the year. In the SCR mainstem, perennial flows are only observed in areas of rising groundwater in the Piru and Fillmore basins, and across the Santa Paula basin (Figure 2-9). Significant efforts were spent during the Regional Model development to capture these complex and dynamic surface flow patterns as accurately as possible. The streamflow calibration analysis was focused on streamflow upstream of the Freeman Diversion Facility, i.e. across the Piru, Fillmore and Santa Paula basins (Figure 2-5). The streamflow calibration includes recharge and surface flow calibration for both Piru and Fillmore basins, as these basins are where most of the recharge percolates. For Santa Paula basin, streamflow calibration is focused on streamflow at the Freeman Diversion facility, as much less streamflow percolation occurs in this basin.

The surface water hydrology calibration for the Regional Model includes a detailed assessment of how well historic spatial and temporal patterns of streamflow, stream channel recharge and rising groundwater were simulated for the 1985-2015 calibration period. While model runs were performed using daily time steps, calibration results were generally shown using averaged (monthly or seasonal) data. The analysis was largely based on assessing the correlation between simulated and observed data, but also by visualization of flow patterns using “heat maps” and comparing to known spatiotemporal flow trends.

4.2.1 BASIN RESPONSE DURING RAINY SEASON

Direct observations of stream channel recharge during the rainy season are very limited due to (1) the difficulty of accurately and safely performing manual discharge measurements during high flows for calculating recharge rates, and (2) a lack of appropriate locations for automated gaging stations at the downstream end of Piru and Fillmore basins (because of the high degree and variability of sediment scour and deposition in the sandy river channel associated with large storm events). Therefore, groundwater basin responses to recharge during the rainy season were assessed by comparing simulated and observed groundwater elevations increases between January 1 and May 1 for Piru and Fillmore basin key wells (see Section 2.7). Groundwater elevation increases were calculated by subtracting January 1 elevations from May 1 elevations, resulting in one data point each for observed and simulated groundwater elevation increases annually. For Piru basin, simulated basin responses ranged from - 10 ft to 53 ft, and correlated well with observed basin responses, ranging from – 19 ft to 57 ft (Figure 4-67). For Fillmore basin, simulated basin responses ranged from - 3 ft to 8 ft, and also correlated well with observed basin responses, ranging from- 4 ft to 13 ft (Figure 4-68). However, one outlier year was observed (1991), when water level increases were under predicted by approximately 9 ft (4 ft simulated versus 13 ft observed).

4.2.2 SURFACE FLOWS AND BASIN RESPONSE DURING CONSERVATION RELEASES

United monitors streamflow at multiple locations in the watershed during conservation releases, in order to monitor the progress of the release and allow calculation of recharge benefits to each of the groundwater basins upstream of the Freeman Diversion Facility. Measurements used for the Regional Model streamflow calibration were available for all fourteen releases performed between 1999 and 2012.

4.2.2.1 PIRU BASIN

Monthly simulated and observed streamflow at the downstream end of Piru basin (upstream of the rising groundwater) generally correlated well, except for one month (September 2003) where the streamflow was significantly over predicted (Figure 4-69). Simulated and observed recharge to Piru basin also correlated well, except for the year 2003 for which recharge to Piru basin was significantly under predicted (Figure 4-70). Generally, the recharge to Piru basin during conservation releases was somewhat over predicted. On the other hand, the over prediction of streamflow for September 2003 observed in Figure 4-69 was clearly associated with the under prediction of recharge in the reach just upstream. The 2003 release was exceptional in that it had the highest volume of recharge to Piru basin among all releases, even though the total release volume was slightly below average. It is not well understood what conditions led to this high recharge, and it is acceptable and expected that the Regional Model was not able to simulate recharge very accurately for this outlier year.

The response of Piru basin to recharge during the conservation releases was assessed by comparing simulated and observed groundwater elevations increases due to releases for the Piru basin key well. Groundwater elevation increases were calculated by subtracting elevations just before release from elevations just after release, resulting in one data point each for observed and simulated groundwater elevation increases annually. The increase in groundwater elevations in the Piru basin key well (04N18W29M02S) due to conservation releases was reasonably well simulated by the Regional Model (Figure 4-71 A). Simulated groundwater level changes generally varied between - 9 and 9 ft, while observed groundwater level changes varied between - 3 and 14 ft. Again, 2003 was an outlier year where the recharge and therefore also the water level increase due to the conservation release was under predicted. When excluding the year 2003, the best-fit linear trend line matches the 1:1 line better. For the remaining years, groundwater level responses to conservation releases were somewhat under predicted for many years, especially for observed water level increases exceeding 7 ft. This observation could not be explained by the simulated recharge during conservation releases, which was generally somewhat over predicted (Figure 4-70). Excluding year 2003, the under prediction of groundwater level increases never exceeds 8 ft, which is acceptable given the range of groundwater elevations observed (Figure 4-71 B). It should be noted that the hydrograph for this key well (04N18W29M02S) generally shows a very good calibration (Figure 4-71 B).

4.2.2.2 FILLMORE BASIN

Monthly simulated and observed streamflow at the downstream end of Fillmore basin (upstream of the rising groundwater) generally correlated well, even though there were a few months where the streamflow was significantly over predicted (Figure 4-72). Simulated and observed recharge to Fillmore basin also correlated reasonably well for most years, but the correlation was not as good as for Piru basin. For Fillmore basin, simulated recharge was significantly different (more than 3,000 AF) from observed recharge for four out of fourteen years (Figure 4-73).

The response of Fillmore basin to recharge during the conservation releases was assessed by comparing simulated and observed groundwater elevation increases due to releases for the Fillmore basin key well. Groundwater elevation increases were calculated by subtracting elevations just before release from elevations just after release, resulting in one data point each for observed and simulated groundwater elevation increases annually. The increase in groundwater elevations in the Fillmore basin key well (03N20W02A01S) due to conservation releases was well simulated by the Regional Model (Figure 4-74 A). Overall, groundwater elevations changed little in response to conservation releases, with observed changes varying between 0 and 5 ft, and simulated changes between 1 and 3 ft. The hydrograph for this key well (03N20W02A01S) shows very good calibration (Figure 4-74 B)

The simulation discrepancies shown for some years in Figure 4-73 do not have a big impact on calibration of groundwater elevations for the Fillmore basin, since groundwater elevations for the Fillmore basin key well are relatively insensitive to stream channel recharge during conservation releases (Figure 4-74 A).

4.2.3 SURFACE FLOW PATTERNS

4.2.3.1 PIRU BASIN

A heat map for flows in Piru basin shows spatial and temporal trends in simulated monthly flows, compared to observed losing and gaining reaches (Figure 4-75). The heat map rows indicate monthly time steps, from the oldest on top to the most recent at the bottom (in this case January 2011 to March 2013). The heat map columns indicate location along the SCR stream channel (each column is one model grid cell along the stream channel, or “stream cell”), in this case from Ventura/Los Angeles County line to Fillmore Fish Hatchery. Flow direction is from left to right, corresponding to the general flow direction from east to west. The value in each cell is the simulated monthly streamflow (cfs). Each row essentially provides a monthly snapshot of the streamflow from upstream (left) to downstream (right). Blue colors indicate high flows, yellow colors intermediate flows and red colors low flows. Watershed features are listed for reference in the top row above the heat map, and colors in the top row indicate known losing reaches (red), gaining reaches (green) or stable reaches (yellow). The Piru losing reach (also known as “dry gap”) starts downstream of the gage USGS 11109000. Accordingly, simulated streamflows rapidly decreased to zero in this area for example years 2011-2013, except during the wettest months when surface flows persisted across the basin (Figure 4-75 A). During a conservation release, simulated flow inputs from Piru creek decreased due to channel percolation, but surface flows persisted across the basin, matching field observations (Figure 4-75 B). Simulated flows in the area of rising groundwater consistently increased and accurately showed transition from a dry to a wetted stream channel, even during dry periods (Figure 4-75 C).

4.2.3.2 FILLMORE BASIN

A heat map for flows in Fillmore basin shows spatial and temporal trends in simulated monthly flows, compared to observed losing and gaining reaches (Figure 4-76). The Fillmore losing reach starts downstream of the Fillmore Fish Hatchery. During conservation releases, simulated flows decreased in this reach as expected (Figure 4-76 A). During drier periods, however, simulated surface flows persisted across the basin, which does not quite match field observations (Figure 4-76 B). Field observations have shown that low flows from Piru basin (or rising groundwater from Piru-Fillmore basin boundary) generally all percolate to groundwater in Fillmore basin. Recharge of low flows in Fillmore basin are a small part of the basin water balance, and simulated groundwater elevations are therefore not very sensitive to this component. Simulated flows in the area of rising groundwater consistently increased and accurately showed transition from a dry to a wetted stream channel, even during dry periods (Figure 4-76 C).

4.2.4 RISING GROUNDWATER IN PIRU AND FILLMORE BASINS

Measurements of rising groundwater at the Piru-Fillmore and Fillmore-Santa Paula basin boundaries are available for the period 2011-2019, which includes periods with high and low groundwater elevations. Observations were available for dry months only, as it is difficult to measure rising groundwater when streamflow is high and dynamic. For both basins, observed rising groundwater correlates well with groundwater elevations at selected wells (see observed data in Figure 4-77 and Figure 4-78).

Simulated rising groundwater in Piru basin was approximately 50% lower compared to observed rising groundwater, at the same groundwater elevation (Figure 4-77). Still, overall the rising groundwater characteristics in Piru basin (location, quantity and correlation to groundwater elevations) were reasonably well predicted by the Regional Model.

Simulated rising groundwater in Fillmore basin varied between 0 and 7 cfs, and was often almost tenfold lower compared to observed rising groundwater flows, which varied between 0 and 27 cfs. While the location of rising groundwater was accurately predicted for Fillmore basin, the rising groundwater flow rate could be improved in the future. A large portion of the rising groundwater from Fillmore basin reaches the Freeman Diversion, and makes up an important part of diversions during the dry season.

4.2.5 STREAMFLOW AND DIVERSION AT FREEMAN DIVERSION FACILITY

In the Santa Paula basin, simulated and observed daily streamflow just upstream of the Freeman Diversion correlated well (Figure 4-79). However, there was significant scatter in the lower flow ranges, which are most relevant to operations of the Freeman Diversion (up to about 3,000 cfs), and the simulated values underpredicted higher flows (Figure 4-80).

To better understand the impact of streamflow simulation discrepancy on simulated diversions, the Hydrological Operations Simulation System (HOSS) was used to calculate simulated diversions based on observed and simulated streamflow at the Freeman Diversion. For the purpose of this comparison, the HOSS calculated diversions based on bypass flow operations proposed in United’s Freeman Diversion Multiple Species Habitat Conservation Plan, without any infrastructure improvements. A more detailed description of the HOSS and modeling scenarios is available in the Regional Model documentation report for future simulations (UWCD, 2021).

Simulated diversions based on observed and simulated streamflow correlate well (Figure 4-81). However, simulated diversions based on simulated streamflow are biased low for most years. On average, simulated diversions are 65,060 AFY based on observed streamflow, and 57,297 AFY based on streamflow simulated by the Regional Model (Table 4-3). Accurate prediction of the annual diversions is important for the purpose of GSP development for basins downstream of the Freeman Diversion Facility. Therefore, United opted to use its Upper Basins Surface Water Hydrology Model to simulate streamflow at the Freeman Diversion, instead of the Regional Model. Predicted streamflow and diversions based on the surface water hydrology model were much closer to observed (Table 4-3). A more detailed description of United's Upper Basins Surface Water Hydrology Model and its integration with the Regional Model is described in the Regional Model documentation report for future simulations (UWCD, 2021).

4.2.6 SUMMARY ON THE CALIBRATION OF STREAMFLOW COMPONENT

Three criteria were used to evaluate the calibration of the streamflow across the Piru, Fillmore and Santa Paula basins. They are stream channel recharge (in Section 4.2.1), rising groundwater (in Section 4.2.4), and streamflow (in Sections 4.2.2, 4.2.3, and 4.2.5). From the results shown in Sections 4.2.1 to 4.2.5, it is summarized in the following,

- Stream channel recharge: The simulated recharge in Piru and Fillmore basins is well correlated to the observed recharge during conservation releases. The location and seasonal occurrence of the dry gap in Piru basin was also accurately simulated. Outside the conservation release periods, recharge of natural baseflows in Fillmore basin was slightly under-estimated, however the calibration of groundwater elevations in the basin was not affected. Stream channel recharge was not assessed for Santa Paula basin as recharge is relatively low there.
- Rising groundwater: The location of the simulated rising groundwater is in general agreement with observed locations, i.e. at Piru-Filmore and Fillmore-Santa Paula basin boundaries. The volume of rising groundwater is under-estimated by the model, especially for the Fillmore basin. The simulated groundwater elevations in the areas of rising groundwater are well calibrated, but heads have a tendency to be under predicted in Fillmore basin, which may cause the under estimation of rising groundwater. Because the simulated rising groundwater is sensitive to water levels changes of less than one foot to a few feet, it may be too sensitive for the numerical model to simulate the rising groundwater adequately. The model may simulate rising groundwater as shallow underflow, in which case groundwater level calibrations are not affected.
- Streamflow: The streamflow patterns and magnitudes across the Piru and Fillmore basins were adequately simulated. The numerical groundwater model has limited surface routing capabilities, and was not expected to capture the highly flashy streamflow conditions in the SCR on a daily basis. However, a consistent under prediction of flow magnitude at the Freeman Diversion Facility led to a significant under prediction of annual average diversions. Therefore, United opted to use an alternative surface water spreadsheet model to simulate streamflow at the Freeman Diversions.

Based on the above summary, the Regional Model is well calibrated for simulating the basin recharges from the streamflow, which is the main goal of the groundwater model. Daily streamflow patterns and magnitudes were adequately captured, but as expected the numerical groundwater model was inherently limited for the purpose of streamflow simulations.

4.3 FLOW BUDGET

Tables 4-4 through 4-10 detail the annual average flow budget for the seven basins covered by the Regional Model, with the river basins (Piru, Fillmore, and Santa Paula basins) discussed in detail in the following sections. Additionally, monthly flow budgets are provided in Appendix B for the seven basins covered in the Regional Model. Overall, the Regional Model annual average values for major water budget components fall within the previously reported ranges reported by previous studies (Table 2-16). In all basins it is noted that ET rates were not detailed separately in previous investigations, but rather were combined together at a total outflow component of consumptive use, in which applied water and precipitation on a given basin (including phreatophytes). When annual average ET and pumping from wells is combined from the Regional Model, the values for Piru and Santa Paula fall within the range of consumptive use previously estimated, and the value for Fillmore basin larger in the Regional Model domain. Several differences between the values reported in previous investigations and the Regional Model simulated results include varying periods of estimation, varying reporting periods (calendar year in this report, and previous reporting varying between calendar years and water years),

4.3.1 PIRU BASIN

The most significant inflow to Piru basin is the stream percolation (73,000 AFY), related to the UWCD conservation releases and streamflows from Los Angeles County. The second most significant inflow is the areal recharge (10,000 AFY) from the areal recharge from agricultural and domestic uses. The combination of the SCR underflow and mountain front recharge yields 10,000 AFY of inflow. The most significant outflow is the flux to Fillmore basin at 47,000 AFY. The second most significant outflow is through the extraction (pumping) wells at 13,000 AFY. The significant flow from Piru to Fillmore indicates the important connection between the two basins. Comparing the annual average water budget component terms with values estimated in previous investigations, most of the components fall within the previously reported ranges. The Regional Model annual average percolation and mountain front recharge rates were simulated slightly higher than the upper limit of previously reported values.

4.3.2 FILLMORE BASIN

The first three most significant inflows, in descending order, are the subsurface inflow from Piru basin (47,000 AFY), areal recharge (21,000 AFY), and stream percolation (14,000 AFY). The first three most significant outflows, in descending order, are the extraction wells (47,000 AFY), the outflow to Santa Paula basin (18,000 AFY), and the rising groundwater to streamflow at 10,000 AFY.

Comparing the annual average water budget component terms with values estimated in previous investigations, most all of the components fall within the previously reported ranges. Similar to Piru basin, the Regional Model annual average mountain front recharge rates were simulated slightly higher than the upper limit of previously reported values. Comparing with the inter-basin flow reported in Section, 2.8.2, the simulated flow from Piru to Fillmore, 47,000 AFY, is within the range of the inter-basin flow from Piru to Fillmore from 12,750 – 111,210 AFY.

4.3.3 SANTA PAULA BASIN

There are two significant inflows for Santa Paula basin: the subsurface inflow from Fillmore (18,000 AFY) and the areal recharge (16,000 AFY). The three most significant outflows include the extraction by pumping wells (25,000 AFY), the rising groundwater to streamflow (6,000 AFY), and the subsurface outflow to Mound basin (6,000 AFY). The subsurface outflow to Oxnard basin is approximately 2,000 AFY. The relatively low outflow from Santa Paula to Oxnard and Mound basins suggests that the three river basins are relatively isolated from the coastal plain basins in terms of the hydrogeological system. It should be emphasized that the surface water system is completely different as the SCR brought an average of 210,000 AFY of surface streamflow to the Oxnard Plain from 1985 to 2019. UWCD diverted an average of 63,000 AFY and the remaining average streamflow of 147,000 AFY continues past Freeman Diversion.

Comparing the annual average water budget component terms with values estimated in previous investigations, most all of the components fall within the previously reported ranges. Comparing with the inter-basin flow reported in Section 2.8.3, the simulated flow from Fillmore to Santa Paula, 18,000 AFY, is within the range of the reported inter-basin flow from Fillmore to Santa Paula from 3,900 – 30,910 AFY. The simulated outflows from Santa Paula to Oxnard and Mound, 2,000 and 6,000 AFY, are on the high side of the reported flow from 1,800 to 7,350 AFY.

4.3.4 COASTAL BASINS

The flow budget of the other four coastal plain basins (Oxnard, Pleasant Valley, West Las Posas, and Mound basins) are relatively unchanged from the Coastal Plain Model. The readers are referred to the Coastal Plain Model report (UWCD, 2018) for further detail.

5 MODEL SENSITIVITY

On the Regional Model, a sensitivity analysis was performed to evaluate the uncertainty of input parameters on the model calibration and inter-basin flows. The Coastal Plain Model has documented the sensitivity analysis of the input parameters in the coastal plain basins. In this report, the sensitivity analysis is focused on the input parameters in the three river basins: Santa Paula, Fillmore, and Piru basins.

Each input parameter was decreased and increased by a percentage, typically ranging between 10% (0.1) and 1000% (10.0), systematically and individually. The Regional Model was run with individually adjusted parameter. The calibration residuals, inter-basin flows, and streamflow percolation within the three river basins were calculated for analysis. The sensitivity analysis was applied to the following parameters:

- SCR underflow from LA County
- Evapotranspiration (ET) rate
- ET extinction depth
- Conductance of faults in the river basins
- Surface recharge from precipitation
- Surface recharge from applied water
- Surface recharge from pumped water
- Stream flow conductance in the three river basins
- Horizonal hydraulic conductivity by zones in each of 10 model layers in the three river basins.
- Ratio of horizonal hydraulic conductivity to vertical hydraulic conductivity by zones in each of 10 model layers in the three river basins.
- Storage coefficient (dimensionless) by zones in each of 10 model layers in the three river basins.
- Specific yield by zones in each of 10 model layers in the three river basins

The calibration residual statistics for each river basin including RM, ARM, RMS, and Std. Dev. as well as the inter-basin flow in the three Aquifer Systems (A, B, and C) and the stream percolation in the three river basins were generated for analysis.

The differences in the residual statistics by individually adjusted parameters are listed in Table 5-1 in terms of the statistical difference and the percentage in statistical difference from the residual statistics from the calibrated model. The sum of the absolute difference percentages is calculated for evaluation. In this report, an ad hoc approach was used to categorize the residual sensitivity in 3 levels: Low, Medium, and High. If the sum is less than 25%, it is assigned “Low” sensitivity.

If the sum is between 25% and 50%, it is assigned “Medium”. If the sum is larger than 50%, it is assigned “High”. It is noted from Table 5-1 that:

- SCR underflow is highly sensitive
- ET rates are highly sensitive while the EVT extinct depth is not
- County Club Fault (HFB #9) is highly sensitive while other faults in the river basins are not sensitive
- Areal recharge rates from precipitation and pumped water are as highly sensitive in Fillmore and Piru basins
- The conductance in Piru Creek and Sespe Creek is highly sensitive as the Piru Creek and Sespe Creek constitute a significant streamflow
- The SCR conductance in Piru basin is highly sensitive as the SCR percolation in Piru basin is typically more significant than percolation in Fillmore and Santa Paula basins
- The horizontal hydraulic conductivity in the aquifers (Layers 3, 5, 7, 9, and 10) and in the Layer 8 aquitard are highly sensitive along the valley floor of river basins (Zones 26, 32, 33, 34, and 35)
- The vertical hydraulic conductivity in Layer 2 in Fillmore basin is sensitive. The vertical hydraulic conductivity in Layer 8 from Fillmore to Santa Paula basin is also sensitive
- The storage coefficient is not sensitive throughout the Piru, Fillmore and Santa Paula basins
- The specific yield is sensitive in Layer 3 in Piru basin reflecting the important role of surface water streamflow percolation

The difference in the inter-basin flows and stream percolation for each basin is listed in Table 5-2. The sum of the absolute difference in inter-basin flows is calculated for each adjusted parameter for evaluation. The percentage in sum of absolute differences relative to the sum of the absolute inter-basin flows is also calculated. An ad hoc approach was used to categorize the inter-basin flow sensitivity in 3 levels: Low, Medium, and High. If the percentage in difference is less than 5%, it is assigned “Low” sensitivity. If the sum is between 5% and 10%, it is assigned “Medium”. If the sum is larger than 10%, it is assigned “High”. It is noted in Table 5-2 that:

- ET rate is highly sensitive while the EVT extinct depth is not
- County Club Fault (HFB #9) is sensitive while other faults in the river basins are not sensitive
- The stream conductance in Piru basin for Piru Creek and SCR are sensitive
- The horizontal conductivity in the aquifers (Layers 3, 5, and 7) are highly sensitive along the river basins’ valley floor (Zones 32, 33, 34, and 35)
- The vertical hydraulic conductivity, storage coefficient, and specific yield are not sensitive throughout the river basins

For an overall evaluation, the sensitivity levels from the calibration residual statistics and the inter-basin flows are tabulated in Table 5-3. It is noted that

- ET rate is sensitive to the model calibration and the inter-basin flows
- County Club Fault (HFB #9) is sensitive to the model calibration and the inter-basin flow as the Country Club Fault controls the flux from Santa Paula basin to Mound basin
- The Piru Creek and SCR conductance in Piru basin are sensitive in the stream percolation in Piru basin as the Piru basin plays a dominant role in the stream percolation
- The conductivity in the aquifers (layers 3, 5, and 7) along the river basins’ valley floor (Zones 32, 33, 34, and 35) are highly sensitive

Finally, it is noteworthy to point out that there is no parameter in the river basins that is not sensitive to the model calibration and is sensitive to the inter-basin flow. This suggests that the input parameters in the three river basins are relatively well defined and less uncertain in the inter-basin flow while there are input parameters in the coastal plain basins that are not sensitive to model calibration and are more sensitive in the inter-basin flow in the coastal plain (UWCD, 2018).

6 MODEL REVIEW

To ensure the quality of the groundwater model, UWCD formed an Expert Panel comprised of three experienced and well-known experts in groundwater flow model development and application to advise and review United's model development since 2016. The experts on the panel are:

- Dr. Sorab Panday:
    - Co-author of the two most recent versions of MODFLOW: MODFLOW-NWT and MODFLOW-USG
    - Member of the National Academy of Engineering (NAE)
    - Principal of GSI Environmental, Inc
- Jim Rumbaugh:
    - President of Environmental Simulations Inc.
    - Developer of the widely used MODFLOW pre- and post-processor, Groundwater Vistas
- John Porcello:
    - Consultant with extensive experience in groundwater modeling in general, and specific experience with hydrogeologic conditions in Ventura County
    - Principal Groundwater Hydrologist of GSI Water Solutions, Inc.
    - Licensed Geologist and Hydrogeologist in Oregon and Washington

The Expert Panel thoroughly reviewed the Coastal Plain Model and released a model review report in 2018 (GSI Water Solutions and others, 2018) and concluded that the Coastal Plain Model was well built and well calibrated.

In the current model expansion from 2019, The Expert Panel has continued to review the model expansion effort since 2019. Several rounds of in-depth review were performed by the experts. The Expert Panel will provide a Final memo regarding both (1) the Regional Model expansion to include the Piru, Fillmore, and Santa Paula basins as well as (2) the Regional Model update to include 2016-2019 data. The Regional Model update document is yet to be reviewed by the Expert Panel, however, interim feedback from the Expert Panel included the assessment of the Regional Model expansion described in this report that:

- The model calibration to both heads and streamflows is very good, especially considering the size of the model grid cells compared to stream dimension in these three basins that have been added to the model.
- The three experts believe that the model replicates the historically observed conditions quite well during the calibration period.
- Accordingly, the United Water District should feel proud of the current model.

7 CONCLUSIONS AND MODEL LIMITATIONS

The Regional Model is found to be well calibrated based on the residual analysis on the groundwater level measurements and the streamflow analysis on the streamflow measurements. The Regional Model is suitable for regional groundwater management simulations and can provide meaningful interpretation of the inter-basin flow budget covering the seven basins within Ventura County. The Regional Model also simulates well the streamflow interaction with groundwater for the basin scale analysis. It is noted that the simulated daily streamflow may be further improved in the future, particularly for calculating streamflow at the Freeman Diversion. The various components of the SCR corridor may be analyzed with a refined model grid for potential improvement, including potential spatial variability of riparian vegetation evapotranspiration parameters and streambed parameters, such as stream bed elevations

All numerical models have limitations inherent in the assumptions made in developing the conceptual model and the numerical model. The Regional Model is no exception. The assumptions listed in Sections 2 and 3 form the limitations of the Regional Model. The limitations of the Regional Model are as follows:

- The uncertainty in the cross sections interpreted from the e-logs
- The simplification of the groundwater systems and the interaction of the streamflow and groundwater
- The numerical resolution based on the grid size and temporal scale
- The calibration errors and uncertainties from the numerical model including but not limited to water levels in droughts, stream flow interaction with aquifers, the SCR underflow from LA County, areal recharge, and fault lines.
- The measurements error from water level, streamflow, and groundwater extraction records, plus from other hydrologic data
- The data gap in the underflows from Arroyo Las Posas from the Las Posas Valley basin, and the streamflow records along Arroyo Las Posas and Conejo Creek

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TABLES

Tables 3-7, 3-8, and 3-10 are embedded in Section 3 of the report, and noted in the List of Tables.

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Table 2-1. Piru, Fillmore, and Santa Paula Population Center Trends, Based on United States Census Bureau Data.

Population	*Piru*	*Fillmore*	*Santa Paula*
1980[1]	1,284	9,602	20,658
1990[1]	1,157	11,992	25,062
2000 [2]	1,196	13,643	28,598
2010[2]	2,063	15,002	29,321
2019 estimate[3]	1,805*4	15,644*5	32,900*6
areal extent[2] **(mi^2)**	2.8	3.4	4.6

[1] https://docs.vcrma.org/images/pdf/planning/demographics/Census_Pop_Ventura_Co_1850-2000.pdf

[2] https://data.census.gov/cedsci/

[3] 2019 American Community Survey 5-Year Estimates

*4 https://data.census.gov/cedsci/profile?g=1600000US0657372

*5 https://data.census.gov/cedsci/table?q=Fillmore%20city,%20California&tid=ACSDT5Y2019.B01003

*6 https://data.census.gov/cedsci/table?q=Santa%20Paula%20CCD,%20Ventura%20County,%20California&tid=ACSDT5Y2019.B01003

Table 2-2. Long-Term Annual Precipitation Records for Piru, Fillmore, and Santa Paula Basins.

				Annual Precipitation (inches)			
Basin	*Station*	*Elevation (ft)*	*Period (Water Years)*	*Average*	*Median*	*Minimum*	*Maximum*
Piru	25	825	1928 - 2015	17.1	14.4	5.4	44.5
Fillmore	171	465	1957 - 2015	18.3	16.1	5.3	43.2
Santa Paula	245a*	300	1850 - 2015	16.8	15.0	5.0	44.8

*Full record period created considering that site moved overtime from nearby locations

Table 2-3. Annual Average Streamflow (CFS) in Piru, Fillmore, and Santa Paula Basins.

Streamgage	Santa Clara River LA County Line USGS 11108500 Near Piru, CA USGS 11109000	Piru Creek* USGS 11109800	Hopper Creek USGS 11110500	Pole Creek VCWPD 713	Sespe Creek USGS 11113000	Santa Paula Creek USGS 11113500
1985	33.79	29.65	0.97	0.85	14.86	4.71
1986	66.33	28.02	10.26	3.54	138.40	27.88
1987	36.19	44.66	0.79	0.70	12.99	3.93
1988	50.43	33.62	2.04	0.81	65.13	10.19
1989	34.25	14.37	0.36	0.55	15.80	3.54
1990	32.42	6.88	0.62	0.29	6.21	3.34
1991	48.21	52.80	6.03	1.07	110.24	21.56
1992	94.46	107.61	10.76	3.19	290.64	47.69
1993	211.04	186.82	22.79	6.45	630.70	98.86
1994	44.25	62.72	5.63	6.85	35.92	10.68
1995	113.83	134.40	28.81	17.67	461.05	87.81
1996	67.58	30.58	3.93	2.50	91.46	17.41
1997	50.80	53.35	6.02	1.83	74.54	20.66
1998	283.35	170.97	44.38	9.11	523.87	111.30
1999	53.80	35.49	1.55	1.17	24.62	5.91
2000	60.49	72.08	4.22	1.41	61.25	11.93
2001	47.85	88.57	9.53	3.89	203.51	34.45
2002	34.66	35.32	0.87	0.67	11.90	3.21
2003	49.92	45.11	2.82	1.11	71.17	11.56
2004	68.70	22.25	6.57	2.05	104.21	16.45
2005	362.27	256.03	62.03	17.35	686.71	139.73
2006	90.94	66.13	6.89	2.54	208.95	30.97
2007	38.77	61.75	0.83	0.64	12.75	3.93
2008	80.28	65.97	12.95	1.92	192.30	38.67
2009	57.71	41.43	1.92	0.66	46.27	9.03
2010	82.32	50.84	3.89	1.07	137.00	24.54
2011	85.98	50.22	7.46	1.24	172.27	41.34
2012	41.08	55.25	0.85	1.27	18.46	4.86
2013	31.63	7.88	0.13	0.17	5.59	1.24
2014	33.34	8.98	2.96	0.15	30.34	2.78
2015	26.11	9.03	0.07	0.23	6.87	1.03
1985 - 2015 Average	**77.83**	**62.22**	**8.68**	**3.00**	**144.06**	**27.46**

*Data from USGS and VCWPD, as described in Section 2.3; Units: CFS; *United Santa Felicia Dam spills added to USGS gage data*

Table 2-4. Total Annual Spills from Lake Piru from 1985 – 2005.

Year	SFD Spills (AFY)
1985	0
1986	0
1987	0
1988	0
1989	0
1990	0
1991	0
1992	2,224
1993	56,176
1994	0
1995	7,749
1996	0
1997	0
1998	47,795
1999	0
2000	0
2001	790
2002	0
2003	0
2004	0
2005	107,062

Data from UWCD records

Table 2-5. Benefits of the SFD Conservation Releases, 1999-2015.

Calendar Year	Total Conservation Released from SFD AF	Direct Deliveries in AF of SFD Release to:			
		Piru Basin (groundwater recharge)	Fillmore Basin (groundwater recharge)	Lower Basins* (groundwater recharge)	Surface water Ag Deliveries via Pipelines
1999	22,800	5,700	3,500	11,200	2,400
2000	47,200	13,800	6,100	24,150	3,150
2001	47,400	14,000	2,900	28,300	2,200
2002	20,200	8,000	5,100	6,530	570
2003	29,000	21,000	3,500	3,600	900
2004	12,200	8,000	2,150	1,600	550
2005	9,100	3,500**	1,100**	4,500***	0
2005	23,400	4,550**	1,500**	17,200***	150
2006	30,900	9,200**	2,900**	17,200***	1,600
2007	40,700	15,900	6,300	12,200	6,400
2008	44,400	15,400	5,700	17,400	5,800
2009	26,700	13,200	4,700	5,200	3,000
2010	33,000	14,500	4,800	10,700	3,200
2011	31,700	12,400	3,300	14,100	1,600
2012	35,200	13,600	8,600	9,300	3,700
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
Average	**25,217**	**9,597**	**3,453**	**10,177**	**1,957**
Total (over all 18 releases)	**453,900**	**172,750**	**62,150**	**183,180**	**35,220**

Notes:*Direct Deliveries to Santa Paula basin are not able to be estimated due to inability to adequately measure the percolation losses within the total basin, as discussed above in Section 2.3.1.1.2 It is noted here that most of the remaining flows after Fillmore basin arrive to United's Freeman diversion after some losses to Santa Paula basin due to percolation and evapotranspiration.
2005 had two conservation releases. Portion of the release includes spill water when the lake was full.
*2005 had two conservation releases. 2005 and 2006 were not measurable due to high flow rates in the Santa Clara River. Direct Deliveries for Piru and Fillmore Basins are estimated.
*** measured at the Freeman Diversion
Table modified from United Water's 2013 Groundwater and Surface Water Condition Report (UWCD, 2014) and updated to include calendar years 2014 and 2015. Table from United's 2014 and 2015 Piru and Fillmore Basin's Biennial Groundwater Conditions Report (United, 2016).

Table 2-6. Sespe Streamflow Daily Record Data Source Overview.

Start Date	End Date	Description
1/1/1985	9/30/1985	USGS_11113000_SESPE_C_NR_FILLMORE
10/1/1985	9/29/1988	USGS_11113001_SESPE_C_+_FILLMORE_IRR_CO_CN_NR_FILLMORE_CA note: subtracted estimated diversions based on rainfall from this record
9/30/1988	9/30/1989	Correlation with Santa Paula Creek for wet years
10/1/1989	9/30/1990	USGS_11113001_SESPE_C_+_FILLMORE_IRR_CO_CN_NR_FILLMORE_CA note: subtracted estimated diversions based on rainfall from this record
10/1/1990	1/14/1993	USGS_11113000_SESPE_C_NR_FILLMORE
1/15/1993	9/30/1993	Correlation with Santa Paula Creek for dry years
10/1/1993	12/31/2015	USGS_11113000_SESPE_C_NR_FILLMORE

Table 2-7. Average Annual Streamflow Diversions (AFY) in Piru, Fillmore, and Santa Paula Basins.

Diversion	Isola	Camulos	Rancho Temescal 1	Rancho Temescal 2	Piru Mutual	United (Piru)	Fillmore Irr. Co.	Beans Ranch	Limoneira	Canyon Irr. Co.	Farmers Irr. Co.	Zaragosa	Hyde-Turner Ditch	Southfork	United (Freeman)
Approximate Area (ac)	209.9	770.2	241.6	314.3	546.4	47.0	1104.7	82.2	126.3	783.7	3177.6	1.8	345.8	158.9	416.0
							Total Diversions (AFY)								
Year															
1985	568.0	1092.0	0.0	0.0	1273.0	249.9	2535.9	53.5	0.0	348.0	0.0	0.0	499.1	230.0	42765.6
1986	568.0	1092.0	0.0	0.0	1273.0	2346.4	2649.9	53.5	0.0	975.0	0.0	0.0	499.1	230.0	69834.1
1987	568.0	1092.0	0.0	0.0	1273.0	4542.1	2478.5	53.5	0.0	693.0	0.0	0.0	499.1	230.0	37684.0
1988	568.0	1092.0	0.0	0.0	1277.0	4903.1	2673.7	53.5	0.0	922.0	0.0	0.0	499.1	230.0	49144.3
1989	632.0	1092.0	0.0	0.0	1273.0	0.0	2242.4	53.5	0.0	697.0	0.0	0.0	499.1	230.0	24413.4
1990	601.0	0.0	0.0	0.0	1273.0	1319.0	1567.2	53.5	0.0	454.0	0.0	0.0	499.1	230.0	7805.0
1991	601.0	0.0	0.0	0.0	1273.0	299.5	2722.2	53.5	0.0	1108.0	0.0	0.0	499.1	230.0	45232.3
1992	601.0	514.0	0.0	0.0	1274.0	22375.5	2853.6	53.5	0.0	1071.0	0.0	0.0	499.1	230.0	118713.5
1993	273.0	780.0	0.0	0.0	1273.0	15875.1	2546.8	53.5	156.9	1011.0	0.0	0.0	499.1	230.0	117966.9
1994	216.0	410.0	0.0	0.0	921.0	4994.2	2649.9	52.0	27.2	962.0	0.0	0.0	499.1	270.0	71250.5
1995	67.0	460.0	0.0	0.0	927.0	8519.0	2538.8	55.0	0.0	1020.0	0.0	0.0	499.1	289.2	120914.8
1996	465.0	0.0	0.0	0.0	1392.0	776.1	2586.4	53.5	67.0	489.0	0.0	0.0	499.1	308.4	69129.9
1997	500.0	0.0	0.0	0.0	1258.0	1574.9	2634.0	53.5	0.0	1143.0	0.0	0.0	499.1	327.6	72063.5
1998	317.0	446.0	0.0	0.0	1298.0	9062.5	2443.6	53.5	0.0	866.0	0.0	0.0	499.1	346.8	146729.3
1999	526.0	1809.0	0.0	0.0	1163.0	782.5	2578.5	53.5	0.0	283.8	0.0	0.0	499.1	366.0	57455.2
2000	705.0	2195.0	0.0	0.0	1957.0	55.5	2578.5	53.5	0.0	899.3	0.0	0.0	499.1	385.2	76437.0
2001	588.0	2586.0	0.0	0.0	1722.0	2768.9	3248.3	53.5	36.0	694.5	289.1	0.0	499.1	404.4	107393.1
2002	590.0	3008.0	486.6	11.0	1722.0	708.1	2721.3	60.0	0.0	317.1	129.0	0.0	499.1	423.6	29768.8
2003	436.0	1785.0	601.1	6.5	1722.0	95.0	2642.0	50.0	1.0	490.0	278.1	0.0	499.1	442.8	46581.8
2004	477.0	1785.0	282.6	93.0	1727.0	95.4	2657.8	57.0	0.0	479.6	213.3	0.0	499.1	462.0	33602.0

Table 2-7 continued, below

Table 2-7. Average Annual Streamflow Diversions (AFY) in Piru, Fillmore, and Santa Paula Basins

Diversion	**Isola**	**Camulos**	**Rancho Temescal 1**	**Rancho Temescal 2**	**Piru Mutual**	**United (Piru)**	**Fillmore Irr. Co.**	**Beans Ranch**	**Limoneira**	**Canyon Irr. Co.**	**Farmers Irr. Co.**	**Zaragosa**	**Hyde-Turner Ditch**	**Southfork**	**United (Freeman)**
Approximate Area (ac)	209.9	770.2	241.6	314.3	546.4	47.0	1104.7	82.2	126.3	783.7	3177.6	1.8	345.8	158.9	416.0
							Total Diversions (AFY)								
Year															
2005	0.0	1785.0	320.1	139.8	1722.0	2653.1	50.0	40.0	0.0	299.7	11.3	0.0	499.1	481.2	138050.2
2006	0.0	1475.6	597.6	80.1	1471.4	2266.7	174.0	55.0	1.0	118.1	25.4	0.0	499.1	500.4	101178.2
2007	0.0	1333.2	1004.8	181.9	1325.7	75.0	0.0	60.0	0.5	23.0	13.4	0.0	499.1	519.6	44725.9
2008	0.0	1487.4	979.8	55.6	1231.2	228.5	0.0	51.0	0.0	254.4	113.6	0.0	499.1	520.0	73428.5
2009	0.0	1310.0	984.1	44.9	1217.4	0.0	0.0	99.0	0.0	225.0	75.3	0.0	362.0	520.0	41149.1
2010	0.0	3540.0	863.9	13.0	1124.1	0.0	0.0	104.4	34.4	263.7	328.2	0.0	306.7	520.0	64113.4
2011	0.0	2510.0	976.9	147.6	2400.0	0.0	0.0	116.0	69.3	589.1	214.9	0.4	310.1	520.0	93958.5
2012	0.0	3853.0	1124.0	168.8	2400.0	0.0	0.0	74.8	0.0	161.3	0.0	0.4	290.4	520.0	39165.9
2013	0.0	4402.0	1262.8	247.0	2400.0	0.0	0.0	146.4	0.0	104.8	0.0	0.4	699.0	527.8	8767.6
2014	0.0	784.5	1294.8	226.4	1261.3	0.0	0.0	135.7	0.0	80.7	0.0	0.4	696.6	527.8	4543.6
2015	0.0	862.4	1163.9	220.5	1321.9	0.0	0.0	84.4	0.0	38.0	33.0	0.4	629.5	450.0	2539.9
1985 - 2015 Average	**318.3**	**1438.1**	**385.3**	**52.8**	**1456.3**	**2792.5**	**1670.1**	**65.9**	**12.7**	**551.0**	**55.6**	**0.1**	**492.7**	**377.5**	**63113.1**

Data from State Water Board, CH2M Hill/HGL (2008) and United Records, as described in Section 2.3.8

Units: AFY

Table 2-8. Fillmore Irrigation Company Sespe Creek Diversion Data Source Overview.

Start Date	End Date	Description
1/1/1985	9/29/1988	USGS_11113001_SESPE_C_+_FILLMORE_IRR_CO_CN_NR_FILLMORE_CA note: estimated diversions based on rainfall for data gaps
9/30/1988	9/30/1989	Filled data gaps with estimated diversions based on rainfall
10/1/1989	9/30/1990	USGS_11113001_SESPE_C_+_FILLMORE_IRR_CO_CN_NR_FILLMORE_CA note: estimated diversions based on rainfall for data gaps
10/1/1990	1/12/1993	USGS_11112500_FILLMORE_IRR_CO_CN_NR_FILLMORE_CA
1/13/1993	12/31/2000	Filled data gaps with estimated diversions based on rainfall
1/1/2001	12/31/2001	Reported monthly data distributed evenly across month
1/1/2002	12/31/2004	Filled data gaps with estimated diversions based on rainfall
1/1/2005	12/31/2006	Reported monthly data distributed evenly across month
1/1/2007	12/31/2015	No diversions

Table 2-9. Annual Average Wastewater Discharge (AFY) in Piru, Fillmore, and Santa Paula Basins.

Wastewater Plant	Piru WWTP	Fillmore			Santa Paula WRF	Todd Rd. Co. Jail WWTP
		Percolation Ponds	Santa Clara River	Total		
1985	137.65	1118.87	0.00	1118.87	2291.03	0.00
1986	137.65	1118.87	0.00	1118.87	2291.03	0.00
1987	137.65	1118.87	0.00	1118.87	2291.03	0.00
1988	138.03	1121.93	0.00	1121.93	2352.68	0.00
1989	137.65	1118.87	0.00	1118.87	2234.77	0.00
1990	122.81	1118.87	0.00	1118.87	2141.50	0.00
1991	119.12	1118.87	0.00	1118.87	2057.74	0.00
1992	137.53	1121.93	0.00	1121.93	2275.82	0.00
1993	134.12	1118.87	0.00	1118.87	2279.70	0.00
1994	134.13	1118.87	0.00	1118.87	2188.33	0.00
1995	172.16	1118.87	0.00	1118.87	1978.56	43.11
1996	171.93	1121.93	0.00	1121.93	1911.65	43.22
1997	140.15	1118.87	0.00	1118.87	2011.26	43.11
1998	117.68	1156.42	705.77	1862.19	2439.31	43.11
1999	127.65	974.60	1127.40	2102.00	2299.74	43.11
2000	176.49	1017.72	0.00	1017.72	2355.85	43.22
2001	184.70	1040.28	915.93	1956.20	2424.38	43.11
2002	254.39	986.36	1138.29	2124.65	2381.05	43.11
2003	254.10	1174.34	759.89	1934.23	2395.51	43.11
2004	252.88	1128.81	380.89	1509.70	2473.14	43.22
2005	225.64	1295.52	0.00	1295.52	2629.74	43.11
2006	230.06	1299.74	0.00	1299.74	2572.39	43.11
2007	242.66	1118.87	673.47	1792.34	2488.50	43.11
2008	225.17	1121.93	0.00	1121.93	2665.72	43.22
2009	212.27	1058.29	0.00	1058.29	2666.91	43.11
2010	169.23	1210.38	0.00	1210.38	2173.39	43.11
2011	212.96	1124.43	0.00	1124.43	2263.80	35.48
2012	202.44	993.18	0.00	993.18	2136.68	39.09
2013	164.42	998.22	0.00	998.22	2086.66	44.19
2014	137.73	981.00	0.00	981.00	1976.03	46.88
2015	133.49	984.68	0.00	984.68	1904.09	40.28
1985 - 2015 Average	172.40	1103.85	183.92	1287.77	2278.64	28.91

Data from data submitted to State Water Resources Control Board , as described in Section 2.8;
Units: AFY

Table 2-10. Revised Model Layering in Piru, Fillmore, and Santa Paula Basins.

Aquifer or Aquitard	Hydrostratigraphic Unit Description	Model Layer
Surficial Deposits and Colluvium	Interbedded, poorly sorted surficial deposits including colluvium, landslide deposits, and alluvial fan material. Generally absent in vicinity of Santa Clara River channel. Thickness ranges from 0 to over 400 ft.	1
Aquitard		2
Recent (younger) Alluvium	Stream-deposited sands and gravels, with some finer-grained interbeds; primarily permeable sands and gravels. Thickness ranges from 0 to 190 ft.	3
Aquitard		4
Older Alluvium	Stream-deposited sands and gravels with finer grained interbeds; similar to younger alluvium deposits, with greater variation in grain size. Thickness ranges from 0 to 340 ft.	5
Aquitard		6
Upper Saugus/ San Pedro	Semi-consolidated lenticular deposits of sands, gravels, and some clays of the Upper Saugus Formation. Underlies alluvial aquifers throughout the upper basins.	7
Aquitard		8
Lower Saugus/San Pedro	Semi-consolidated lenticular deposits of sands, gravels, and some clays of the Lower Saugus Formation.	9
Undifferentiated Sedimentary Deposits	Undifferentiated, semi-consolidated sediments of the San Pedro Formation.	10

Table 2-11. Layering of Coastal Basins (Oxnard, Pleasant Valley, and West Las Posas Basins).

Aquifer or Aquitard	Hydrostratigraphic Unit Description	Model Layer
Semi-perched Aquifer	Stream and coastal-deposited sands and gravels with minor silt and clay interbeds	1
"Clay Cap" Aquitard	Silt and clay with interbedded sands	2
Oxnard Aquifer	Marine and non-marine sands, gravels, and cobbles with some clay and silt interbeds	3
Oxnard-Mugu Aquitard	Interbedded clay, sand, and gravel	4
Mugu Aquifer	Marine and non-marine sand and gravel with silt and clay interbeds	5
Mugu-Hueneme Aquitard	Interbedded clay, silt, sand, and gravel of the Upper San Pedro Formation. This bed, where present, marks the top of the lower aquifer system (LAS).	6
Hueneme Aquifer	Marine and non-marine interbedded sand, silt, clay, and minor gravel of the Upper San Pedro Formation.	7
Hueneme-Fox Canyon Aquitard	Marine and non-marine silt and clay with interbedded sand and gravel.	8
Fox Canyon Aquifer - upper	Marine interbedded sand with some gravel, silt, clay, and sandy clay of the San Pedro Formation.	9
Fox Canyon Aquitard	Marine and non-marine silt and clay, with interbedded sand and gravel of the basal San Pedro Formation	10
Fox Canyon Aquifer - basal	Marine interbedded sand with some gravel, silt, clay, and sandy clay (similar composition as the Fox Canyon Aquifer – upper)	11
Santa Barbara and/or other Formation	Silt and clay with interbedded sand and gravel of the basal San Pedro Formation and Upper Santa Barbara Formation.	12
Grimes Canyon Aquifer	Sands and gravels of the Upper Santa Barbara Formation. Localized and not continuous or present in some basins	13
Older sedimentary rocks and Conejo Volcanics	Sedimentary and igneous rock of low permeability or containing saline groundwater.	Boundary

Table 2-12. Estimated Hydraulic Conductivity Estimates and Aquifer System Statistics for Piru Basin

Basin	Well	Estimated Hydraulic Conductivity (ft/d)	Aquifer System	Estimated Hydraulic Conductivity System Statistics (ft/d)					
Piru	04N19W33C03S	343.89	AB						
Piru	04N18W26E01S	205.66	AB						
Piru	04N18W27H03S	100.26	AB	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Piru	04N18W27H02S	138.60	AB	177.06	197.10	172.13	100.26	343.89	4
Piru	04N19W27R03S	220.33	B						
Piru	04N19W33C02S	286.46	B						
Piru	04N18W20R01S	247.15	B						
Piru	04N19W34D01S	139.25	B						
Piru	04N19W33F01S	213.89	B	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Piru	04N18W30E01S	311.15	B	229.09	236.37	233.74	139.25	311.15	6
Piru	04N18W19P03S	91.40	BC						
Piru	04N18W28C02S	44.00	BC	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Piru	04N18W29K01S	126.76	BC	79.89	87.39	91.40	44.00	126.76	3

Table 2-13. Estimated Hydraulic Conductivity Estimates and Aquifer System Statistics for Fillmore Basin

Basin	Well	Estimated Hydraulic Conductivity (ft/d)	Aquifer System	Estimated Hydraulic Conductivity System Statistics (ft/d)					
Fillmore	03N20W01P04S	30.08	A						
Fillmore	03N21W01P03S	546.25	A						
Fillmore	03N21W12H03S	13.37	A	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Fillmore	03N20W02R09S	5.57	A	33.26	148.82	21.72	5.57	546.25	4
Fillmore	04N20W25B01S	62.77	AB						
Fillmore	04N19W30P05S	155.96	AB						
Fillmore	04N19W31D04S	73.13	AB						
Fillmore	04N20W34N05S	285.74	AB						
Fillmore	03N20W02F05S	14.24	AB						
Fillmore	03N20W01P05S	0.86	AB						
Fillmore	03N20W02K05S	114.58	AB						
Fillmore	03N20W04R02S	197.18	AB						
Fillmore	04N20W36J05S	286.46	AB	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Fillmore	03N20W03H03S	150.39	AB	68.95	134.13	132.49	0.86	286.46	10
Fillmore	04N20W31J01S	1.54	ABC	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Fillmore	03N20W06D03S	4.72	ABC	2.70	3.13	3.13	1.54	4.72	2
Fillmore	04N20W23N02S	16.51	B						
Fillmore	04N19W29R05S	114.06	B						
Fillmore	04N19W33D06S	121.32	B						
Fillmore	04N19W33D05S	206.54	B						
Fillmore	03N20W03D05S	61.89	B						
Fillmore	03N20W05C04S	4.27	B						
Fillmore	03N20W01H03S	55.96	B						
Fillmore	03N20W06N02S	227.87	B						
Fillmore	04N20W13N01S	1.00	B						
Fillmore	04N19W33D04S	132.72	B						
Fillmore	04N20W33C03S	8.72	B	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Fillmore	04N20W31H02S	0.84	B	27.06	79.31	58.92	0.84	227.87	12
Fillmore	04N20W24R02S	7.12	C	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Fillmore	03N20W06A03S	3.82	C	5.22	5.47	5.47	3.82	7.12	2

Table 2-14. Estimated Hydraulic Conductivity Estimates and Aquifer System Statistics for Santa Paula Basin

Basin	Well	Estimated Hydraulic Conductivity (ft/d)	Aquifer System	Estimated Hydraulic Conductivity System Statistics (ft/d)					
Santa Paula	03N21W29C02S	116.97	A						
Santa Paula	03N21W29K01S	253.99	A						
Santa Paula	03N21W29K02S	233.94	A	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Santa Paula	03N21W16P01S	4.81	A	76.05	152.43	175.46	4.81	253.99	4
Santa Paula	03N21W29G02S	33.15	AB						
Santa Paula	03N21W20A01S	39.84	AB						
Santa Paula	03N21W21B03S	29.14	AB						
Santa Paula	03N21W20J04S	222.31	AB						
Santa Paula	02N22W02K06S	121.38	AB						
Santa Paula	02N22W10A02S	12.30	AB	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Santa Paula	03N21W11E03S	48.39	AB	48.35	72.36	39.84	12.30	222.31	7
Santa Paula	03N21W02P01S	86.49	B						
Santa Paula	03N21W12E07S	60.16	B						
Santa Paula	03N22W36K04S	151.06	B						
Santa Paula	03N22W36R01S	177.80	B						
Santa Paula	03N21W17P02S	69.65	B						
Santa Paula	03N21W19G02S	43.45	B						
Santa Paula	03N21W19G03S	26.74	B						
Santa Paula	03N21W11F03S	75.00	B						
Santa Paula	03N21W09R04S	92.51	B						
Santa Paula	03N21W15C06S	79.81	B						
Santa Paula	03N21W16A02S	178.20	B						
Santa Paula	03N21W11D02S	1.47	B						
Santa Paula	03N21W30F01S	184.08	B						
Santa Paula	03N21W30H07S	26.20	B						
Santa Paula	03N22W36H01S	168.97	B						
Santa Paula	03N22W35Q02S	21.12	B						
Santa Paula	03N21W16G01S	260.68	B						
Santa Paula	03N21W16K03S	88.10	B						
Santa Paula	03N21W19G04S	96.12	B	Mean (Geometric)	Mean (Arithmetic)	Median	Minimum	Maximum	n
Santa Paula	02N22W10C02S	118.58	B	69.73	100.31	87.29	1.47	260.68	20

Table 2-15. Chronology of Previous Investigations Related to Piru, Fillmore, and Santa Paula Basins Water Budget Components.

Entity	Year Published	Reference	Budget Components Provided?	Representative Years
California Department of Public Works, Division of Water Resource	1933	DWR, 1933	All, various	1927 - 1932
California State Water Resources Board	1956	DWR, 1956	All, various	1936 - 1951
John F. Mann and Associates	1959	Mann, 1959	All, various	1936 - 1957
California Department of Water Resources	1974, 1975	DWR, 1974 1975	Piru, subsurface inflow	1956 - 1967
Law/Crandall Inc.	1993	Law/Crandall, 1993	Fillmore, subsurface outflow	1956 - 1990
United States Geological Survey	2003	Reichard and others, 2003	Fillmore, subsurface outflow	1984 – 1993
CH2M HILL	2004	CH2M HILL, 2004	Piru, subsurface inflow	1980 - 1999
CH2M HILL	2005	CH2M HILL, 2005	Piru, subsurface inflow	1980 - 2005
CH2M HILL/ HydroGeoLogic Inc; HydroMetrics (United-sponsored analysis)	2008	CH2M HILL/ HGL, 2008	Piru and Fillmore, subsurface inflow	1975 - 2005
HydroMetrics (United-sponsored updates)	2015	LWA and others, 2015	All, various	1996 - 2012
Steve Bachman	2015	Bachman, 2015	Fillmore, subsurface outflow	1947 - 2014
Daniel B. Stephens and Associates, Inc/ Richard C. Slade and Associates LLC	2017	DBS&A and RCS, 2017	Fillmore and Santa Paula, various	1999 - 2012

Table 2-16. Range of Water Budget components from Previous Investigations Related to Water Budget Components for the Piru, Fillmore, and Santa Paula Basins Listed in Table E-1.

	Piru		***Fillmore***		***Santa Paula***	
Budget Components (AFY)	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
Inflows						
Subsurface underflow	240	18,800	12,570	111,210	3,900	30,910
Stream Percolation	6,400	61,850	1,790	49,130	4,210	24,440
Precipitation Recharge	190	20,200	470	54,200	40	25,590
Mountain Front Recharge	2,620	2,620	3,530	3,530	3,600	3,600
Managed Recharge	0	11,800	--	--	--	--
Local Wastewater Treatment Percolation Ponds	210	210	1,040	1,040	2,230	2,230
Imported	0	5,840	4,900	11,770	4,220	8,570
Outflows						
Subsurface underflow	12,570	111,210	3,900	30,910	1,800	7,350
Rising groundwater	0	37,800	6,030	48,200	2,040	17,340
Consumptive use*	6,450	15,000	20,590	36,200	15,420	33,730
Exported	2,200	6,450	0	5,160	310	2,100
Change in Groundwater Storage*	***-19,600***	***44,600***	***-20,170***	***49,300***	***-10,900***	***21,680***

*Of applied water and precipitation on basin (including phreatophytes)

**Reported changes in annual storage (not calculated from inflows and outflows presented here)

Notes:

Majority of values extracted from DWR (1956) or Mann (1959), with other references being CH2M HILL (2004, 2005), CH2M HILL/HGL (2008), LWA and others (2015) and DBS&A and RCS (2017).

Values rounded to nearest 10 AF.

Table 3-1. Parameters by Layer and Zone, Horizontal Hydraulic Conductivity

	Horizontal Hydraulic Conductivity in Each Zone (ft/day)																	
Layer	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**18**	**19**	**20**
1	200	200	200	200	300	200	200	300	200	200	200	200	50	50	200	300	200	200
2	0.01	0.01	0.01	0.01	0.01	0.01	1.00E-03	0.01	0.01	0.01	100	100	50	50	200	300	200	0.01
3	100	100	100	0.01	300	100	100	200	100	100	100	50	10	10	200	250	200	100
4	1	1	0.1	0.01	1	1	1	200	1	20	100	20	1	1	200	250	200	1
5	100	50	50	100	200	50	50	200	100	20	100	20	1	1	200	200	100	100
6	1.00E-03	1.00E-03	1.00E-03	0.01	3.00E-03	0.01	1.00E-03	1.00E-03	5.00E-04	1.00E-02	50	0.01	0.01	0.01	1.00E-03	1.00E-04	0.1	1.00E-03
7	20	20	20	20	20	20	20	0.5	20	20	10	10	10	1	20	1.00E-04	20	20
8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.1	0.1	1.00E-03	0.1	0.1	0.1	0.1	1.00E-04	0.1	0.1
9	10	10	10	10	10	10	10	0.5	10	20	5	1	1	1	10	1.00E-04	10	10
10	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.1	0.1	0.01	0.1	0.1	0.1	0.1	1.00E-04	0.1	0.1
11	5	5	5	10	5	5	5	0.5	5	5	5	1	1	1	10	1.00E-04	5	5
12	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.00E-04	0.1	0.1
13	1	1	1	1	1	1	1	0.1	1	1	5	1	0.5	0.5	1	1.00E-04	1	1

	Horizontal Hydraulic Conductivity in Each Zone (ft/day)																	
Layer	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
1	200	100	100	50	800	1	200	200	200	1200	1200	600	200	200	200	200	200	10
2	1.00E-04	100	100	50	0.1	0.01	200	100	100	0.1	0.1	0.1	0.1	0.1	0.1	100	0.1	10
3	100	50	80	10	600	1	200	100	100	1200	1200	400	100	100	100	100	100	10
4	1	20	50	1	400	0.01	200	100	100	1000	1000	200	100	1	1	100	1	10
5	50	20	50	1	400	1	200	100	100	1000	1000	200	100	100	100	100	100	10
6	1.00E-03	0.1	1	5.00E-03	1	1.00E-03	0.01	0.1	0.1	1	1	1	1	1	0.1	1	0	0.1
7	20	10	20	1	100	0.1	20	20	10	200	200	100	100	50	50	5	20	5
8	0.1	0.1	0.1	0.1	0.01	0.01	15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01
9	10	5	10	1	100	0.1	10	10	5	100	100	100	100	50	50	5	20	5
10	0.1	0.1	0.1	0.1	100	0.01	0.01	0.01	0.01	100	100	100	100	50	50	1	20	1
11	10	1	5	1	1.00E-12	0.1	5	5	2	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	10	1.00E-12
12	10	0.1	0.01	0.01	1.00E-12	0.01	0.1	0.1	0.5	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	0.1	1.00E-12
13	1	1	1	0.01	1.00E-12	0.1	5	5	2	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1.00E-12	1	1.00E-12

Table 3-2. Parameters by Layer and Zone, Vertical Anisotropy Ratio

	Vertical Anisotropy Ratio in Each Zone (unitless)																																			
Layer	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**18**	**19**	**20**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
1	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
3	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
4	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
5	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
6	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
7	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
8	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
11	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
13	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Table 3-3. Fault Name, Layer Location, Parameterization, and Reference Numbering

Fault Name	Layers	Hydraulic Characteristic (1/d)*	Fault Reference Number**
Round Mountain and Long Canyon	3 to 13	0.04	1
Sycamore Canyon	5 to 13	0.06	2
Bailey in UAS	3 to 6	0.0001, 0.005	3a
Bailey in LAS	7 to 13	1.0e04, 1.0e-6	3b
Springville	1 to 13	1.1E-04	4
Santa Rosa	3 to 13	1.0E-06	5
Camarillo	3 to 13	1.0E-06	51
Santa Rosa Valley	3 to 13	1.0E-06	52
Las Posas and Santa Rosa	3 to 13	1.0E-06	53
Hueneme Canyon	6 to 13	0.03	6
Montalvo	7 to 13	1.0	7
Oak Ridge in Mound and OP	7 to 13	1.0	8
Country Club***	3 to 13	0.001	9
Oak Ridge in Forebay***	3 to 13	1.04E-02 to 1.04E-06	10
North Mugu Lagoon	7 to 13	1.0E-04	11
Connecting Country Club and Oak Ridge Faults***	3 to 13	1.0E-06	19
Split WLP and PV basins, Extension of Springville Fault	6 to 13	4.0E-04	22
Spur off Springville Fault	3 to 13	5.0E-04	41
No name in Santa Paula basin***	3 to 13	1.0E-03	71
No name in Fillmore basin***	1 to 13	1.07E-07	73
La Loma and Fox Canyon	7 to 13	1.10E-04	75
No name in North WLP	7 to 13	1.08E-04	76
Foothill-North***	7 to 13	1.10E-04	98
Foothill***	7 to 13	1.10E-05	99
Foothill extension to Ventura Fault in Mound basin***	7 to 13	1.10E-05	100

*Hydraulic Characteristic (1/d) = Hydraulic Conductivity (ft/d)/Thickness (ft).
Thickness is numerically represented as 1 foot.

**Fault Reference Number represented in Boundary Condition Figures, 3-14 to 3-26

***Faults added in 2020 Regional Model Expansion

Table 3-4. Parameters by Layer and Zone, Specific Yield

	Specific Yield in Each Zone (unitless)																	
Layer	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**18**	**19**	**20**
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.10	0.10	0.15	0.15	0.15	0.15
2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
3	0.15	0.15	0.15	0.05	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.10	0.10	0.15	0.15	0.15	0.15
4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.10	0.10	0.15	0.15	0.15	0.15
6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
7	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
9	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
13	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

	Specific Yield in Each Zone (unitless)																	
Layer	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
1	0.15	0.15	0.10	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.15
3	0.15	0.15	0.10	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
5	0.15	0.15	0.10	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
7	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
9	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.10
11	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
13	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Table 3-5. Parameters by Layer and Zone, Storage Coefficient

	Storage Coefficient in Each Zone (unitless)																	
Layer	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**18**	**19**	**20**
1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
6	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
7	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
11	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
12	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
13	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001

	Storage Coefficient in Each Zone (unitless)																	
Layer	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
6	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
7	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
11	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
12	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
13	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table 3-6. Stream (STR) Segment Numbering

Name	STR Segment Number	Type	Name	STR Segment Number	Type
Piru Creek	1	Stream	SCR Main Stem	27	Stream
Rancho Temescal Pump No 1	2	Diversion	SCR Main Stem	28	Stream
Piru Creek	3	Stream	SCR Main Stem	29	Stream
Rancho Temescal Pump No 2	4	Diversion	SCR Main Stem	30	Stream
Piru Creek	5	Stream	SCR Main Stem	31	Stream
Piru Mutual Diversion	6	Diversion	SCR Main Stem	32	Stream
Piru Creek	7	Stream	SCR Main Stem	33	Stream
UWCD Piru Diversion	8	Diversion	SCR Main Stem	34	Stream
Piru Creek	9	Stream	Hyde Turner Diversion	35	Diversion
Hopper Canyon Creek	10	Stream	SCR Main Stem	36	Stream
Pole Creek	11	Stream	South Fork Diversion	37	Diversion
Sespe Creek	12	Stream	SCR Main Stem	38	Stream
Boulder Creek	13	Stream	SCR Main Stem	39	Stream
Timber Canyon Creek	14	Stream	SCR Main Stem	40	Stream
Santa Paula Creek	15	Stream	Freeman Diversion	41	Diversion
Canyon Irrigation Company Diversion	16	Diversion	SCR Main Stem	42	Stream
Santa Paula Creek	17	Stream	SCR Main Stem	43	Stream
Adams Barranca	18	Stream	SCR Main Stem	44	Stream
Todd Barranca	19	Stream	Arroyo Las Posas	45	Stream
Ellsworth Barranca	20	Stream	Conejo Creek	46	Stream
Harmon Barranca	21	Stream	Camrosa Diversion	47	Diversion
Balcom Canyon Creek	22	Stream	Conejo Creek	48	Stream
SCR Main Stem	23	Stream	Camarillo Sanitation District	49	Discharge
Camulos Diversion	24	Diversion	Conejo Creek	50	Stream
SCR Main Stem	25	Stream	Calleguas Creek	51	Stream
Isola Diversion	26	Diversion	Calleguas Creek	52	Stream

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
04N18W03K01S	40	--	70	--	PIRU	OUTSIDE	80	1	71	1	1979	2	2019	2
04N18W03Q02S	--	--	--	--	PIRU	OUTSIDE	81	40	3,211	250	1979	2	2019	2
04N18W20M02S	160	--	369	--	PIRU	PIRU	78	79.2	6,180	234	1981	1	2019	2
04N18W20M01S	220	--	420	--	PIRU	PIRU	81	87	7,038	323	1979	2	2019	2
04N18W19Q01S	422	--	622	--	PIRU	PIRU	81	74	5,982	243	1979	2	2019	2
04N18W20R01S	190	--	319	--	PIRU	PIRU	82	204	16,732	990	1979	1	2019	2
04N18W20N01S	220	--	441	--	PIRU	PIRU	80	5.0	401	14	1979	2	2019	2
04N18W19R01S	220	--	401	--	PIRU	PIRU	17	12.7	215	58	1979	2	1997	2
04N18W19P02S	415	--	630	--	PIRU	PIRU	80	126.3	10,102.9	720.5	1979	2	2019	2
04N18W19N01S	--	--	--	--	PIRU	PIRU	81	98	7,899	184	1979	2	2019	2
04N18W29C01S	356	--	500	--	PIRU	PIRU	81	147.1	11,917.0	325.5	1979	2	2019	2
04N18W28C02S	390	--	750	--	PIRU	PIRU	82	348.6	28,588	1,176	1979	1	2019	2
04N18W27B01S	156	--	280	--	PIRU	PIRU	82	20.9	1,717	197.7	1979	1	2019	2
04N18W27B02S	140	--	255	--	PIRU	PIRU	67	13.9	931.7	237.1	1979	2	2019	2
04N19W25A02S	267	--	460	--	PIRU	PIRU	63	74.5	4,691	140	1988	2	2019	2
04N19W25C02S	265	--	504	--	PIRU	PIRU	77	25	1,946	46	1979	2	2019	2
04N18W30D01S	120	--	285	--	PIRU	PIRU	80	47	3,779	131	1979	2	2019	2
04N18W29D01S	--	--	--	--	PIRU	PIRU	81	59.9	4,851.8	138.0	1979	2	2019	2
04N18W29E01S	--	--	--	--	PIRU	PIRU	81	67	5,460	174	1979	2	2019	2
04N19W26H01S	568	--	612	--	PIRU	PIRU	81	174.5	14,137	416.5	1979	2	2019	2
04N18W30F02S	200	--	280	--	PIRU	PIRU	81	41.7	3,379.2	130.8	1979	2	2019	2
04N18W30G01S	282	--	392	--	PIRU	PIRU	81	65.2	5,285	134	1979	2	2019	2
04N18W29F01S	110	--	275	--	PIRU	PIRU	75	42.0	3,149	158	1980	1	2019	2
04N18W30L01S	200	--	430	--	PIRU	PIRU	81	137	11,119	247	1979	2	2019	2
04N18W29M01S	120	--	230	--	PIRU	PIRU	69	32.3	2,227	71	1985	1	2019	2
04N18W30J01S	116	--	246	--	PIRU	PIRU	80	107	8,580	301	1979	2	2019	2
04N18W30J02S	116	--	246	--	PIRU	PIRU	58	1	60	2	1991	1	2019	2
04N18W30G03S	--	--	--	--	PIRU	PIRU	81	36	2,948	77	1979	2	2019	2
04N18W30G02S	--	--	--	--	PIRU	PIRU	81	16.6	1,344	83	1979	2	2019	2
04N19W25J04S	300	--	500	--	PIRU	PIRU	81	162	13,140	1,009	1979	2	2019	2
04N19W25K02S	120	--	290	--	PIRU	PIRU	40	82	3,270	161	1979	2	1999	2
04N18W30K01S	--	--	--	--	PIRU	PIRU	81	2.8	226	5.3	1979	2	2019	2
04N18W29K01S	465	--	745	--	PIRU	PIRU	82	142.4	11,678	464	1979	1	2019	2
04N18W30J03S	125	--	225	--	PIRU	PIRU	81	0.7	54.7	1.4	1979	2	2019	2
04N19W26J02S	--	--	--	--	PIRU	PIRU	81	42	3,417	88	1979	2	2019	2
04N18W30M03S	280	--	460	--	PIRU	PIRU	81	69	5,550	135	1979	2	2019	2
04N19W26J03S	400	--	650	--	PIRU	PIRU	82	257.9	21,149	728	1979	1	2019	2
04N19W25M01S	--	--	--	--	PIRU	PIRU	81	0.2	18	2	1979	2	2019	2
04N19W25K01S	--	--	--	--	PIRU	PIRU	81	80.1	6,491	174.7	1979	2	2019	2
04N19W25M02S	526	--	626	--	PIRU	PIRU	81	86.7	7,027	296.4	1979	2	2019	2
04N19W26Q03S	--	--	--	--	PIRU	PIRU	81	42	3,389	60	1979	2	2019	2
04N19W27Q02S	271	--	350	--	PIRU	PIRU	81	22.1	1,789.2	61.7	1979	2	2019	2
04N19W27Q01S	272	--	335	--	PIRU	PIRU	55	0.5	27.5	0.5	1992	2	2019	2
04N19W25L04S	385	--	485	--	PIRU	PIRU	81	90	7,288	194	1979	2	2019	2
04N19W26P01S	222	--	282	--	PIRU	PIRU	82	166	13,639	428	1979	1	2019	2
04N19W28Q01S	--	--	--	--	PIRU	PIRU	81	49.2	3,981.6	180.0	1979	2	2019	2
04N19W27R01S	--	--	--	--	PIRU	PIRU	79	64	5,074	157	1979	2	2019	2
04N19W26P02S	--	--	--	--	PIRU	PIRU	82	32.9	2,697	411	1979	1	2019	2
04N19W27R03S	240	--	402	--	PIRU	PIRU	81	53.2	4,306	69	1979	2	2019	2
04N18W29P01S	--	--	232	--	PIRU	PIRU	81	1	64	2	1979	2	2019	2
04N19W27P02S	210	--	290	--	PIRU	PIRU	81	51.4	4,160	105	1979	2	2019	2
04N19W34B01S	--	--	--	--	PIRU	PIRU	59	60.0	3,537	105.4	1990	2	2019	2
04N19W33B01S	206	--	306	--	PIRU	PIRU	81	8.5	692	41.0	1979	2	2019	2

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
04N18W31D01S	224	--	374	--	PIRU	PIRU	81	88.7	7,183	150	1979	2	2019	2
04N19W33C01S	165	--	400	--	PIRU	PIRU	34	175	5,951	348	2003	1	2019	2
04N18W31D02S	220	--	500	--	PIRU	PIRU	81	111.7	9,051	177	1979	2	2019	2
04N19W35C01S	--	--	--	--	PIRU	PIRU	82	82.7	6,779	742	1979	1	2019	2
04N19W34D01S	160	--	304	--	PIRU	PIRU	81	39.0	3,163	127	1979	2	2019	2
04N19W33A02S	283	--	355	--	PIRU	PIRU	81	30.0	2,431	45	1979	2	2019	2
04N19W33C02S	205	--	345	--	PIRU	PIRU	81	188.6	15,280	634.2	1979	2	2019	2
04N19W34C02S	--	--	--	--	PIRU	PIRU	52	107.6	5,594	191.5	1979	2	2006	1
04N19W34C03S	219	--	291	--	PIRU	PIRU	30	114.8	3,444	262.6	2005	1	2019	2
04N19W34D05S	--	--	--	--	PIRU	PIRU	59	26.5	1,565	72	1990	2	2019	2
04N19W34D04S	283	--	355	--	PIRU	PIRU	70	39.6	2,773	92.1	1985	1	2019	2
04N18W31C01S	--	--	--	--	PIRU	PIRU	31	25.9	802	35	2004	2	2019	2
04N19W33G01S	--	--	--	--	PIRU	PIRU	76	6.8	518	123	1982	1	2019	2
04N19W33F01S	300	--	600	--	PIRU	PIRU	76	69.9	5,310	819	1982	1	2019	2
04N19W33H01S	237	--	362	--	PIRU	PIRU	81	93.7	7,590	342	1979	2	2019	2
04N19W34G01S	70	--	220	--	PIRU	PIRU	81	83	6,735	345	1979	2	2019	2
04N19W35L05S	80	--	302	--	PIRU	PIRU	72	91.2	6,567	472.8	1984	1	2019	2
04N19W34J01S	72	--	120	--	PIRU	PIRU	81	48.9	3,960	143.8	1979	2	2019	2
04N19W34K01S	5	--	120	--	PIRU	PIRU	11	1.3	15	2	2014	2	2019	2
04N19W35L01S	40	--	130	--	PIRU	PIRU	81	6.4	522	96.2	1979	2	2019	2
04N19W35K01S	40	--	400	--	PIRU	PIRU	77	1.2	89	4.0	1981	2	2019	2
04N19W35K02S	--	--	--	--	PIRU	PIRU	81	73.1	5,924	215	1979	2	2019	2
04N19W34M02S	--	--	--	--	PIRU	PIRU	81	65	5,272	240	1979	2	2019	2
04N19W33K07S	57	--	93	--	PIRU	PIRU	81	22.2	1,797	136	1979	2	2019	2
04N19W33K04S	--	--	--	--	PIRU	PIRU	14	2.6	37	10	2013	1	2019	2
04N19W33J01S	--	--	--	--	PIRU	PIRU	80	0.5	38.6	1.8	1979	2	2019	2
04N19W23R02S	150	--	200	--	PIRU	OUTSIDE	56	4.5	252.7	13.3	1991	1	2019	2
04N19W26Q04S	115	--	156	--	PIRU	PIRU	63	1.9	117.2	4.0	1988	2	2019	2
04N19W34J03S	50	--	95	--	PIRU	PIRU	67	20.3	1361.3	22.4	1986	2	2019	2
04N18W20P01S	795	--	995	--	PIRU	PIRU	40	28.2	1129.0	170.6	1979	2	1999	2
04N18W30J05S	52	--	207	--	PIRU	PIRU	21	2.2	46.4	12.0	2009	2	2019	2
04N18W30G05S	157	--	237	--	PIRU	PIRU	41	2.0	80.2	3.7	1999	2	2019	2
04N18W30F04S	--	--	--	--	PIRU	PIRU	26	0.7	19.3	1.0	2007	1	2019	2
04N18W20K02S	120	--	200	--	PIRU	PIRU	46	10.6	486.4	15.0	1997	1	2019	2
04N19W25K04S	220	--	370	--	PIRU	PIRU	43	16.0	688.9	24.0	1998	1	2019	2
04N19W26J05S	200	--	250	--	PIRU	PIRU	46	1.5	70.0	3.0	1997	1	2019	2
04N19W25M03S	210	--	250	--	PIRU	PIRU	18	1.0	18.0	1.0	2011	1	2019	2
04N19W28Q03S	407	--	707	--	PIRU	PIRU	35	38.6	1352.2	176.0	2002	2	2019	2
04N19W28P02S	310	--	800	--	PIRU	PIRU	18	30.5	549.4	53.5	2011	1	2019	2
04N18W27K01S	50	--	130	--	PIRU	PIRU	30	37.0	1110.6	150.2	2005	1	2019	2
04N18W30L02S	125	--	245	--	PIRU	PIRU	20	2.2	44.3	8.5	2010	1	2019	2
04N19W34L01S	90	--	430	--	PIRU	PIRU	35	126.5	4427.1	453.8	2002	2	2019	2
04N18W20M03S	160	--	450	--	PIRU	PIRU	32	284.0	9087.3	495.0	2004	1	2019	2
04N19W25J05S	180	--	380	--	PIRU	PIRU	29	12.4	359.4	25.8	2005	2	2019	2
04N18W31H01S	360	--	520	--	PIRU	OUTSIDE	30	1.0	29.5	6.9	2005	1	2019	2
04N18W19J02S	187	--	447	--	PIRU	PIRU	26	32.1	834.3	54.9	2006	2	2019	2
04N19W25J06S	120	--	400	--	PIRU	PIRU	28	174.3	4881.2	482.3	2005	2	2019	2
04N18W27G03S	40	--	120	--	PIRU	PIRU	24	131.0	3144.7	247.3	2008	1	2019	2
04N18W27H01S	40	--	120	--	PIRU	PIRU	24	88.3	2119.3	184.7	2008	1	2019	2
04N18W30A03S	90	--	190	--	PIRU	PIRU	18	3.2	57.1	6.6	2011	1	2019	2
04N18W30J04S	79	--	250	--	PIRU	PIRU	21	0.5	9.6	1.2	2009	2	2019	2
04N19W25G01S	200	--	400	--	PIRU	PIRU	23	46.3	1065.2	318.2	2008	2	2019	2
04N19W34A01S	110	--	200	--	PIRU	PIRU	79	0.9	70.1	2.0	1980	1	2019	2

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
04N19W34J04S	60	--	160	--	PIRU	PIRU	20	38.3	765.3	82.4	2010	1	2019	2
04N19W25L07S	40	--	140	--	PIRU	PIRU	17	0.0	0.8	0.8	2010	1	2019	2
04N19W23R03S	120	--	207	--	PIRU	OUTSIDE	19	2.1	39.6	12.0	2009	2	2019	2
04N18W30B01S	280	--	430	--	PIRU	PIRU	18	156.9	2823.3	320.0	2011	1	2019	2
04N18W30L03S	120	--	240	--	PIRU	PIRU	23	12.3	281.8	21.6	2008	1	2019	2
04N18W30L04S	120	--	240	--	PIRU	PIRU	24	16.5	396.8	27.8	2008	1	2019	2
04N19W25H01S	120	--	240	--	PIRU	PIRU	24	5.5	131.5	17.6	2008	1	2019	2
04N18W30J06S	--	--	--	--	PIRU	PIRU	21	9.9	207.4	12.3	2009	2	2019	2
04N18W30F03S	143	--	243	--	PIRU	PIRU	63	2.7	171.5	12.1	1988	2	2019	2
04N18W30E01S	300	--	590	--	PIRU	PIRU	14	167.3	2342.6	373.0	2013	1	2019	2
04N18W03Q03S	27	--	70	--	PIRU	OUTSIDE	12	12.1	145.8	70.1	2014	1	2019	2
04N18W26E01S	21	--	60	--	PIRU	PIRU	14	12.5	175.5	98.9	2013	1	2019	2
04N18W27H03S	26	--	66	--	PIRU	PIRU	14	11.2	156.8	94.6	2013	1	2019	2
04N18W27H02S	30	--	98	--	PIRU	PIRU	14	0.9	13.2	12.4	2013	1	2019	2
04N20W12G02S	80	--	100	--	FILLMORE	OUTSIDE	58	1.9	112	14	1991	1	2019	2
04N20W13P02S	--	--	--	--	FILLMORE	FILLMORE	81	47.6	3,859	172	1979	2	2019	2
04N20W13P01S	--	--	--	--	FILLMORE	FILLMORE	20	6	118	118	1979	2	1997	2
04N20W13N01S	203	--	403	--	FILLMORE	FILLMORE	81	26.2	2,122	65.3	1979	2	2019	2
04N20W24C01S	564	--	704	--	FILLMORE	FILLMORE	81	216.2	17,515	472	1979	2	2019	2
04N20W24D01S	190	--	308	--	FILLMORE	FILLMORE	81	38.6	3,127.2	116.1	1979	2	2019	2
04N20W23F01S	--	--	--	--	FILLMORE	FILLMORE	81	26.1	2,114.5	80.0	1979	2	2019	2
04N20W23G01S	--	--	--	--	FILLMORE	FILLMORE	82	6.7	553	58	1979	1	2019	2
04N20W24J03S	135	--	308	--	FILLMORE	FILLMORE	81	0.7	54	6	1979	2	2019	2
04N20W24J01S	245	--	535	--	FILLMORE	FILLMORE	82	308.9	25,330.6	520.8	1979	1	2019	2
04N20W23J02S	216	--	505	--	FILLMORE	FILLMORE	81	75	6,055	151	1979	2	2019	2
04N20W23L01S	270	--	400	--	FILLMORE	FILLMORE	77	20	1,578	186	1981	2	2019	2
04N20W24R02S	730	--	1,820	--	FILLMORE	FILLMORE	81	168	13,568	540	1979	2	2019	2
04N20W23Q02S	327	--	567	--	FILLMORE	FILLMORE	81	66.0	5,345	120.5	1979	2	2019	2
04N20W24N01S	--	--	--	--	FILLMORE	FILLMORE	81	46	3,711	54	1979	2	2019	2
04N20W23Q01S	134	--	224	--	FILLMORE	FILLMORE	67	29	1,936	64	1986	1	2019	2
04N20W23N01S	219	--	388	--	FILLMORE	FILLMORE	29	0.6	16	10	2000	1	2019	2
04N20W23N02S	220	--	390	--	FILLMORE	FILLMORE	81	104.4	8,453.2	295.6	1979	2	2019	2
04N20W25D01S	67	--	187	--	FILLMORE	FILLMORE	81	127.0	10,284	731	1979	2	2019	2
04N20W25B01S	50	--	280	--	FILLMORE	FILLMORE	81	568	46,032	999	1979	2	2019	2
04N20W26C02S	155	--	255	--	FILLMORE	FILLMORE	81	2.6	209	11	1979	2	2019	2
04N20W26A02S	40	--	254	--	FILLMORE	FILLMORE	81	339.0	27,459	669	1979	2	2019	2
04N19W30D01S	60	--	380	--	FILLMORE	FILLMORE	81	84.5	6,848	167	1979	2	2019	2
04N20W25D02S	80	--	100	--	FILLMORE	FILLMORE	82	0	41	1	1979	1	2019	2
04N20W25C01S	103	--	311	--	FILLMORE	FILLMORE	49	10	501	55	1979	2	2003	2
04N20W26D01S	180	--	500	--	FILLMORE	FILLMORE	81	247.5	20,045.5	467.6	1979	2	2019	2
04N20W26C03S	120	--	270	--	FILLMORE	FILLMORE	81	7.3	590	13	1979	2	2019	2
04N20W26H02S	76	--	113	--	FILLMORE	FILLMORE	81	101.7	8,239	404.8	1979	2	2019	2
04N20W26F01S	124	--	442	--	FILLMORE	FILLMORE	81	310.6	25,158	771.3	1979	2	2019	2
04N20W26E01S	--	--	--	--	FILLMORE	FILLMORE	81	444.5	36,006.3	841.8	1979	2	2019	2
04N19W30H01S	140	--	500	--	FILLMORE	FILLMORE	81	48.6	3,937.6	251.7	1979	2	2019	2
04N20W25K03S	--	--	--	--	FILLMORE	FILLMORE	18	8	137	13	1979	2	1997	2
04N20W28M02S	270	--	555	--	FILLMORE	FILLMORE	54	15	827	19	1993	1	2019	2
04N20W25M01S	120	--	200	--	FILLMORE	FILLMORE	59	1	54	1	1990	2	2019	2
04N19W29K01S	--	--	--	--	FILLMORE	FILLMORE	19	0.9	17	1	1979	2	1997	2
04N19W29L02S	40	--	90	--	FILLMORE	FILLMORE	65	3.9	255	27	1985	2	2019	2
04N19W30K01S	160	--	479	--	FILLMORE	FILLMORE	54	0	1	1	1979	2	2006	1
04N19W29R02S	--	--	--	--	FILLMORE	FILLMORE	82	0.6	48.8	2.0	1979	1	2019	2
04N19W29R06S	174	--	204	--	FILLMORE	FILLMORE	69	1	47	1	1985	2	2019	2

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
04N19W30R01S	173	--	300	--	FILLMORE	FILLMORE	57	18	1,006	36	1979	2	2008	1
04N19W30Q02S	310	--	510	--	FILLMORE	FILLMORE	34	43	1,473	48	1989	2	2006	1
04N19W30P02S	102	--	232	--	FILLMORE	FILLMORE	81	17	1,397	78	1979	2	2019	2
04N19W29R04S	80	--	180	--	FILLMORE	FILLMORE	81	142	11,506	589	1979	2	2019	2
04N20W27Q01S	236	--	483	--	FILLMORE	FILLMORE	81	108.6	8,794.1	516.2	1979	2	2019	2
04N19W29Q03S	--	--	--	--	FILLMORE	FILLMORE	39	122.4	4,772	497	1984	2	2003	2
04N19W30P03S	--	--	--	--	FILLMORE	FILLMORE	13	10.9	141	94	1979	2	1997	2
04N20W26Q01S	--	--	--	--	FILLMORE	FILLMORE	73	108.6	7,931	332	1979	2	2015	2
04N20W29Q01S	100	--	480	--	FILLMORE	FILLMORE	11	1	13	3	2014	2	2019	2
04N19W29R05S	100	--	209	--	FILLMORE	FILLMORE	80	364	29,110	1,350	1979	2	2019	2
04N20W25N02S	--	--	--	--	FILLMORE	FILLMORE	81	70.2	5,685.8	220.0	1979	2	2019	2
04N20W33C01S	416	--	897	--	FILLMORE	FILLMORE	81	45.6	3,690	101	1979	2	2019	2
04N19W33D06S	200	--	600	--	FILLMORE	PIRU	81	1,319	106,804	4,712	1979	2	2019	2
04N20W36D01S	46	--	266	--	FILLMORE	FILLMORE	81	2.8	230	13	1979	2	2019	2
04N19W33D05S	200	--	600	--	FILLMORE	PIRU	81	2,270.7	183,924	5,085	1979	2	2019	2
04N20W36B01S	--	--	--	--	FILLMORE	FILLMORE	33	5.1	169	12.5	1990	2	2006	2
04N20W33B01S	195	--	297	--	FILLMORE	FILLMORE	81	33	2,692	108	1979	2	2019	2
04N19W31D04S	80	--	250	--	FILLMORE	FILLMORE	81	175.8	14,238.3	747.7	1979	2	2019	2
04N19W33D03S	140	--	506	--	FILLMORE	PIRU	80	743.6	59,492	1,905.9	1980	1	2019	2
04N20W36C02S	--	--	--	--	FILLMORE	FILLMORE	57	12	692	14	1979	2	2007	2
04N20W36D02S	--	--	--	--	FILLMORE	FILLMORE	69	0.7	50	1.0	1979	2	2015	2
04N19W33D04S	140	--	486	--	FILLMORE	PIRU	82	454.4	37,261	1,559.0	1979	1	2019	2
04N19W32A02S	--	--	--	--	FILLMORE	FILLMORE	81	204.7	16,578	3,077.5	1979	2	2019	2
04N20W36C03S	--	--	--	--	FILLMORE	FILLMORE	77	0.5	40.1	0.8	1980	2	2019	2
04N20W36D06S	--	--	--	--	FILLMORE	FILLMORE	81	1.0	78.6	2.1	1979	2	2019	2
04N20W36D04S	34	--	68	--	FILLMORE	FILLMORE	79	52.1	4,115	162	1979	2	2019	2
04N20W33C03S	470	--	700	--	FILLMORE	FILLMORE	81	60.8	4,921	165	1979	2	2019	2
04N20W35H01S	--	--	--	--	FILLMORE	FILLMORE	58	15	851	123	1991	1	2019	2
04N19W31F01S	60	--	100	--	FILLMORE	FILLMORE	60	0.9	56	4	1989	2	2019	2
04N20W32H01S	325	--	380	--	FILLMORE	FILLMORE	81	42.5	3,441	92	1979	2	2019	2
04N19W31H01S	55	--	395	--	FILLMORE	FILLMORE	80	18.2	1,456	83.2	1979	2	2019	2
04N19W31E01S	--	--	--	--	FILLMORE	FILLMORE	81	53.8	4,354.3	157.7	1979	2	2019	2
04N19W32F03S	165	--	345	--	FILLMORE	FILLMORE	55	104.7	5,758	232	1979	1	2006	1
04N19W32G01S	136	--	409	--	FILLMORE	FILLMORE	81	188.6	15,275	738	1979	2	2019	2
04N19W32F02S	81	--	245	--	FILLMORE	FILLMORE	81	6.7	539	41.2	1979	2	2019	2
04N20W31H01S	345	--	390	--	FILLMORE	FILLMORE	81	13.1	1,061	55.2	1979	2	2019	2
04N20W31H02S	370	--	610	--	FILLMORE	FILLMORE	81	29	2,374	63	1979	2	2019	2
04N19W33M04S	55	--	278	--	FILLMORE	PIRU	81	42	3,384	137	1979	2	2019	2
04N20W34J01S	260	--	480	--	FILLMORE	FILLMORE	80	3.0	239	50	1979	1	2019	2
04N19W32J05S	40	--	130	--	FILLMORE	FILLMORE	81	0.5	40	1	1979	2	2019	2
04N19W33M02S	--	--	--	--	FILLMORE	FILLMORE	76	208.9	15,876	411	1982	1	2019	2
04N20W34K04S	54	--	101	--	FILLMORE	FILLMORE	27	2.1	56	3	2006	2	2019	2
04N19W32J06S	50	--	150	--	FILLMORE	FILLMORE	81	138	11,175	686	1979	2	2019	2
04N19W31L01S	--	--	--	--	FILLMORE	FILLMORE	81	113.8	9,215.6	304.6	1979	2	2019	2
04N19W33M03S	--	--	--	--	FILLMORE	FILLMORE	81	429.8	34,810.1	2,880.0	1979	2	2019	2
04N19W33M05S	37	--	107	--	FILLMORE	FILLMORE	82	58.2	4,773	151	1979	1	2019	2
04N20W34K01S	--	--	--	--	FILLMORE	FILLMORE	81	40.8	3,303	78.8	1979	2	2019	2
04N20W31L01S	633	--	1,100	--	FILLMORE	FILLMORE	81	6.4	518	18	1979	2	2019	2
04N19W32L01S	50	--	160	--	FILLMORE	FILLMORE	81	55.5	4,499	210	1979	2	2019	2
04N20W36J02S	--	--	--	--	FILLMORE	FILLMORE	81	25.4	2,058	105	1979	2	2019	2
04N20W36R02S	80	--	160	--	FILLMORE	FILLMORE	81	17	1,356	38	1979	2	2019	2
04N20W36R06S	--	--	--	--	FILLMORE	FILLMORE	81	13.1	1,057.6	23.8	1979	2	2019	2
04N20W36K02S	--	--	--	--	FILLMORE	FILLMORE	81	102.4	8,295.2	216.0	1979	2	2019	2

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
04N19W32J01S	--	--	--	--	FILLMORE	FILLMORE	81	89.7	7,264.0	280.5	1979	2	2019	2
04N20W36R05S	--	--	--	--	FILLMORE	FILLMORE	60	0.6	36	1	1990	1	2019	2
04N20W34R01S	--	--	--	--	FILLMORE	FILLMORE	82	64.8	5,310	112	1979	1	2019	2
04N19W31R01S	60	--	137	--	FILLMORE	FILLMORE	81	156	12,628	345	1979	2	2019	2
04N20W34P01S	--	--	--	--	FILLMORE	FILLMORE	81	69	5,586	479	1979	2	2019	2
04N20W31Q01S	300	--	485	--	FILLMORE	FILLMORE	81	233	18,870	849	1979	2	2019	2
04N19W31P01S	--	--	--	--	FILLMORE	FILLMORE	81	1	42	1	1979	2	2019	2
04N20W32P01S	260	--	384	--	FILLMORE	FILLMORE	81	32	2,568	77	1979	2	2019	2
04N20W36Q03S	75	--	185	--	FILLMORE	FILLMORE	81	208.8	16,910	526	1979	2	2019	2
04N20W31P01S	230	--	450	--	FILLMORE	FILLMORE	81	173	14,001	748	1979	2	2019	2
04N19W31N03S	105	--	169	--	FILLMORE	FILLMORE	70	73.2	5,122.1	191.6	1985	1	2019	2
04N20W36R07S	80	--	260	--	FILLMORE	FILLMORE	59	0.6	36.5	1.8	1990	2	2019	2
04N20W32Q01S	--	--	--	--	FILLMORE	FILLMORE	59	0.6	37.3	1.0	1990	2	2019	2
04N20W35R01S	56	--	156	--	FILLMORE	FILLMORE	56	12	694	25	1992	1	2019	2
04N20W36Q04S	--	--	--	--	FILLMORE	FILLMORE	81	0.6	52.2	1.0	1979	2	2019	2
04N20W36N03S	60	--	100	--	FILLMORE	FILLMORE	81	0.6	51.0	1.5	1979	2	2019	2
04N20W34N05S	80	--	200	--	FILLMORE	FILLMORE	20	56	1,128	88	2010	1	2019	2
04N20W32R01S	105	--	240	--	FILLMORE	FILLMORE	75	41.9	3,143	145	1982	2	2019	2
04N19W32N02S	--	--	--	--	FILLMORE	FILLMORE	60	0.5	31	1	1990	1	2019	2
04N20W36P02S	60	--	150	--	FILLMORE	FILLMORE	81	34.8	2,823	88	1979	2	2019	2
04N20W32P02S	241	--	324	--	FILLMORE	FILLMORE	81	52	4,210	209	1979	2	2019	2
03N19W06D02S	216	--	405	--	FILLMORE	FILLMORE	81	120.9	9,793	345	1979	2	2019	2
03N20W01C04S	49	--	218	--	FILLMORE	FILLMORE	81	119	9,661	409	1979	2	2019	2
03N19W06D03S	184	--	400	--	FILLMORE	FILLMORE	81	183	14,787	455	1979	2	2019	2
03N20W01A03S	385	--	545	--	FILLMORE	FILLMORE	81	140.6	11,390.9	468.5	1979	2	2019	2
03N20W01D03S	--	--	--	--	FILLMORE	FILLMORE	81	0.6	47	1.0	1979	2	2019	2
03N20W02B03S	362	--	522	--	FILLMORE	FILLMORE	81	65.8	5,328	137	1979	2	2019	2
03N20W06A01S	--	--	--	--	FILLMORE	FILLMORE	81	169	13,682	1,238	1979	2	2019	2
03N20W06A03S	520	--	940	--	FILLMORE	FILLMORE	68	186	12,639	301	1986	1	2019	2
03N20W05D03S	200	--	385	--	FILLMORE	FILLMORE	81	57.4	4,648	214	1979	2	2019	2
03N20W03D07S	224	--	484	--	FILLMORE	FILLMORE	80	5	411	143	1979	2	2019	2
03N20W03D05S	274	--	436	--	FILLMORE	FILLMORE	81	183.4	14,858	1,269	1979	2	2019	2
03N20W03D03S	102	--	397	--	FILLMORE	FILLMORE	80	598	47,856	1,272	1979	2	2019	2
03N20W06D03S	160	--	500	--	FILLMORE	FILLMORE	74	46.5	3,438	152	1983	1	2019	2
03N20W05C01S	125	--	405	--	FILLMORE	FILLMORE	38	50	1,887	286	2001	1	2019	2
03N20W05C02S	135	--	402	--	FILLMORE	FILLMORE	49	244.8	11,995	554	1979	2	2003	2
03N20W01A02S	--	--	--	--	FILLMORE	FILLMORE	17	0.1	2	0.5	2011	1	2019	2
03N20W02B02S	--	--	--	--	FILLMORE	FILLMORE	81	69.6	5,637	143	1979	2	2019	2
03N20W06B01S	320	--	640	--	FILLMORE	FILLMORE	81	37	2,993	116	1979	2	2019	2
03N20W05C03S	221	--	362	--	FILLMORE	FILLMORE	81	3.2	256	6	1979	2	2019	2
03N20W02A04S	80	--	100	--	FILLMORE	FILLMORE	68	0.9	61.7	1.9	1979	2	2019	2
03N20W02A01S	--	--	--	--	FILLMORE	FILLMORE	81	3.0	242.0	12.2	1979	2	2019	2
03N20W01H03S	200	--	243	--	FILLMORE	FILLMORE	71	0.5	39	1	1984	2	2019	2
03N20W01B01S	--	--	--	--	FILLMORE	FILLMORE	81	0.6	46	1	1979	2	2019	2
03N21W01C01S	112	--	138	--	FILLMORE	FILLMORE	77	0.6	47	1.9	1981	1	2019	2
03N20W04C01S	160	--	332	--	FILLMORE	FILLMORE	81	412.9	33,445	1,024	1979	2	2019	2
03N20W01G02S	150	--	220	--	FILLMORE	FILLMORE	59	1	30	1	1990	2	2019	2
03N20W02F05S	96	--	265	--	FILLMORE	FILLMORE	81	8	662	11	1979	2	2019	2
03N21W01B01S	--	--	--	--	FILLMORE	FILLMORE	81	1	70	2	1979	2	2019	2
03N20W05D02S	--	--	--	--	FILLMORE	FILLMORE	12	57	687	224	1979	2	1997	2
03N20W06G01S	158	--	230	--	FILLMORE	FILLMORE	81	21	1,733	27	1979	2	2019	2
03N20W02E01S	--	--	--	--	FILLMORE	FILLMORE	81	36	2,912	60	1979	2	2019	2
03N20W05H01S	139	--	370	--	FILLMORE	FILLMORE	65	21	1,382	289	1979	2	2019	2

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
03N20W01F02S	--	--	--	--	FILLMORE	FILLMORE	81	1	67	1	1979	2	2019	2
03N21W01F01S	110	--	160	--	FILLMORE	FILLMORE	81	1	47	1	1979	2	2019	2
03N20W02H05S	238	--	310	--	FILLMORE	FILLMORE	60	33.1	1,984.9	290.1	1990	1	2019	2
03N20W03H01S	--	--	--	--	FILLMORE	FILLMORE	81	36.5	2,955	90.5	1979	2	2019	2
03N20W03H02S	100	--	397	--	FILLMORE	FILLMORE	82	32.2	2,637.2	98.3	1979	1	2019	2
03N20W06G02S	--	--	--	--	FILLMORE	FILLMORE	63	116.4	7,334.7	688.1	1979	2	2010	2
03N21W01F03S	80	--	180	--	FILLMORE	FILLMORE	81	0.6	46	1.2	1979	2	2019	2
03N20W02E02S	133	--	205	--	FILLMORE	FILLMORE	81	23.2	1,879.7	40.0	1979	2	2019	2
03N20W05F01S	80	--	492	--	FILLMORE	FILLMORE	81	248.0	20,087.5	605.1	1979	2	2019	2
03N20W02F01S	--	--	--	--	FILLMORE	FILLMORE	81	2.8	230.5	12.9	1979	2	2019	2
03N20W01E01S	--	--	--	--	FILLMORE	FILLMORE	43	0.7	31	1.0	1990	2	2011	2
03N20W02G02S	--	--	--	--	FILLMORE	FILLMORE	61	4.0	246.2	16.1	1989	2	2019	2
03N20W02G03S	120	--	200	--	FILLMORE	FILLMORE	59	0.7	44	1.0	1990	2	2019	2
03N20W02F04S	60	--	108	--	FILLMORE	FILLMORE	81	0.8	65	9	1979	2	2019	2
03N20W02F02S	--	--	--	--	FILLMORE	FILLMORE	81	15	1,214	48	1979	2	2019	2
03N20W02L06S	48	--	80	--	FILLMORE	FILLMORE	80	0.6	46	1.2	1980	1	2019	2
03N20W02M01S	161	--	--	--	FILLMORE	FILLMORE	81	28	2,273	60	1979	2	2019	2
03N20W01J01S	--	--	--	--	FILLMORE	FILLMORE	81	28	2,232	637	1979	2	2019	2
03N20W03J01S	--	--	--	--	FILLMORE	FILLMORE	81	106.3	8,612	299.4	1979	2	2019	2
03N20W06J03S	--	--	--	--	FILLMORE	FILLMORE	59	56.7	3,346.4	83.3	1990	2	2019	2
03N20W06J02S	95	--	288	--	FILLMORE	FILLMORE	81	127.8	10,351	513	1979	2	2019	2
03N20W06L01S	--	--	--	--	FILLMORE	FILLMORE	81	42.4	3,435	75	1979	2	2019	2
03N20W06J01S	--	--	--	--	FILLMORE	FILLMORE	81	68.8	5,570	157	1979	2	2019	2
03N20W03J02S	70	--	210	--	FILLMORE	FILLMORE	81	406.7	32,940	784	1979	2	2019	2
03N20W06K01S	--	--	--	--	FILLMORE	FILLMORE	59	0.6	38	1	1990	2	2019	2
03N20W02L05S	--	--	--	--	FILLMORE	FILLMORE	80	1.1	91	13.0	1979	2	2019	2
03N20W02J01S	108	--	123	--	FILLMORE	FILLMORE	80	0.7	53	1	1980	1	2019	2
03N20W03N01S	120	--	172	--	FILLMORE	FILLMORE	59	94.5	5,576	136.9	1990	2	2019	2
03N20W01P03S	--	--	--	--	FILLMORE	FILLMORE	81	1	83	13	1979	2	2019	2
03N20W03P02S	192	--	300	--	FILLMORE	FILLMORE	81	227	18,404	774	1979	2	2019	2
03N21W01P05S	180	--	380	--	FILLMORE	FILLMORE	82	279	22,904	617	1979	1	2019	2
03N20W02N03S	--	--	--	--	FILLMORE	FILLMORE	49	18.7	918	37	1979	2	2003	2
03N20W02R04S	90	--	125	--	FILLMORE	FILLMORE	73	0.5	37	5.0	1979	2	2015	2
03N20W02R05S	93	--	133	--	FILLMORE	FILLMORE	81	0.5	43	1	1979	2	2019	2
03N21W01P06S	200	--	240	--	FILLMORE	FILLMORE	81	4.0	328	5.8	1979	2	2019	2
03N20W04N03S	186	--	266	--	FILLMORE	FILLMORE	81	85.3	6,910.2	250.0	1979	2	2019	2
03N20W02P02S	--	--	--	--	FILLMORE	FILLMORE	58	28.7	1,664	41	1979	2	2008	1
03N20W04N04S	60	--	155	--	FILLMORE	FILLMORE	81	54.2	4,392	105	1979	2	2019	2
03N21W01P01S	--	--	--	--	FILLMORE	FILLMORE	58	10.4	605.1	17.8	1991	1	2019	2
03N20W01P05S	71	--	305	--	FILLMORE	FILLMORE	58	0.1	4.3	1.0	1991	1	2019	2
03N20W02Q02S	--	--	--	--	FILLMORE	FILLMORE	80	1.2	95	2	1979	2	2019	2
03N21W01P03S	75	--	104	--	FILLMORE	FILLMORE	81	17.8	1,443	58	1979	2	2019	2
03N20W04R02S	95	--	215	--	FILLMORE	FILLMORE	81	249.2	20,182	605	1979	2	2019	2
03N20W04Q02S	--	--	--	--	FILLMORE	FILLMORE	81	97.5	7,894.8	213.9	1979	2	2019	2
03N20W04Q03S	--	--	--	--	FILLMORE	FILLMORE	81	52.9	4,286	125	1979	2	2019	2
03N20W02N01S	--	--	--	--	FILLMORE	FILLMORE	32	34	1,093	55	2004	1	2019	2
03N21W01P07S	220	--	260	--	FILLMORE	FILLMORE	81	1	89	2	1979	2	2019	2
03N20W04R01S	--	--	--	--	FILLMORE	FILLMORE	81	74.5	6,032.7	116.2	1979	2	2019	2
03N20W04Q01S	--	--	--	--	FILLMORE	FILLMORE	81	60	4,881	75	1979	2	2019	2
03N20W06P01S	50	--	100	--	FILLMORE	FILLMORE	52	17.2	897	44	1994	1	2019	2
03N20W04P02S	--	--	--	--	FILLMORE	FILLMORE	81	117.0	9,474	313	1979	1	2019	2
03N20W06P02S	110	--	245	--	FILLMORE	FILLMORE	55	429.2	23,606	806	1979	2	2006	2
03N20W04P01S	--	--	--	--	FILLMORE	FILLMORE	81	54.0	4,373	158	1979	2	2019	2

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
03N20W04N01S	136	--	--	--	FILLMORE	FILLMORE	36	35.9	1,293	81	2002	1	2019	2
03N20W02P01S	--	--	--	--	FILLMORE	FILLMORE	81	1	61	1	1979	2	2019	2
03N21W01R01S	--	--	--	--	FILLMORE	FILLMORE	81	0.5	44	1	1979	2	2019	2
03N20W06N01S	125	--	328	--	FILLMORE	FILLMORE	82	172.6	14,152	420	1979	1	2019	2
03N20W06N02S	240	--	350	--	FILLMORE	FILLMORE	81	42.9	3,477	251	1979	2	2019	2
03N21W01P02S	75	--	104	--	FILLMORE	FILLMORE	81	0.6	50	1.3	1979	2	2019	2
03N20W11C01S	--	--	--	--	FILLMORE	FILLMORE	81	12	991	44	1979	2	2019	2
03N20W12D01S	--	--	--	--	FILLMORE	FILLMORE	81	1	69	1	1979	2	2019	2
03N20W09D01S	210	--	310	--	FILLMORE	FILLMORE	81	240.7	19,497	469	1979	2	2019	2
03N20W10D02S	50	--	135	--	FILLMORE	FILLMORE	77	67.1	5,170	124	1979	2	2019	2
03N21W12C01S	--	--	--	--	FILLMORE	FILLMORE	59	0.8	49	1	1990	2	2019	2
03N21W12D01S	--	--	--	--	FILLMORE	FILLMORE	59	0.8	45	1.2	1990	2	2019	2
03N20W08B02S	202	--	307	--	FILLMORE	FILLMORE	81	182.7	14,800	413	1979	2	2019	2
03N21W12A01S	--	--	--	--	FILLMORE	FILLMORE	81	55.9	4,529	66	1979	2	2019	2
03N20W11C02S	--	--	--	--	FILLMORE	FILLMORE	81	0.5	39	1.0	1979	2	2019	2
03N20W11D05S	--	--	--	--	FILLMORE	FILLMORE	23	1.1	25	1	2008	2	2019	2
03N21W12D02S	91	--	122	--	FILLMORE	FILLMORE	59	10.6	626	14.1	1990	2	2019	2
03N20W11A01S	127	--	150	--	FILLMORE	FILLMORE	81	26.7	2,161	54.0	1979	2	2019	2
03N20W12D05S	39	--	150	--	FILLMORE	FILLMORE	81	0.6	45	1.0	1979	2	2019	2
03N20W08C01S	70	--	352	--	FILLMORE	FILLMORE	35	78.9	2,761	154.8	2002	2	2019	2
03N21W12B03S	105	--	150	--	FILLMORE	FILLMORE	81	44.7	3,623	90.6	1979	2	2019	2
03N21W12B01S	--	--	--	--	FILLMORE	FILLMORE	81	1.1	92	2.1	1979	2	2019	2
03N21W12A02S	50	--	90	--	FILLMORE	FILLMORE	76	0.5	38	4.2	1979	2	2019	2
03N20W11C03S	--	--	--	--	FILLMORE	FILLMORE	81	21.3	1,728.7	51.3	1979	2	2019	2
03N21W12A05S	60	--	100	--	FILLMORE	FILLMORE	81	1.7	134.3	2.3	1979	2	2019	2
03N21W12H02S	38	--	80	--	FILLMORE	FILLMORE	78	0	39	1	1979	1	2019	2
03N21W12A04S	60	--	120	--	FILLMORE	FILLMORE	81	0.8	62	1	1979	2	2019	2
03N20W08A01S	--	--	--	--	FILLMORE	FILLMORE	81	27.7	2,247	379	1979	2	2019	2
03N21W12H01S	74	--	150	--	FILLMORE	FILLMORE	81	65.2	5,284.7	194.8	1979	2	2019	2
03N20W07H01S	56	--	155	--	FILLMORE	FILLMORE	81	5.7	458	27.4	1979	2	2019	2
03N20W10H01S	130	--	190	--	FILLMORE	FILLMORE	59	10.7	633.8	27.3	1990	2	2019	2
03N20W09F01S	--	--	--	--	FILLMORE	FILLMORE	78	0.6	46	2	1979	2	2019	2
03N20W08E01S	150	--	200	--	FILLMORE	FILLMORE	59	22.1	1,305	61.0	1990	2	2019	2
03N20W08F04S	28	--	116	--	FILLMORE	FILLMORE	81	66.5	5,386	149.0	1979	2	2019	2
03N20W08F02S	--	--	--	--	FILLMORE	FILLMORE	81	0.8	61	1	1979	2	2019	2
03N20W08F01S	100	--	152	--	FILLMORE	FILLMORE	82	23.9	1,961.7	77.6	1979	1	2019	2
03N21W01N02S	200	--	400	--	FILLMORE	FILLMORE	65	160.7	10444.1	464.2	1987	2	2019	2
03N20W02G05S	122	--	262	--	FILLMORE	FILLMORE	59	9.4	552.9	12.3	1990	2	2019	2
03N20W02G06S	131	--	251	--	FILLMORE	FILLMORE	56	2.5	138.8	7.5	1992	1	2019	2
03N20W02J02S	142	--	258	--	FILLMORE	FILLMORE	57	11.5	655.7	20.2	1991	2	2019	2
03N20W02M02S	122	--	162	--	FILLMORE	FILLMORE	59	0.6	34.6	16.1	1990	2	2019	2
03N20W03J03S	50	--	250	--	FILLMORE	FILLMORE	58	27.4	1591.7	33.9	1991	1	2019	2
03N20W04N05S	100	--	250	--	FILLMORE	FILLMORE	56	25.4	1421.0	65.9	1992	1	2019	2
03N20W06N03S	50	--	100	--	FILLMORE	FILLMORE	52	11.0	573.3	40.0	1994	1	2019	2
03N20W09H01S	60	--	140	--	FILLMORE	FILLMORE	54	0.5	29.2	1.0	1991	2	2019	2
04N19W29R01S	--	--	--	--	FILLMORE	FILLMORE	81	31.0	2508.4	40.0	1979	2	2019	2
04N19W31Q01S	100	--	250	--	FILLMORE	FILLMORE	55	247.7	13621.6	550.5	1992	2	2019	2
04N20W24D02S	360	--	660	--	FILLMORE	FILLMORE	60	167.6	10058.6	197.0	1990	1	2019	2
04N20W34M01S	220	--	480	--	FILLMORE	FILLMORE	58	15.5	901.4	53.0	1991	1	2019	2
04N20W36N04S	225	--	285	--	FILLMORE	FILLMORE	48	12.0	574.1	48.8	1996	1	2019	2
04N19W32N03S	54	--	114	--	FILLMORE	FILLMORE	39	21.5	839.8	81.4	1992	2	2011	2
04N19W32L02S	140	--	400	--	FILLMORE	FILLMORE	56	240.0	13441.7	479.9	1992	1	2019	2
04N19W33M08S	200	--	460	--	FILLMORE	FILLMORE	49	101.0	4950.2	827.4	1995	2	2019	2

Table 3-9. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	DWR (2019) Basin ID	Traditional Basin	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
04N20W24Q04S	90	--	300	--	FILLMORE	FILLMORE	43	516.5	22210.2	1116.2	1998	2	2019	2
04N20W27Q03S	--	--	--	--	FILLMORE	FILLMORE	81	629.7	51004.0	1003.7	1979	2	2019	2
04N20W36D07S	120	--	280	--	FILLMORE	FILLMORE	81	110.2	8927.3	260.2	1979	2	2019	2
03N19W06D04S	--	--	--	--	FILLMORE	FILLMORE	55	20.9	1151.4	38.8	1992	2	2019	2
03N20W01K01S	--	--	--	--	FILLMORE	FILLMORE	16	0.1	1.3	0.5	2012	1	2019	2
03N20W01L04S	--	--	--	--	FILLMORE	FILLMORE	24	0.5	13.0	0.8	2008	1	2019	2
03N20W02B05S	131	--	251	--	FILLMORE	FILLMORE	41	7.1	290.5	18.9	1999	2	2019	2
04N20W25B02S	130	--	450	--	FILLMORE	FILLMORE	17	53.5	910.3	332.9	1993	2	2001	2
04N20W32L01S	500	--	920	--	FILLMORE	FILLMORE	45	39.3	1766.4	96.6	1997	2	2019	2
04N20W35H03S	120	--	280	--	FILLMORE	FILLMORE	57	10.0	569.3	60.0	1991	2	2019	2
04N20W26B03S	120	--	240	--	FILLMORE	FILLMORE	18	8.6	154.7	22.7	2011	1	2019	2
04N20W34E01S	100	--	212	--	FILLMORE	FILLMORE	18	2.2	40.0	6.0	2011	1	2019	2
04N20W34G01S	26	--	86	--	FILLMORE	FILLMORE	18	0.8	14.4	0.8	2011	1	2019	2
04N20W34L01S	28	--	88	--	FILLMORE	FILLMORE	18	2.0	36.0	2.4	2011	1	2019	2
03N20W06P04S	190	--	330	--	FILLMORE	FILLMORE	26	453.9	11800.5	618.0	2007	1	2019	2
03N20W02N04S	70	--	120	--	FILLMORE	FILLMORE	34	1.0	33.9	1.6	2003	1	2019	2
03N21W01P09S	120	--	365	--	FILLMORE	FILLMORE	24	104.6	2511.3	228.3	2008	1	2019	2
03N20W01N01S	118	--	198	--	FILLMORE	FILLMORE	16	0.4	6.6	1.1	2011	1	2019	2
04N20W24G01S	100	--	260	--	FILLMORE	FILLMORE	37	251.7	9311.6	500.8	2001	2	2019	2
04N20W24E01S	80	--	500	--	FILLMORE	FILLMORE	36	523.2	18836.4	924.3	2002	1	2019	2
04N20W34K05S	29	--	89	--	FILLMORE	FILLMORE	18	1.5	27.2	1.6	2011	1	2019	2
04N20W34M02S	380	--	480	--	FILLMORE	FILLMORE	18	4.0	72.1	8.3	2011	1	2019	2
03N20W01D05S	150	--	250	--	FILLMORE	FILLMORE	18	3.6	64.1	5.0	2011	1	2019	2
03N20W02P03S	160	--	260	--	FILLMORE	FILLMORE	18	9.1	162.9	18.3	2011	1	2019	2
03N20W02R06S	105	--	255	--	FILLMORE	FILLMORE	20	6.3	125.7	9.6	2010	1	2019	2
04N20W32R02S	220	--	300	--	FILLMORE	FILLMORE	35	27.4	959.2	59.7	2002	2	2019	2
03N20W05B03S	520	--	680	--	FILLMORE	FILLMORE	35	248.4	8694.6	404.5	2002	2	2019	2
03N20W06J04S	140	--	300	--	FILLMORE	FILLMORE	18	0.5	9.5	1.0	2011	1	2019	2
03N20W08B03S	55	--	135	--	FILLMORE	FILLMORE	30	0.2	6.3	0.6	2005	1	2019	2
03N20W08L01S	30	--	90	--	FILLMORE	FILLMORE	18	0.4	7.5	0.5	2010	1	2019	2
04N20W34P07S	120	--	280	--	FILLMORE	FILLMORE	18	0.9	17.0	3.2	2011	1	2019	2
03N20W06C01S	350	--	760	--	FILLMORE	FILLMORE	30	100.9	3026.7	166.0	2005	1	2019	2
03N20W04R03S	--	--	--	--	FILLMORE	FILLMORE	17	59.5	1012.0	116.2	2011	2	2019	2
04N20W26G04S	--	--	--	--	FILLMORE	FILLMORE	36	17.9	643.8	25.9	2002	1	2019	2
04N20W22Q03S	--	--	--	--	FILLMORE	FILLMORE	17	12.1	204.9	32.2	2011	2	2019	2
03N20W01E03S	100	--	160	--	FILLMORE	FILLMORE	24	0.6	14.1	1.0	2008	1	2019	2
03N20W01L05S	60	--	160	--	FILLMORE	FILLMORE	24	1.0	24.9	1.4	2008	1	2019	2
03N20W06H02S	108	--	268	--	FILLMORE	FILLMORE	20	14.7	294.1	75.7	2010	1	2019	2
03N20W09F02S	60	--	157	--	FILLMORE	FILLMORE	24	2.3	54.4	6.2	2008	1	2019	2
03N20W09B03S	80	--	140	--	FILLMORE	FILLMORE	24	1.1	26.4	2.0	2008	1	2019	2
03N20W01F07S	140	--	240	--	FILLMORE	FILLMORE	24	25.9	621.3	33.7	2008	1	2019	2
03N20W01M04S	60	--	180	--	FILLMORE	FILLMORE	22	6.2	135.9	25.6	2008	1	2019	2
03N20W11B02S	150	--	250	--	FILLMORE	FILLMORE	24	1.7	40.9	5.0	2008	1	2019	2
03N20W02A08S	80	--	140	--	FILLMORE	FILLMORE	27	0.4	12.0	0.6	2006	2	2019	2
03N20W02H06S	120	--	240	--	FILLMORE	FILLMORE	27	0.6	15.9	1.5	2006	2	2019	2
03N21W01N03S	350	--	650	--	FILLMORE	FILLMORE	30	148.2	4445.7	281.4	2005	1	2019	2
04N20W36R08S	125	--	265	--	FILLMORE	FILLMORE	29	132.4	3840.3	348.6	2005	2	2019	2
04N20W27N02S	430	--	600	--	FILLMORE	FILLMORE	27	21.6	583.8	142.9	2006	2	2019	2
03N20W01C05S	100	--	240	--	FILLMORE	FILLMORE	20	9.0	180.5	12.5	2010	1	2019	2
03N20W02A06S	60	--	100	--	FILLMORE	FILLMORE	28	0.5	13.5	0.5	2006	1	2019	2
03N20W12D08S	90	--	240	--	FILLMORE	FILLMORE	18	1.1	20.2	11.4	2010	1	2019	2
03N20W12D09S	65	--	275	--	FILLMORE	FILLMORE	18	5.9	106.3	11.4	2010	1	2019	2
04N20W33L01S	100	--	202	--	FILLMORE	FILLMORE	17	0.5	8.0	0.5	2011	1	2019	2