# DRAFT

# Groundwater-Dependent Ecosystems in the San Luis Obispo Valley Groundwater Basin Technical Memorandum

# San Luis Obispo Valley Basin Groundwater Sustainability Plan

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| **Available for viewing in the June 21, 2021 Agenda Packet:** | **June 16, 2021** |
| **Recommended the GSAs to receive and file for public comments:** | **June 21, 2021** |
| **Available for public comments on www.slowaterbasin.com:** | **June 22, 2021** |
| **Close of public comment period:** | **July 22, 2021** |

Per the GSC's recommendation on June 21, 2021, Groundwater-Dependent Ecosystems in the San Luis Obispo Valley Groundwater Basin Technical Memorandum will be distributed to the City and County GSAs to receive and file. This draft document is now posted on the web portal: www.slowaterbasin.com for public comments. Comments from the public are being collected using a comment form available at www.slowaterbasin.com by clicking on "Submit Comment". If you require a paper form to submit by postal mail, please contact your local Groundwater Sustainability Agency (GSA). All comments submitted will also be posted online for viewing.

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# TECHNICAL MEMORANDUM

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| DATE: | October 19, 2020 |
| TO: | WSC and Cleath-Harris Geologists |
| FROM: | Aleksandra Wydzga and Ethan Bell (Stillwater Sciences) |
| SUBJECT: | Groundwater-Dependent Ecosystems in the San Luis Obispo Valley Groundwater Basin |

The purpose of this memo is to summarize known information about surface water hydrology relevant to Groundwater Dependent Ecosystems (GDEs) in the San Luis Obispo (SLO) Valley Groundwater Basin (Section 1), identify GDEs overlying and dependent upon the SLO Valley Groundwater Basin (Section 2), identify sustainable GDE indicators (Section 3) for the SLO Valley Groundwater Basin, and propose a hydrologic monitoring network to track these indicators over time (Section 4). GDEs are defined in California's Sustainable Groundwater Management Act (SGMA) as "ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR § 351(m)).

# 1 EXISTING SURFACE WATER HYDROLOGY

## 1.1 Overview of GDE Relevant Surface and Groundwater Hydrology

The Basin is overlain by two watersheds: San Luis Obispo (SLO) and Pismo (Figure 1). Flows in SLO and Pismo Creeks can be divided into wet season flows, typically occurring from January to April, and dry season flows, typically from June to October. Short transitional periods occur between the wet and dry seasons. Wet season instream flows originate from a range of sources including precipitation-driven surface runoff events, water draining from surface depressions or wetlands, shallow subsurface flows (e.g., soil), and groundwater. Dry season instream flows, however, if present, are fed primarily by groundwater. As groundwater levels fall over the dry season, so do the corresponding instream flows. If groundwater elevations remain above instream water elevations, groundwater discharges into the stream and surface flows continue through the entire dry season (creating perennial conditions). If groundwater elevations fall below the streambed elevation, the stream can go dry. Streams that typically flow in the wet season and dry up in the dry season are termed intermittent. Due to climactic changes or groundwater pumping, over time streams can transition from historically perennial to intermittent conditions (Barlow and Leake 2012). Dry season flows supported by groundwater in the SLO and Pismo Creeks are critical for the survival of various special-status species, including but not limited to the federally threatened California red-legged frog (CRLF) *(Rana draytonii)* and Steelhead (*Oncorhynchus mykiss)*.

SLO Creek and Pismo Creek are underlain by numerous aquifers. These aquifers are connected to one another, and to surface waters, but the degree of connection varies spatially. Aquifers can include confined aquifers, unconfined aquifers, and perched aquifers (see Chapter 4 of the Draft

Groundwater Sustainability Plan). Aquifers may be hydrologically linked with ponds, lakes, wetlands, and creeks. In the SLO Valley Groundwater Basin, few data exist to characterize the connection between surface water and groundwater.

The SLO Valley Groundwater Basin is divided into two sub-basins: the SLO Valley sub-basin and the Edna Valley sub-basin. While the groundwater in these basins is hydraulically connected, a shallow subsurface bedrock divide between the two sub-basins partially isolates the deeper portions of the two aquifers (Appendix A). Groundwater in the Edna sub-basin flows both towards the SLO Valley sub-basin in the northwest portion of the basin and towards Price Canyon in the southwest portion of the basin. Groundwater flowing towards Price Canyon rises to the surface as it approaches the bedrock constriction of Price Canyon and the Edna fault system. A 1954 DWR map (Appendix B) best illustrates the groundwater flow from the Edna Valley sub-basin both towards SLO and into Price Canyon. As groundwater from the Edna sub-basin flows towards Price Canyon and rises to the surface, it creates a perennial reach of Pismo Creek that flows through Price Canyon and supports year-round critical habitat for threatened steelhead.

## 1.2 Losing and Gaining Reaches

Streams are often subdivided into losing and gaining reaches to describe their connection to groundwater. In a losing reach water flows from the stream to the groundwater while in a gaining reach water flows from the groundwater into the stream. The connection between losing reaches to the regional aquifer may be unclear as water can be trapped in perched aquifers above the regional water table. Figure 1 shows the likely extent of known gaining and losing reaches in SLO and Pismo Creeks during typical late spring and dry season conditions. This map is compiled from various data sources, including a field survey of wet and dry reaches of SLO Creek (Bennett 2015), field surveys and flow measurements of Pismo Creek (Balance Hydrologics 2008), an instream flow study of Pismo Creek (Stillwater Sciences 2012), a regional instream flow assessment that included SLO and Pismo Creeks (Stillwater Sciences 2014), spring and summer low flow measurements in SLO and Pismo Creeks (2015–2018) (Creek Lands Conservation 2019), and consideration of the effects of local geologic features such as bedrock outcrops and faults, both of which can force deeper groundwater to the surface. The effect of faults and bedrock outcrops can be localized or extend for some distance downstream. Portions of the SLO and Pismo Creeks and their tributaries for which no data exist are left unhighlighted in Figure 1. In general, the extent of losing or gaining reaches can vary by water year type or pumping conditions. For example, East Corral de Piedra and West Corral de Piedra on the north-east side of the basin can be dry in the spring and summer during drier years but be flowing in wetter years (Creek Lands Conservation 2019). In contrast, gaining reaches shown on SLO Creek appear fairly consistent across water year types (Bennett 2015, Creek Lands Conservation 2019). Figure 1 is based on limited data sources and improved mapping of losing and gaining reaches is recommended (Section 4).

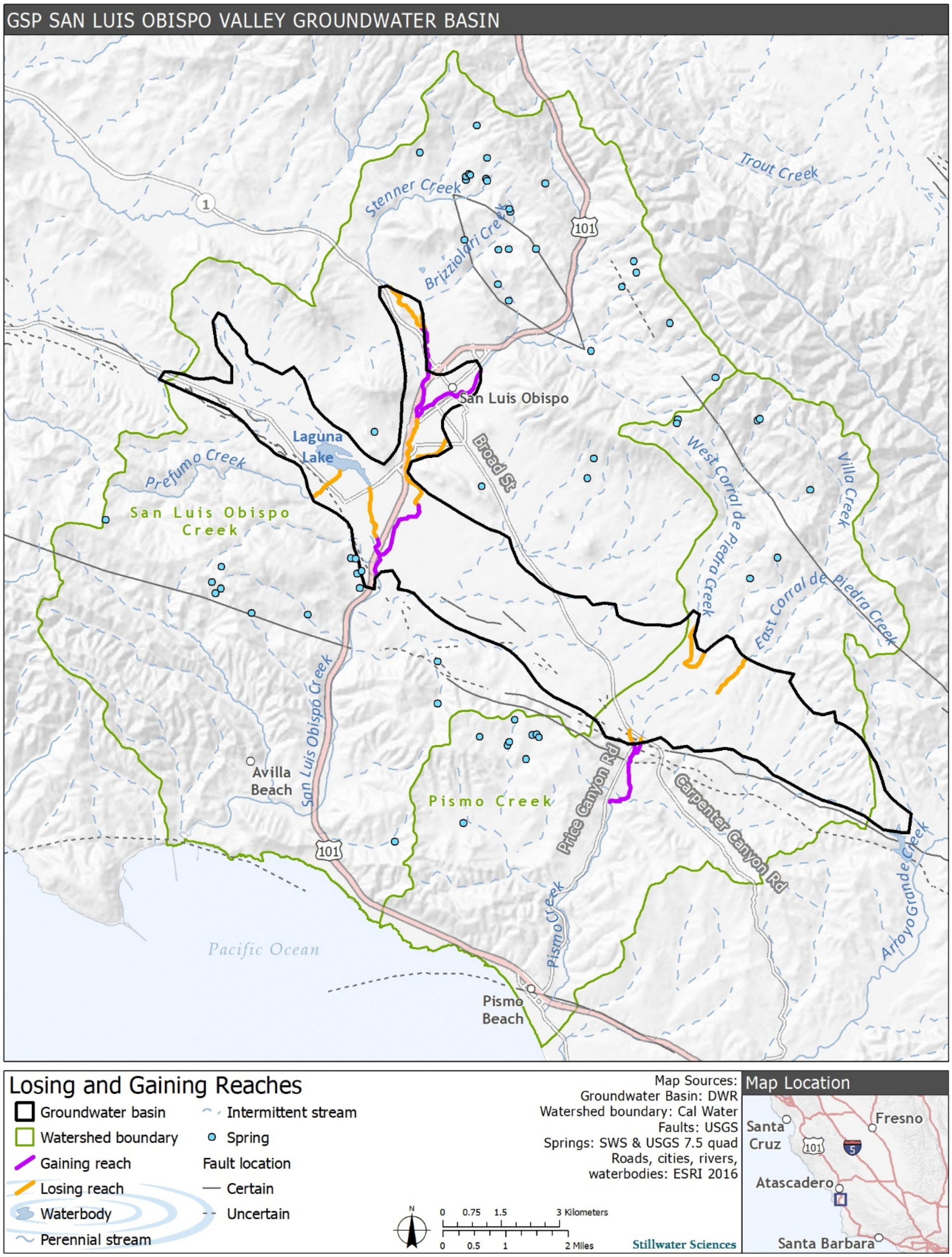



**Figure 1.** Typical late spring and dry season losing and gaining reaches in the basin. Portions of the SLO and Pismo Creeks and their tributaries for which no data exist are left unhighlighted.

### 1.3 Relevance to GDEs

Depending on location and time of year, GDEs that overly the SLO Valley Groundwater Basin can be supported by a range of water sources including direct precipitation, surface runoff, shallow subsurface flow, and groundwater. Shallow subsurface flow can vary from short-term precipitation driven flow (e.g. macro-pores filled during a precipitation event that drain on the order of days to weeks) to flow that is directly connected to groundwater (e.g. groundwater discharge into streams during the dry season). In the wet season, GDEs overlying the SLO Groundwater Basin are supported by a wider range of surface and groundwater hydrological sources than in the dry season. In the dry season, the primary water source supporting the GDEs is groundwater, although in some reaches irrigation return flow may be present. Irrigation return flow can have surface water sources from outside the basin (e.g. City of SLO parcels) or local groundwater (e.g. Edna Valley). Groundwater supporting GDEs overlying the SLO Valley Groundwater Basin can originate outside of the groundwater basin or within the groundwater basin. Both our proposed our strategy to identify sustainable GDE indicators (Section 3) and our proposed monitoring network (Section 4) take advantage of and integrate these hydrologic realities to focus on the assessment and monitoring of GDEs in locations and during seasons that are reliant on groundwater originating in the SLO Groundwater Basin.

# 2 POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEMS (GDES) AND ASSOCIATED FLORA AND FAUNA

### 2.1 Distribution of Potential GDEs Based on Best Available Vegetation and Wetland Data

Groundwater dependent ecosystems (GDEs) are defined in California's Sustainable Groundwater Management Act (SGMA) as "ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR § 351(m)). As described in The Nature Conservancy's guidance for GDE analysis (Rohde et al. 2018), a GDE's dependence on groundwater refers to reliance of GDE species and/or communities on groundwater for all or a portion of their water needs. The Department of Water Resources (DWR) compiled a statewide Natural Communities Commonly Associated with Groundwater database (DWR 2019). This database identifies potentially groundwater dependent ecosystems based on the best available vegetation and wetland data (Klausmeyer et al. 2018). DWR (2019) identifies potentially groundwater dependent wetland areas using National Wetland Inventory (NWI) wetland data (USFWS 2018). These data were evaluated and assessed to accurately capture wetland and riverine features. In the SLO Valley Groundwater Basin, the best available vegetation mapping dataset (FVEG) was from the California Fire and Resource Assessment Program Vegetation (California Department of Forestry and Fire Protection 2015). FVEG is a remotely sensed dataset that classifies vegetation to coarse types (i.e., the California Wildlife Habitat Relationship System). Given the limitations of this dataset to accurately capture and identify vegetation using a precise classification system, it was deemed inappropriate for use in determining potential GDEs in the SLO Groundwater Basin. Instead, a manual assessment of vegetation with potential groundwater dependence was conducted using National Agricultural Imagery Program 2018 color aerial imagery (NAIP 2018). Vegetation communities identified as potentially groundwater dependent included riparian trees and shrubs, and oak woodlands. Oak woodlands were considered potentially groundwater dependent, particularly coast live oak riparian woodlands, because coast live oak (*Quercus agrifolia*) is known to make use of groundwater at depths of up to 36 ft (see Steinberg 2002 and references cited therein). Some other species of California oak, particularly blue oak (*Q. douglasii*) are known to develop deeper roots that can access deeper groundwater in fractured bedrock on hillslopes (up to 70 feet [Lewis and Burgy 1964]), however such landscape positions are substantially different from what would be expected for GDEs occurring within a recognized groundwater basin on valley bottom or floodplain alluvial deposits. Therefore, we rely on the species-specific rooting and groundwater depth data for coast live oak cited by Steinberg (2002).

Potential vegetation and wetland GDEs were retained if the underlying depth to water in 2019 was inferred to be 30 feet or shallower based on the existing well network (Figure 2). Depth to groundwater was interpolated from seventeen wells for which groundwater level data was available in the spring of 2019 (WSC in progress). The depth to groundwater shown in Figure 2 is assumed to represent regional groundwater levels; however, the screening depth is known for only 6 of the 17 of the wells. Wells where the screened depth is unknown may be measuring groundwater levels for deeper aquifers that are unconnected to the shallow groundwater system, and thus groundwater deeper than 30 ft for a given well may not reflect the absence of shallow groundwater, but instead reflects the absence of data. To determine the hydraulic connectivity between potential perched aquifers to the regional aquifer, additional monitoring with nested piezometers could be utilized.

For the purposes of differentiating between potential and unlikely GDEs, different assumptions were made for the SLO versus Edna Valley sub-basins in areas of no groundwater data. In the SLO sub-basin (underlying SLO Creek), it was assumed that the depth to regional groundwater was less than 30 feet because the limited available data indicate that groundwater in this sub-basin is generally relatively shallow. In the Edna Valley (underlying Pismo Creek), it was assumed that the depth to regional groundwater was more than 30 feet because the limited available data indicate that the groundwater in this sub-basin is generally deeper. One exception to this assumption was made on upper East Corral de Piedra where the conditions were assumed to be similar to those on upper West Corral de Piedra where early dry season wet conditions have been observed by Stillwater Sciences and Balance Hydrologics (2008). The 30-foot depth criterion is consistent with guidance provided by The Nature Conservancy (Rohde et al. 2019) for identifying GDEs.

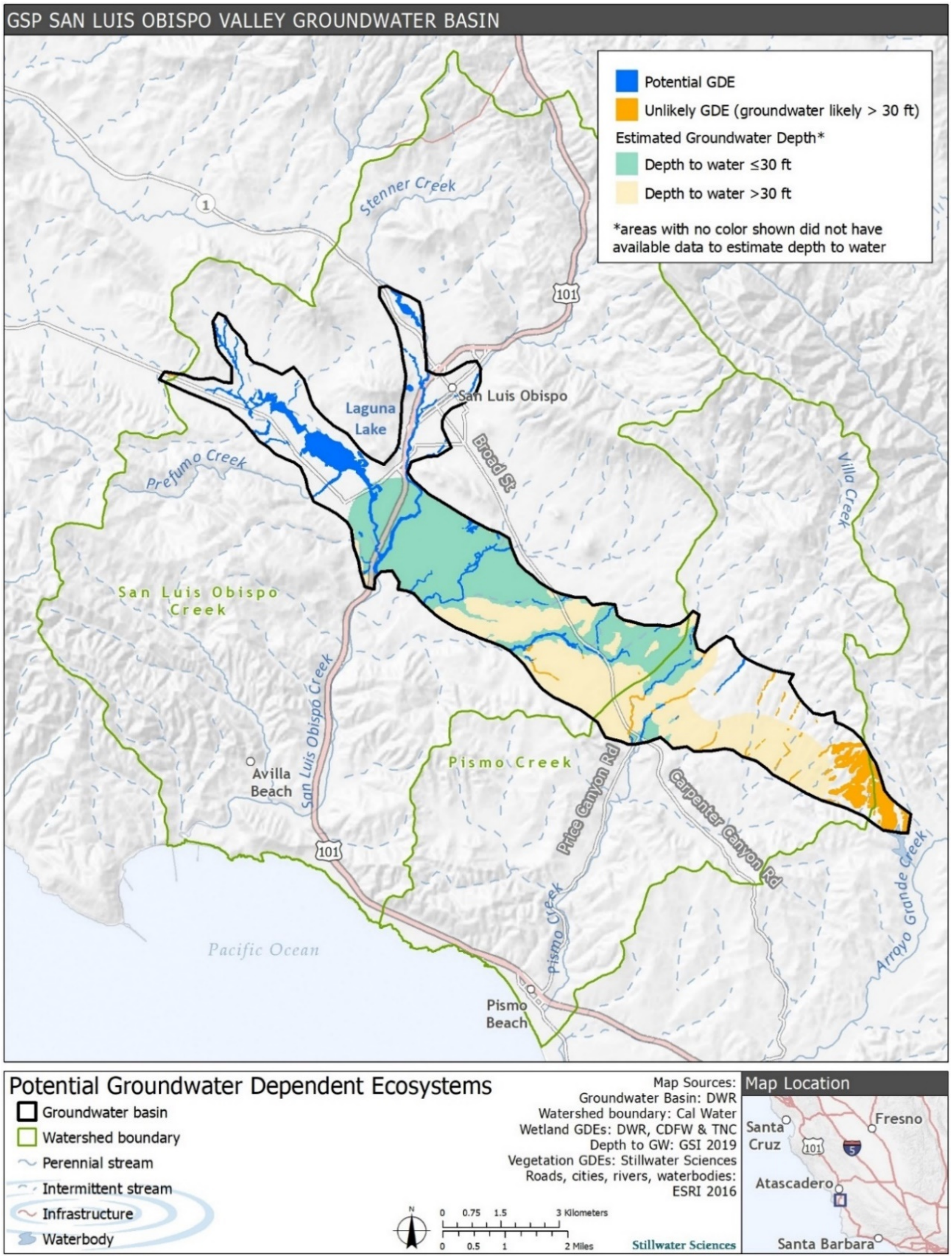



**Figure 2.** Potential Groundwater Dependent Ecosystems.

## 2.2 Special-Status Species and Sensitive Natural Communities Associated with GDEs

For the purposes of this memorandum, special-status species are defined as those:

- listed, proposed, or under review as endangered or threatened under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA);
- designated by California Department of Fish and Wildlife (CDFW) as a Species of Special Concern;
- designated by CDFW as Fully Protected under the California Fish and Game Code (Sections 3511, 4700, 5050, and 5515);
- designated as rare under the California Native Plant Protection Act (CNPPA); and/or
- included on CDFW's most recent *Special Vascular Plants, Bryophytes, and Lichens List* (CDFW 2020) with a California Rare Plant Rank (CRPR) of 1, 2, 3, or 4.

In addition, sensitive natural communities are defined as:

- vegetation communities identified as critically imperiled (S1), imperiled (S2), or vulnerable (S3) on the most recent California Sensitive Natural Communities List (CDFW 2020).

To determine the terrestrial and aquatic special-status species that may utilize potential GDE units overlying the SLO Valley Groundwater Basin, Stillwater ecologists queried existing databases on regional and local occurrences and distributions of special-status species. Databases accessed include the California Natural Diversity Database (CNDDB) (CDFW 2019b), eBird (2019), and TNC freshwater species list (TNC 2019). Spatial database queries were centered on the potential GDEs plus a 1-mile buffer. Stillwater's ecologists reviewed the database query results and identified special-status species and sensitive natural communities with the potential to occur within and to be associated with the vegetation and aquatic communities in or immediately adjacent to the potential GDEs. Table 1 summarizes these special-status species and sensitive natural communities, describes their habitat preferences and potential dependence on GDEs, and identifies known nearby occurrences (Table 1). Wildlife species were evaluated for potential groundwater dependence using the Critical Species Lookbook (Rohde et al. 2019).

The SLO Valley Groundwater Basin supports steelhead belonging to the South-Central California Coast Distinct Population Segment (DPS) which is federally listed as threatened. Within this DPS, the population of steelhead within the SLO Creek, and Pismo Creek portions of the groundwater basin have both been identified as Core 1 populations which means they have the highest priority for recovery actions, have a known ability or potential to support viable populations, and have the capacity to respond to recovery actions (NMFS 2013). One critical recovery action listed by the National Marine Fisheries Service (NMFS) includes the implementation of operating criteria to ensure instream flows allow for essential steelhead habitat functions (NMFS 2013).

The SLO Valley Groundwater Basin was determined to have **high ecological value** because: (1) the known occurrence and presence of suitable habitat for several special-status species including the Core 1 population status of South-Central California Coast Steelhead DPS and several special-status plants and animals that are directly or indirectly dependent on groundwater (Table 1); and (2) the vulnerability of these species and their habitat to changes in groundwater levels (Rohde et al. 2018).

**Table 1.** Special-status species and sensitive natural communities documented in the vicinity of the San Luis Obispo (SLO) Valley Groundwater Basin with a potential GDE association.

| Common name *Scientific name* | Status[1] Federal/ State/CRPR | Potential to occur | Query source | GDE association[2] | Habitat association and occurrence |
|---|---|---|---|---|---|
| ***Birds*** | | | | | |
| Bank swallow *Riparia* | –/ST/– | Some potential | eBird | 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. This species relies on surface water that may be supported by groundwater (Rohde et al 2019). eBird occurrences in SLO Valley including Laguna Lake. |
| Least bittern *Ixobrychus exilis* | –/SSC/– | Some potential | eBird | Direct | Freshwater and brackish marshes with dense aquatic or semiaquatic vegetation interspersed with clumps of woody vegetation and open water. eBird occurrences in SLO Valley including Laguna Lake. |
| Loggerhead shrike *Lanius ludovicianus* | –/SSC/– | Likely | CNDDB, eBird | Indirect | Open shrubland or woodlands with short vegetation and and/or bare ground for hunting; some tall shrubs, trees, fences, or power lines for perching; typically nest in isolated trees or large shrubs. CNDDB occurrences in SLO Valley. |
| Northern harrier *Circus hudsonius* | –/SSC/– | Some potential | eBird | Indirect | Nests, forages, and roosts in wetlands or along rivers or lakes, but also in grasslands, meadows, or grain fields. eBird occurrences in SLO Valley including Laguna Lake. |
| Peregrine falcon *Falco peregrinus* | –/SFP/– | Some potential | eBird | Indirect | Wetlands, woodlands, cities, agricultural lands, and coastal area with cliffs (and rarely broken-top, predominant trees) for nesting; often forages near water. eBird occurrences in SLO Valley including Laguna Lake. |
| Redhead *Aythya americana* | –/SSC/– | Some potential | eBird | Direct | Freshwater emergent wetlands with dense stands of cattails (*Typha* spp.) and bulrush (*Schoenoplectus* spp.) interspersed with areas of deep, open water; forage and rest on large, deep bodies of water. Summer resident in southern California. eBird occurrences in SLO Valley including Laguna Lake along SLO Creek. |

| Common name *Scientific name* | Status[1] Federal/ State/CRPR | Potential to occur | Query source | GDE association[2] | Habitat association and occurrence |
|---|---|---|---|---|---|
| Tricolored blackbird *Agelaius tricolor* | –/ST/– | Likely | CNDDB, eBird | Direct | Feeds in grasslands and agriculture fields; nesting habitat components include open accessible water with dense tall emergent vegetation, a protected nesting substrate (including flooded or thorny vegetation), and a suitable nearby foraging space with adequate insect prey. Relies on groundwater dependent ecosystems for breeding and roosting (Rohde et al 2019). CNDDB occurrence in Edna Valley and eBird occurrence in SLO Valley including Laguna Lake, Pismo Creek, and Stenner Creek. |
| White-tailed kite *Elanus leucurus* | –/SFP/– | Likely | CNDDB, eBird | Indirect | Lowland grasslands and wetlands with open areas; nests in trees near open foraging area. CNDDB and eBird occurrences in SLO Valley including Laguna Lake. |
| ***Mammals*** | | | | | |
| Pallid bat *Antrozous pallidas* | –/SSC/– | Likely | CNDDB | Potential Indirect | Roosts in rock crevices, tree hollows, mines, caves, and a variety of vacant and occupied buildings; feeds in a variety of open woodland habitats. CNDDB occurrence in SLO Valley. |
| ***Amphibians and reptiles*** | | | | | |
| California red-legged frog *Rana draytonii* | FT/SSC/– | Likely | CNDDB | 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). Critical habitat is within the SLO watershed. CNDDB occurrences include SLO Creek and tributaries. |
| Coast Range newt *Taricha torosa* | –/SSC/– | Likely | CNDDB | Direct | Chaparral, oak woodland, and grasslands. Relies on surface water that may be supported by groundwater for breeding. CNDDB occurrences are in SLO Creek and Brizziolari Creek. |
| Foothill yellow-legged frog *Rana boylii* | –/SE/– | Unlikely | CNDDB | 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. All CNDDB occurrences are historical (1958) in Arroyo Grande Creek and population is possibly extirpated. |

| **Common name** ***Scientific name*** | **Status[1] Federal/ State/CRPR** | **Potential to occur** | **Query source** | **GDE association[2]** | **Habitat association and occurrence** |
|---|---|---|---|---|---|
| Northern California legless lizard *Anniella pulchra* | –/SSC/– | Likely | CNDDB | Indirect | Chaparral, pine-oak woodlands, desert scrub, sandy washes, and stream terraces with sycamores, cottonwoods, or oaks. Occurs in moist warm loose soil with plant cover. CNDDB occurrences in Edna Valley. |
| Western pond turtle *Emys marmorata* | –/SSC/– | Likely | CNDDB | Direct | Ponds, lakes, rivers, streams, creeks, marshes, and irrigation ditches with basking sites. Relies on surface water that may be supported by groundwater. CNDDB occurrences include SLO and Edna Valley, as well as, Pismo Creek, Miossi Creek, Prefumo Creek, and Mainstem and East Fork of SLO Creek |
| ***Fish*** | | | | | |
| Steelhead, South Central California DPS *Oncorhynchus mykiss* | FT/–/– | Likely | CNDDB | Direct | Rivers and streams with cold water, clean gravel of appropriate size for spawning, and suitable rearing habitat; typically rear in fresh water for one or more years before migrating to the ocean. Suitable habitat present (migration, rearing); species known to occur in SLO and Pismo Creek and their tributaries (i.e., West Corral de Piedra Creek). |
| ***Plants and Sensitive Natural Communities*** | | | | | |
| San Luis Obispo sedge *Carex obispoensis* | –/–/1B.2 | Likely | CNDDB | Direct | Seeps, often with serpentine and sometimes gabbro soils or clay soils in closed-cone coniferous forest, chaparral, coastal prairie, coastal scrub, and valley and foothill grassland (CNPS 2020); all CNDDB observations are along Prefumo Creek and Froom Creek outside of the groundwater basin |
| Congdon's tarplant *Centromadia parryi* subsp. *congdonii* | –/–/1B.1 | Likely | CNDDB | Direct | Valley and foothill grassland (CNPS 2020); all CNDDB observations are within the SLO Creek watershed including around Laguna Lake and East Fork of SLO Creek |
| Chorro Creek bog thistle *Cirsium fontinale* var. *obispoense* | FE/SE/1B.2 | Likely | CNDDB | Direct | Serpentine seeps and drainages in chaparral, cismontane woodlands, coastal scrub, and valley and foothill grassland (CNPS 2020); CNDDB observations are limited to the SLO Creek watershed and are associated with seeps and springs, |
| Adobe sanicle *Sanicula maritima* | –/CR/1B.1 | Likely | CNDDB | Direct | Clay and serpentine soils in chaparral, coastal prairie, meadows and seeps, and valley and foothill grassland (CNPS 2020); multiple CNDDB occurrences in open grassy area of Laguna Lake Park, along Laguna Creek, and South Hills |

| **Common name** ***Scientific name*** | **Status[1] Federal/ State/CRPR** | **Potential to occur** | **Query source** | **GDE association[2]** | **Habitat association and occurrence** |
|---|---|---|---|---|---|
| Saline clover *Trifolium hydrophilum* | –/–/1B.2 | Likely | CNDDB | Direct | Marshes and swamps, mesic and alkaline soils in valley and foothill grassland, and vernal pools (CNPS 2020); one CNDDB occurrence, located in Laguna Lake Park |
| Coastal and Valley Freshwater Marsh | –/S2.1/– | Likely | CNDDB | Direct | Dominated by perennial, emergent monocots including tules (*Schoenoplectus* spp.) and cattails (*Typha* spp.). May form completely closed canopies (Holland 1986). CNDDB observations around Laguna Lake. |

[1] **Status codes:**

**Federal**

FE = Federally listed endangered
FT= Listed as threatened under the federal Endangered Species Act
– No federal status

**State Rank**

SE = Listed as Endangered under the California Endangered Species Act
ST = Listed as Threatened under the California Endangered Species Act
SFP = CDFW Fully Protected species
SSC = CDFW species of special concern
CR = California State listed as rare
S2.1 = CDFW imperiled and threatened species
– No state status

**California Rare Plant Rank (CRPR)**

1B = Plants rare, threatened, or endangered in California and elsewhere

**CRPR Threat Ranks**

0.1 Seriously threatened in California (high degree/immediacy of threat)
0.2 Fairly threatened in California (moderate degree/immediacy of threat)
– No CRPR status

[2] **Groundwater Association**

**Direct**: Species directly dependent on groundwater for some or all of its water needs (e.g., cottonwood with roots in groundwater, juvenile steelhead in dry season)
**Indirect:** Species dependent upon other species that rely on groundwater for some or all of their water needs (e.g., riparian birds)

# 3 GDE EVALUATION AND SUSTAINABLE INDICATORS

In Section 2 we identified potential GDEs distributed throughout the SLO Valley Groundwater Basin. In Section 3 we identify specific GDE types that are likely or have potential to occur in the SLO Valley Groundwater Basin. Each GDE type has a different requirement to sustainably function. For each GDE type we then identify sustainable GDE indicators and target values. Sustainable GDE indictors are metrics that can be monitored to determine if undesirable impacts are occurring. The target values are set based on the best available data for each GDE type. These values are determined by the needs of special-status species, sensitive natural communities, or keystone species associated with each GDE type. As more data becomes available, the indicator type or target value may be refined. Furthermore, sustainable GDE indicator target values may not be met due to management activities (e.g., pumping) or due to climate (e.g., extended drought conditions). Thus if sustainable indicator target values are not met, additional studies or assessments to determine the cause may be required.

## 3.1 GDE Types

Eight distinct likely or uncertain types of GDEs have been identified in the SLO Valley Groundwater Basin. Likely GDE types include riverine (fast moving), riverine (slow moving), riparian, lacustrine, and wetland/marsh. Three uncertain GDE types include seasonal wetlands/wet meadows, springs and seeps, and oak woodlands. Seasonal wetlands are uncertain because their dependence of surface water versus groundwater is unknown and may be site specific. Spring and seeps are uncertain because they may be dependent on recharge from fractured bedrock in the surrounding hills rather than SLO Valley Groundwater Basin water. Oak woodlands are uncertain because groundwater elevation data from areas they are present (e.g. the eastern Edna Valley) are unavailable. Additional studies for these GDE types are recommended in Section 3.2.

The diversity of GDEs overlying the SLO Valley Groundwater Basin is due to the unique hydrogeomorphology of the basin, whereas the groundwater basin is oriented perpendicular to the general direction of surface water flow (Figure 2). A description of each GDE type along with associated special-status species, natural sensitive communities, and/or keystone species are listed in Table 2. Keystone species are defined as species that serve as indicators of GDEs sustainability. If the sustainable indicator target value is met for a GDE type with a keystone species, all habitats and species associated with that GDE type are assumed to be protected.

While a complete list of special-status species with known occurrence or presence of suitable habitat in potential GDE units overlying or within 1 mile of the SLO Valley Groundwater Basin are listed in Table 1, only those species that have a direct association with GDEs are included in Table 2. Examples of species omitted from Table 2 include species that are believed to have be extirpated from this area (e.g., foothill yellow-legged frog) or have an indirect association with GDEs (e.g., loggerhead shrike). Species that have an indirect association are assumed to be protected if the GDE indicators listed above are met. For example, the loggerhead shrike is known to occur within the SLO Valley Groundwater Basin. It lives in shrublands or woodlands with short vegetation and/or bare ground for hunting, uses tall shrubs and trees for perching, and typically nests in isolated trees. Some trees or shrubs used for perching or nesting may be part of a GDE; which is assumed to be protected if GDE indicators that are developed for each GDE type (Table 2) are met.

**Table 2.** Summary of Groundwater Dependent Ecosystem (GDE) types known to occur in the San Luis Obispo (SLO) Valley Groundwater Basin.

| GDE type | GDE habitat description | Associated special-status species[A], sensitive natural communities[B], or keystone species[C] | Key life stages primarily dependent on groundwater | Sustainable GDE indicator | Monitoring period[D] | Location and target value |
|---|---|---|---|---|---|---|
| Riverine (Fast moving) | Fast moving, flowing water | Steelhead, South Central California DPS[C] *Oncorhynchus mykiss* | Juvenile steelhead | Flow rate (cfs) | Late spring (May-June) and dry season (July–Oct) | 1) Stenner Creek at Nipomo St = 0.85 cfs (late spring); 0.33 cfs (dry season) (SWS 2014) 2) SLO Creek at Marsh St = 1.20 cfs (late spring); 0.90 cfs (late summer) (SWS 2014) |
| | | | | | Late spring (May–June) and dry season (July–Oct) | Pismo Creek at Railroad crossing = 1.50 cfs (late spring)/; 0.50 cfs (dry season) (Stillwater 2016) |
| Riverine (Slow moving) | Slow moving or still water; interspersed or interconnected with wetlands, marshes, or grasslands | California red-legged frog[C] *Rana draytonii* | Larval development and metamorphosis | Water depth (ft) | Late spring (May–June) and dry season (July–Oct) | East Fork of SLO Creek at Jespersen Road = 2.3 ft |
| | | Coast Range newt *Taricha torosa* | Larval development and metamorphosis | | | |
| | | Western pond turtle *Emys marmorata* | Foraging adults and juveniles | | | |
| Lacustrine/ Lacustrine Connected | Open water. Interspersed or interconnected with wetlands, marshes, tributaries, or grasslands | Least bittern *Ixobrychus exilis* | All life stages | TBD[E] | TBD | Laguna Lake<br><br>Target values TBD |
| | | Redhead *Aythya americana* | Adults; potential for limited resident breeding | | | |
| | | Tricolored blackbird *Agelaius tricolor* | All life stages | | | |

| GDE type | GDE habitat description | Associated special-status species[A], sensitive natural communities[B], or keystone species[C] | Key life stages primarily dependent on groundwater | Sustainable GDE indicator | Monitoring period[D] | Location and target value |
|---|---|---|---|---|---|---|
| Wetland/ Marsh | Dominated by perennial, emergent monocots including tules (*Schoenoplectus* spp.) and cattails (*Typha* spp.). May form completely closed canopies (Holland 1986) | Coastal and Valley Freshwater Marsh | Adult plants | TBD | TBD | Tank Farm wetlands<br><br>Target value TBD |
| Riparian | Dominated by mature woody vegetation including cottonwoods, sycamores, and willows | California Sycamore Woodland; Fremont Cottonwood Forest and Woodland and/or Black Cottonwood Forest and Woodland | Adult trees | Depth to groundwater (ft) and/or rate of groundwater elevation change[F] | TBD | See Figure 3 and Table 3 for all proposed locations<br><br>Target values TBD |
| Seasonal wetland/wet meadow | An area that is inundated by water seasonally (i.e., present during the growing season but absent by the end of the growing season in most years) (FGDC 2013) | Adobe sanicle *Sanicula maritima*<br>Congdon's tarplant *Centromadia parryi* ssp. *congdonii,*<br>Saline clover *Trifolium hydrophilum* | Adult plants | TBD | TBD | TBD |
| Springs and seeps | A location where water from the ground rises to the surface, commonly with saturated soil, standing, or flowing water year-round. | Chorro Creek bog thistle *Cirsium fontinale* var. *obispoense*<br>SLO sedge *Carex obispoensis* | Adult plants | TBD | TBD | TBD |

| GDE type | GDE habitat description | Associated special-status species[A], sensitive natural communities[B], or keystone species[C] | Key life stages primarily dependent on groundwater | Sustainable GDE indicator | Monitoring period[D] | Location and target value |
|---|---|---|---|---|---|---|
| Oak woodlands | Coast live oak riparian woodlands | Coast live oak[C] *Quercus agrifolia*; Pallid bat *Antrozous pallidas*[G] | Adult trees | Depth to groundwater (ft) and/or rate of groundwater elevation change | TBD | TBD |

[A] A list of special-status species with known occurrence or presence of suitable habitat in potential GDE units overlying the or within 1 mile of the SLO Valley Groundwater Basin are listed in Table 1. Of those species, only those species that are likely or have some potential to occur and that have a direct association with potential GDEs are listed in Table 2.

[B] Sensitive natural communities as defined as vegetation communities that are critically imperiled, imperiled, or vulnerable on the most recent California Sensitive Natural Communities List (CDFW 2020) or by CNPS 2020.

[C] Keystone species.

[D] Monitoring is proposed only for those time periods for which each GDE type is anticipated to be primarily dependent upon groundwater originating in the SLO Valley groundwater Basin (see Section 4 for discussion).

[E] TBD = To be determined

[F] Depth to groundwater or the rate of groundwater elevation change in the dry season is anticipated to be the sustainable indicator for mature woody riparian vegetation and oak woodland based on research by Amlin, N. M., and S. B. Rood. 2002; Mahoney, J. M., and S. B. Rood. 1998; Rood, S. B., and J. M. Mahoney. 1990; Segelquist, C. A., M. L. Scott, and G. T. Auble. 1993; Shafroth, P. B., J. C. Stromberg, and D. T. Patten. 2002; and Vaghti, M. G., and S. E. Greco. 2007.

[G] Pallid bats utilize oak savannahs, black oaks, oak grasslands, and open oak woodlands (Pierson and Rainey 2002). Oak savannahs are usually characterized by valley oak, blue oak, interior live oak, or coast live oak, with the specific composition dependent on latitude and elevation. Pallid bats typically roost in caves, crevices, bridges, buildings and occasionally tree hollows.

## 3.2 Evaluation of Potential GDEs and GDE Types

The potential GDEs and GDE types identified herein were based on the best available but limited groundwater data, wetland data and low-resolution vegetation data. These potential GDEs and GDE types require ground-truthing to determine the dominant vegetation types and quality, habitat types and quality, existing hydrologic conditions and their spatial extent to improve our understanding of their distribution and groundwater dependence. Ground-truthing should include reconnaissance level field-survey of a sub-set of accessible areas mapped as potential GDEs. At each site, field biologists could assess the following: (1) vegetation data (e.g., dominant vegetation types and plant species, indications of the proportion of live vs. senescent canopy, and vegetation density); (2) qualitative observations of hydrologic conditions (e.g. flowing or standing water); and, (3) habitat conditions for special-status or keystone species by comparing each species' habitat preferences (e.g., large trees, open water or herbaceous cover, etc.) to conditions present at the site. Based on this field data, GDE distribution, GDE type, and habitat for associated special-status species could be refined. Habitat assessments should be focused on federally or state threatened or endangered flora or fauna with direct groundwater association including the state threatened species Tricolored blackbird *(Agelaius tricolor),* the federally threatened California red-legged frog (*R. draytonii*), the federally threatened Steelhead trout (*O. mykiss*), and the federally endangered Chorro Creek bog thistle (*Cirsium fontinale* var. *Obispoense)*.

Furthermore, seven of the eight GDE types (Table 2) may require additional assessment/analysis to either determine the extent to which the GDE type is groundwater dependent, the timing of groundwater dependence, and/or to refine the sustainable GDE indicator or target values. To this extent the following are proposed for consideration:

1. **Riverine (fast moving).** Conduct an instream flow study of mainstem SLO and Stenner Creeks to identify flows required by juvenile steelhead in the late spring and summer/early fall dry season, as well as, an assessment of the quality of steelhead habitat in the East Fork of SLO Creek and Davenport Creek.
2. **Lacustrine.** Conduct a study of Laguna Lake to determine the magnitude, timing and duration of the dependence of the Lake on groundwater originating from the SLO Valley Groundwater Basin (e.g. a surface-groundwater assessment/model). Based on the results of the study and associated special-status species habitat assessments, develop sustainable GDE indicator(s), timing of groundwater dependence, and indicator target values.
3. **Wetland/Marsh.** Conduct an assessment of wetlands and marshes found within the SLO Valley Groundwater Basin that support special-status species or sensitive natural communities; determine the magnitude, timing and duration of their dependence on groundwater originating from the SLO Valley Groundwater Basin; and develop sustainable GDE indicator(s) and associated information.


Oak tree along East Corral de Piedra Creek

4. **Riparian.** Install groundwater monitoring wells at proposed locations (Table 3), collect and analyze data. Refine GDE indicator(s) and develop site specific target values for the depth to groundwater below the surface (ft) that will sustain the GDE at each location.
5. **Seasonal wetlands.** Conduct an assessment of seasonal wetlands and wet meadows found within the SLO Valley Groundwater Basin, especially those that support groundwater dependent special-status species including Adobe sanicle, Congdon's tarplant, and Saline clover. While these plants need soil saturation or inundation for seed germination, establishment and growth, the dependence on groundwater versus surface water is unknown and may be site specific. If seasonal wetlands primarily dependent on groundwater originating in the SLO Groundwater Basin are indentified, develop sustainable GDE indicator(s) and associated information.
6. **Springs and seeps.** Conduct an assessment of springs and seeps within the SLO Valley Groundwater Basin to identify their locations and to determine their dependence on groundwater originating from the SLO Valley Groundwater Basin. The study could include measurements of the magnitude and timing of flow rates and/or an isotopic analysis to identify water sources. It is anticipated that many springs and seeps will be dependent on recharge from fractured bedrock in the surrounding hills rather than SLO Valley Groundwater Basin water. Springs and seeps within the basin that are known to occur include but are not limited to the base of the South Hills, Irish Hills, and hills surrounding Laguna Lake. If appropriate, develop a sustainable groundwater indicator and associated information.
7. **Oak woodlands.** Conduct an assessment of oak woodlands within the SLO Valley Groundwater Basin to determine the oak species composition and distribution, with a particular focus on coast live oak riparian woodlands. Utilize existing wells or install new monitoring wells to monitor depth to groundwater. Utilizing the assessment and monitoring data determine if oak woodlands (e.g. Eastern Edna Valley) (Figure 2) are groundwater dependent. For example, coast live oak may have several deep main roots that tap groundwater if present within approximately 36 feet of the soil surface (Canadell et al 1996; Cooper 1922; Plumb 1980). If the oak woodlands are determined to be groundwater dependent, conduct an assessment of Pallid bat habitat distribution within oak woodlands and develop sustainable GDE indicators and associated data.

## 3.3 Identification of Sustainable GDE Indicators

Each type of GDE (Table 2) has a different suite of fauna and flora associated with it. For some GDE types, we also identified associated sensitive natural communities (as identified by CDFW 2020 or CNPS 2020) or keystone species. Keystone species are defined as species that serve as indicators of GDEs sustainability. To develop indicators for each GDE type the requirements of sensitive or keystone species were considered. To this extent the life histories and habitat requirements of key faunal species are discussed in the following section, along with an explanation of the development of GDE indicators dependent on faunal species.

## 3.4 Life Histories and Habitat Requirements of Key Faunal Species

### 3.4.1 Key aquatic species

**Steelhead**

Steelhead have one of the most complex life histories of any salmonid species, exhibiting both anadromous and freshwater resident life histories. Freshwater residents are typically referred to as rainbow trout, and those exhibiting an anadromous life history are called steelhead (NMFS 1998).

Steelhead exhibit highly variable life history patterns throughout their range but are broadly categorized into winter and summer reproductive ecotypes. Winter steelhead, the most widespread reproductive ecotype and the only type currently present in Central California Coast streams, become sexually mature in the ocean, enter spawning streams in summer, fall or winter, and spawn a few months later in winter or late spring (Meehan and Bjornn 1991; Behnke 1992).The timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches, and seasonal decline of associated lower water temperatures in winter (NMFS 2006)

Spawning occurs primarily from January through March but may begin as early as late December and may extend through April (Hallock 1987). Individual steelhead may spawn more than once, returning to the ocean between each spawning migration. Steelhead may spawn more than one season before dying (iteroparity), in contrast to other species of the *Oncorhynchus* genus. Upon emerging from the gravel, fry rear in edgewater habitats and move gradually into pools and riffles as they grow larger. Cover is an important habitat component for juvenile steelhead, both as velocity refuge and as a means of avoiding predation (Shirvell 1990, Meehan and Bjornn 1991). Steelhead, however, tend to use riffles and other habitats not strongly associated with cover during summer rearing more than other salmonids. In winter, they become inactive and hide in any available cover, including gravel, cobbles, or woody debris. Juvenile steelhead rear a minimum of one and typically two or more years in fresh water before migrating to the ocean during smoltification (the process of physiological change that allows ocean survival). Juvenile migration to the ocean generally occurs from December through August.

Although various steelhead life stages occur in aquatic habitats that overly the SLO Groundwater Basin, these aquatic habitats are supported by a range of surface and groundwater sources (see Section 1 for discussion). However, during the late spring and dry season, the primary source supporting steelhead in GDEs overlying the SLO Valley Groundwater Basin is groundwater. Thus the dependence of steelhead on groundwater is greatest during the late spring and the summer-fall dry season and it is for these times of the year that target values for sustainable GDE indicators are proposed (Table 2). Target values are based on the best available data.

In 2014 Stillwater Sciences completed a county-wide instream flow study for steelhead trout during their two most flow sensitive periods for minimum instream flows: late spring (May and June) and late summer (August and September) (Stillwater 2014). All available hydrologic and physical terrain data and instream flow assessments were reviewed and analyzed to explore appropriate watershed stratification and to assess the ability to extrapolate existing instream flow analyses throughout all watersheds of the County. A predictive model, based on watershed area, was developed to estimate minimum instream flows during these time periods. The purpose of the Stillwater (2014) study analysis was to provide a preliminary estimate of the magnitude and timing of instream flows that would support steelhead in creeks of SLO County and was not intended to provide sufficient precision or detail from which to establish regulatory limits. However, due to an absence of a detailed instream flow study in SLO Creek, this study is utilized to set preliminary target flow values herein. Two sites were selected for monitoring: Stenner Creek at the Nipomo Street Bridge and Mainstem SLO Creek at the Marsh Street Bridge (Table 2, Figure 3). These locations were selected because in the dry season these are in hydrologically gaining reaches, indicating that at the proposed locations the instream flows are primarily supported by SLO Valley Groundwater Basin groundwater. In Stenner Creek at Nipomo Street the sustainable flow target is set at 0.85 cfs for the late spring (May-June) and 0.33 cfs for the dry season (July-Oct) (SWS 2014) and at SLO Creek at the Marsh Street bridge the target is set at 1.20 cfs (late spring) and 0.90 cfs (dry season) (SWS 2014). To evaluate the approximate streamflow values proposed herein, a detailed instream flow study for SLO Creek for SLO and Stenner Creeks is recommended.

In 2016 Stillwater Sciences completed an instream flow study on Pismo Creek (Stillwater 2016). Based on this study, the streamflow target values recommended for mainstem Pismo Creek at the railroad crossing are set at 2.50 cfs in May, 1.50 cfs in June, and 0.50 cfs from July through the end of October. Similar to the approach used for SLO Creek, this location was selected for monitoring because it is located in a hydrologically a gaining reach and is likely supported by groundwater originating in the SLO Valley Groundwater Basin during the dry season.

**California Red-legged Frog (CRLF)**

CRLF is a federally listed as threatened and is a CDFW species of special concern. The species' range occurs from south of Elk Creek in Mendocino County to Baja California, with isolated remnant populations occurring in the Sierra foothills, from sea level to approximately 8,000 ft (Stebbins 1985, Shaffer et al. 2004). Most California red-legged frog populations are currently largely restricted to coastal drainages on the central coast of California.

CRLF habitat includes wetlands, wet meadows, ponds, lakes, and low-gradient, slow-moving stream reaches. Breeding habitats are generally characterized by still or slow-moving water with deep pools (usually at least 2.3 ft deep, although frogs have been known to breed in shallower pools) with emergent and overhanging vegetation (Jennings and Hayes 1994). Breeding sites can be ephemeral or permanent; if ephemeral, inundation is usually necessary into the summer months (through July or August) for successful metamorphosis. Although some adults may remain resident year-round at favorable breeding sites, others may disperse overland up to a mile or more (Fellers and Kleeman 2007). Movements may be along riparian corridors, but many individuals move directly from one site to another without apparent regard for topography or watershed corridors (Bulger et al. 2003). CRLFs sometimes enter a dormant state during summer or in dry weather (aestivation), finding cover in small mammal burrows, moist leaf litter, root wads, or cracks in the soil. However, CRLFs in coastal areas are typically active year-round because temperatures are generally moderate (USFWS 2002, Bulger et al. 2003).

The breeding (i.e., mating and egg-laying) season begins as early as late November and lasts though as late as April (Jennings and Hayes 1994). Females lay egg masses containing approximately 2,000–6,000 eggs (USFWS 2002). Eggs hatch within 6–14 days and tadpoles require approximately 11–20 weeks to metamorphose, generally from May to September (USFWS 2002), although overwintering by CRLFs has been documented at non-forested breeding sites (Fellers et al. 2001). CRLFs become reproductively mature frogs at 2 to 4 years, with females taking longer to develop (Jennings and Hayes 1994).

Pools with water depths greater than 2.3 feet deep are optimal, though not required, to support a majority of the breeding and larval development periods. This water depth is used to set the sustainable GDE target value. Although CRLF begin to breed as early as late November, and tadpole growth and development continues through as late as September, the aquatic habitats utilized by CRLF are supported by a range of surface and groundwater sources throughout the year. However, during the late spring and dry season, the primary source supporting CRLF in GDEs overlying the SLO Valley Groundwater Basin is groundwater. For the slow moving riverine GDE type, the target values for sustainable GDE indicators are proposed based on CRLF requirements for the late spring and summer (Table 2). We propose that CRLF is a keystone species for the slow moving riverine GDE type, and if the proposed sustainable indicator criterion is met for the late spring and summer, it assumed that sufficient groundwater will be available year-round for all habitats and species associated with this GDE type, including newts and western pond turtles.

**Coast Range Newt**

Coast Range newts occur commonly in the Coast Ranges from central Mendocino County south to northern San Diego County. Populations south of the Salinas River in Monterey County are considered by CDFW as a Species of Special Concern. Coast Range newts breed in ponds, reservoirs, and streams. Habitats are often in or near streams in valley-foothill hardwood and hardwood-conifer areas (Morey 1988); in southern California, suitable habitats include a generally drier zone of chaparral, oak woodland, or grassland. Stream-breeding newts in southern California commonly lay eggs in deep, slow pools, occasionally in runs, and almost never in riffles (Gamradt and Kats 1997, as cited in AmphibiaWeb 2020). Egg masses may be attached to aquatic vegetation, branches, and the outer surfaces of rocks; in southern California, egg masses are usually laid under rocks in quiet stream pools (AmphibiaWeb 2020) After metamorphosis, California newts disperse from aquatic habitats to terrestrial uplands. Deep leaf litter and animal burrows may be used as summer aestivation sites. During or after winter/spring rains, Coast Range newts return to their breeding site to mate, often migrating large distances and in large numbers. During a study by Trenham (1988), newts were recaptured up to 3,200 m (nearly two miles) away from the breeding pond where they were originally captured and marked.

Migration from aestivation sites to breeding sites generally begins anywhere from late December to February, depending on the amount of rainfall, though populations that breed in stream pools migrate later, typically in March and April after stream flooding has subsided (Nafis 2020). Egg incubation to hatching times may vary at different locations, ranging from two weeks to two and a half months depending on water temperature, and the larval period lasts several months (Nafis 2020, AmphibiaWeb 2020). Larvae transform and begin to live on land at the end of the summer or in early fall, until as late as October (Nafis 2020). In summary stream-breeding Coast Range newts require quiet stream pools from March through October.

**Western Pond Turtle**

Western pond turtle is a CDFW species of special concern. Western pond turtles inhabit fresh or brackish water characterized by areas of deep water, low flow velocities, moderate amounts of riparian vegetation, warm water and/or ample basking sites, and underwater cover elements, such as large woody debris and rocks (Jennings and Hayes 1994). Along major rivers, western pond turtles are often concentrated in side-channel and backwater areas. Turtles may move to off-channel habitats, such as oxbows, during periods of high instream flows (Holland 1994). Although adults are habitat generalists, hatchlings and juveniles require specialized habitat for survival through their first few years. Hatchlings spend much of their time feeding in shallow water with dense submerged or short emergent vegetation (Jennings and Hayes 1994). Although an aquatic reptile, western pond turtles require upland habitats for basking, overwintering, and nesting, typically within 0.6 mi from aquatic habitats (Holland 1994). Reese and Welsh (1998) recorded frequent and prolonged year-round use of terrestrial habitat up to 0.3 mi (500 m) from the Trinity River for both nesting and overwintering activities.

Western pond turtle eggs are typically laid in June and July, though they may be laid throughout the year (Holland 1994, Reese 1996); local climatic and water level variations can alter the timing of nesting in this species (Crump 2001). Egg-laying sites vary from sandy shorelines to various forest soil types, although they are generally located in grassy meadows, away from trees and shrubs (Holland 1994), with canopy cover commonly less than about 10% (Reese 1996). Incubating eggs are extremely sensitive to increased soil moisture, which can cause high mortality (Bettelheim 2005, Shaffer 2005, Ashton et al. 1997). Young hatch in late fall and emerge either immediately or overwinter in the nest and emerge in early spring. Low fecundity, low hatchling and juvenile survivorships, high adult survivorship, and potentially long lifespans are characteristic of this species (Jennings et al. 1992). Western pond turtles have temperature-dependent sex determination, where the temperature of the egg during incubation determines the sex (Spinks et al. 2003). In summary, while pond turtles nest sites occur only in upland habitats, aquatic habitat is used year-round by foraging adults and juveniles, particularly deep pools with low flow.

### 3.4.2 Key birds

**Least Bittern**

Least bittern is a CDFW species of special concern. The smallest of the ardeids, they are cryptic marsh associates that are seldom seen. Because of their secretive nature, there are significant knowledge gaps regarding breeding behavior and interannual movement patterns.

Breeding populations exist in small patches throughout the state but are concentrated in the Central Valley and along the Southern Coast (Sterling 2008; Poole et al. 2020), with some documented breeding populations in the eastern Sierra (Kirk 1995) and Klamath basin (Poole et al. 2020). SLO County is within the known breeding range (Sterling 2008).
Least bittern are known to breed in both freshwater and brackish marshes (Sterling 2008, Poole et al. 2020), where they build nests atop platforms secured to the stalks of emergent vegetation (usually *Typha* or *Scirpus* spp., but occasionally *Phragmites* spp.) (Weller 1961, Poole et al. 2020). Nests are built up to 75 centimeters above the water surface where water depth is between eight centimeters and one meter. Least bittern show a preference for habitat that includes dense stands of emergent vegetation with adjacent pockets of open water. (Weller 1961, Poole et al. 2020). Breeding usually begins in late April and lasts through August (Kirk 1995, Sterling 2008, Poole et al. 2020). Population abundances decrease outside of the breeding season, which suggests seasonal migration, though some birds are likely winter residents. While foraging, least bittern stalk prey beneath the water surface by perching on the stalks of emergent vegetation (Weller 1961). Important food resources include small fish, terrestrial and aquatic invertebrates, amphibians, and occasionally small mammals (Weller 1961, Poole et al. 2020).

Flooded stands of emergent vegetation are a critical requirement for successful breeding (minimum depth of 8 cm) and foraging. Maintaining stable water levels in Laguna Lake such that emergent vegetation on the lake margins remains inundated throughout the nest selection and breeding season (April–August) is the most important consideration for least bittern in the SLO watershed. However, the role of groundwater in maintaining these water elevations is unclear.

**Redhead**

A CDFW species of special concern, redheads are medium-bodied freshwater diving ducks (pochards) that occur throughout the United States. Pacific flyway redheads breed predominantly in Alaska, Canada, and the midwestern United States (Bellrose 1980, Beedy and Deuel 2008, Baldassarre 2014, Woodin and Michot 2020), however, resident populations occur year-round in California and breed in limited numbers from April through August (Gibbs et al. 1992 as cited in Beedy and Deuel 2008). 2019 CDFW breeding waterfowl surveys estimated 5,051 breeding individuals in the state, with a long-term average of 3,958 breeding individuals (Skalos and Weaver 2019). Seasonal migrants winter throughout California between September and April (Beedy and Deuel 2008, Baldassarre 2014). Resident breeding populations occur mostly in the Central Valley and the northeastern region of the state (in Siskiyou and Modoc County, and the Klamath Basin) (Bellrose 1980, Beedy and Deuel 2008). However, breeding occurrences have been documented outside of the “typical” range in Alameda, Monterey, and Ventura counties

(Beedy and Deuel 2008), so breeding could occur within the SLO watershed if habitat requirements for successful nesting are met.

Redheads tend to build nests in dense stands of emergent vegetation (typically *Typha* and *Scirpus* spp.) over shallow water, though they have been recorded building ground nests in dense cover (Bellrose 1980, Baldassarre 2014, Beedy and Deuel 2008). Proximity to open water is a key requirement for successful breeding, as hens lead broods to water approximately one day after hatching (Bellrose 1980, Yerkes 2000, Baldassarre 2014). Redheads exhibit flexibility in foraging behavior, diving for submerged aquatic vegetation in water up to one meter deep, and tipping up or dabbling in shallower water (Bellrose 1980, Baldassarre 2014, Woodin and Michot 2020). Wigeon grass (*Rupia* spp.), duckweed (*Lemna* spp.), pond weed (*Potamogeton* and *Stuckenia* spp.), and both terrestrial and aquatic invertebrates are important food resources (Bellrose 1980, Baldassarre 2014, Woodin and Michot 2020). Most breeding pairs documented in California occupied permanent or semipermanent wetlands containing ponds with water deeper than one meter (CDFG and USFWS unpubl. data as cited in Beedy and Deuel 2008). Research in other geographic areas has tied reproductive success to water permanence, depth of water beneath nest sites, and overland distance from nest locations to foraging water (Bellrose 1980, Yerkes 2000). Other than maintaining a hydrologic regime conducive to the growth of critical forage plants and nesting substrate, the maintenance of permanent open water approximately one meter deep is the most important consideration for this species in the SLO watershed.

For redheads, maintaining a depth of one meter in open water would be a good target for the breeding season for reproduction and year-round for wintering birds. However, the role of groundwater in maintaining open water is unclear.

**Tricolored blackbird**

Tricolored blackbird is listed as threatened by the state of California. Tricolored blackbirds are the most prodigious colonially nesting bird in North America (Cook and Toft 2005, Beedy et al. 2020). Endemic to California, their breeding range includes most of the Central Valley and parts of the Central and Southern California Coast (Beedy 2008, Beedy et al. 2020). SLO County is within the known breeding range (Beedy 2008), however in 2017 only three birds were observed breeding in the County during annual surveys (Meese 2017).

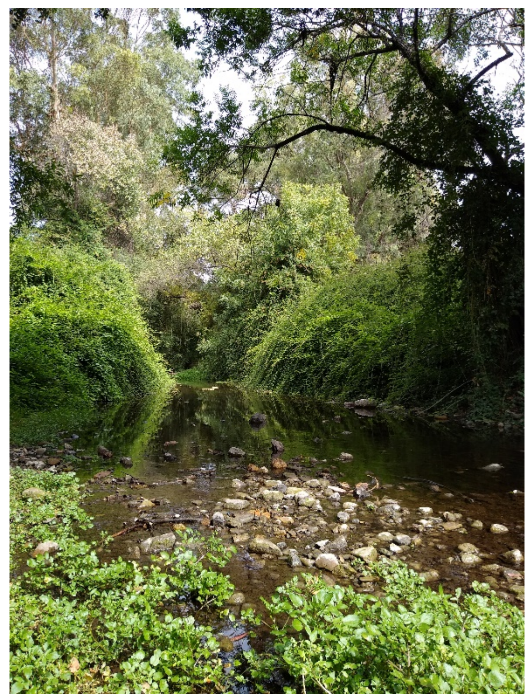
Nest initiation begins in late March with breeding lasting through August (Beedy 2008, Wilson et al. 2016, Beedy et al. 2020). Historically, tricolored blackbird colonies nested in flooded stands of vegetation (particularly *Typha* spp. and *Schoenoplectus* spp.) (Cook and Toft 2005, Wilson et al. 2016, Beedy et al. 2020). However, since the arrival of Europeans in California, there has been an observable shift in behavior, with tricolored blackbirds often utilizing protective stands of non-native upland vegetation such as Himalayan blackberry (*Rubus armeniacus*). It is thought that this switch has resulted from the widespread degradation or outright disappearance of historic Central Valley wetlands. Colonies occupying non-native upland habitat exhibit increased reproductive success when compared to colonies that nest in native flooded vegetation (Cook and Toft 2005).

Successful reproduction for tricolored blackbirds requires a combination of access to open water, appropriate nesting substrate, and proximity to high-quality foraging habitat (Beedy and Hamilton 1997). This species primarily feeds on terrestrial arthropods, including Coleoptera, Orthoptera, Diptera, Hemiptera, Arachnids, and Lepidoptera (Beedy and Hamilton 1997, Crase and DeHaven 1977). Colonies are usually located within a few kilometers of productive grassland, shrubland, forest, or agricultural land (Beedy and Hamilton 1997, Wilson et al. 2016).

Maintaining open water in proximity to suitable nesting habitat (whether emergent vegetation or substantial stands of armored upland vegetation) during the nesting season would be a good target for this species. However, the role of groundwater in maintaining open water in proximity to nesting habitat is unclear.

# 4 PROPOSED SURFACE WATER MONITORING NETWORK

Depending on location and time of year, GDEs that overly the SLO Valley Groundwater Basin can be supported by a range of water sources including direct precipitation, surface runoff, shallow subsurface flow, and groundwater. Shallow subsurface flow can vary from short-term precipitation driven flow (e.g. macro-pores filled during a precipitation event that drain on the order of days to weeks) to flow that is directly connected to groundwater (e.g. groundwater discharge into streams during the dry season). Because GDEs overlying the SLO Groundwater Basin are supported by a wider range of surface and groundwater hydrological processes in the wet season, we propose to focus monitoring of GDEs in the late spring baseflow period and summer/early fall dry season. During the late spring and summer/early fall dry season, the primary sources supporting these GDEs are likely groundwater, although in some reaches irrigation return flow may also be a factor. Irrigation return flow could have surface water sources from outside the basin (e.g. City of SLO parcels) or be dependent on local groundwater (e.g. Edna Valley). Base flows and groundwater levels during the late spring and summer/early fall dry seasons are also critical to ensure sustainable ecological conditions for many groundwater dependent species. Groundwater supporting GDEs overlying the SLO Valley Groundwater Basin can originate outside of the groundwater basin or within the groundwater basin. Our proposed monitoring network accounts for these two sources of groundwater by selecting locations that are likely primarily dependent of groundwater originating in the SLO Groundwater Basin. For example, proposed monitoring locations for instream flows (Table 3, Figure 4) are located in reaches that are likely hydrologically gaining in the late spring and dry season (Figure 1). Herein we assume that if the GDE indicators are met in the late spring and dry season, then sufficient groundwater would also be available in the wet season to sustain GDEs. However, we recommend that as more data becomes available, this assumption be revisited.



Mainstem SLO Creek several hundred feet upstream of the Marsh St Bridge, September 2020

## 4.1 Proposed Monitoring Network

There are six existing County stage gages within or adjacent to the SLO Valley Groundwater Basin (Figure 3, Table 3). An additional three stage gages are proposed. These proposed stream gage locations may be modified as future work is completed in the basin. Rating curves, which correlate stage with stream flows, should be developed for all nine sites. In addition, we propose that groundwater be monitored at all of these nine sites plus five additional sites (Figure 3, Table 3) for riparian and wetland/marsh GDE types.

In addition to the above stage, stream flow, and groundwater monitoring, we recommend that streamflow is spatially mapped across a range of seasons and water year types to identify losing and gaining reaches with the SLO Groundwater Basin. Identifying losing and gaining reaches is fundamental to understanding surface-groundwater connectivity. This type of data collection is conducted by measuring instream flow in multiple locations along a reach of creek in a short period of time and examining the loss or gain of stream flow rates along the length of the stream channel. An example of this type of data collection on Stenner Creek is provided in Appendix C.

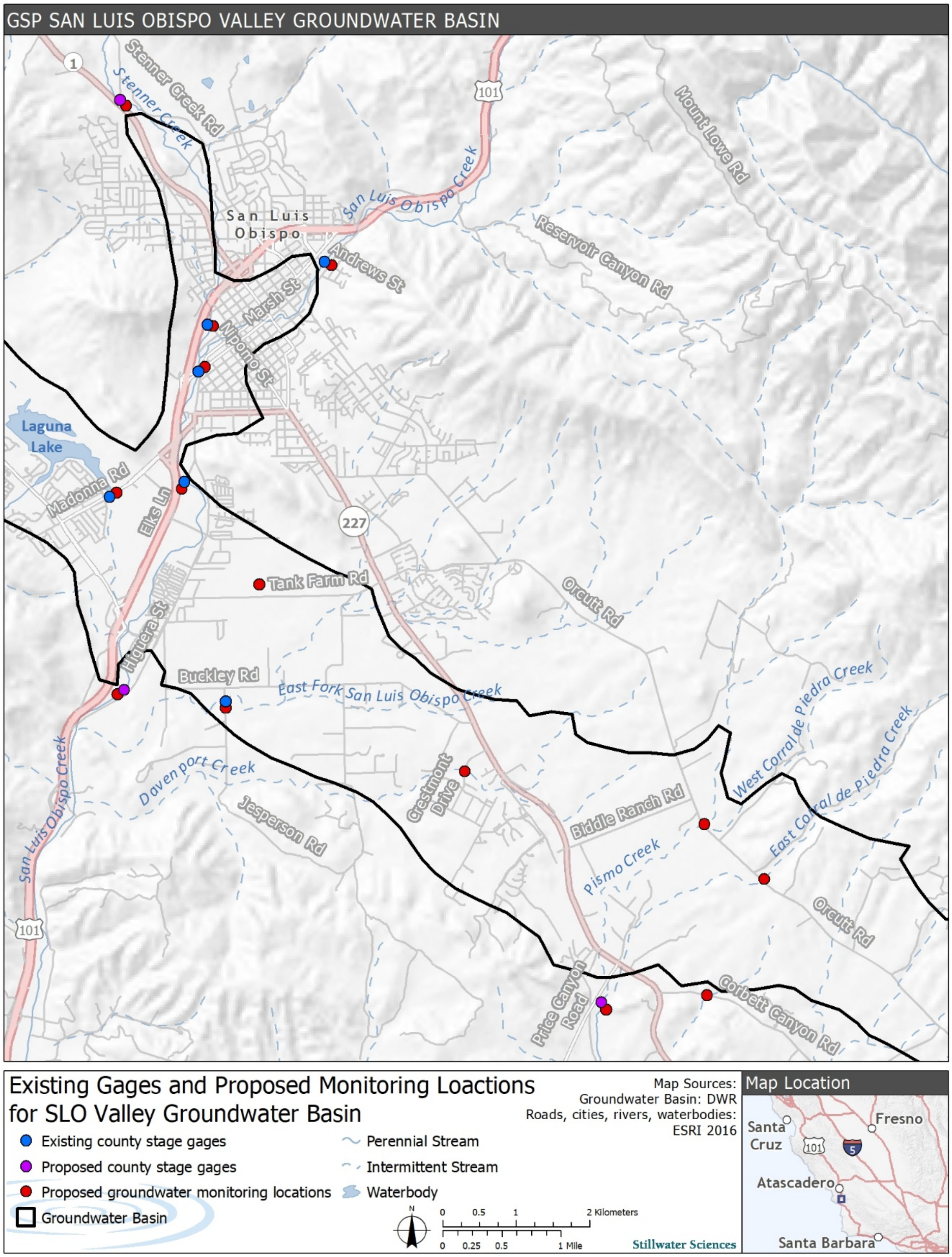



**Figure 3.** Existing and proposed monitoring locations for Groundwater Dependent Ecosystems.

**Table 3.** Summary of proposed hydrologic monitoring for the SLO Valley Groundwater Basin.

| Water Body | Location | Proposed monitoring parameters | Purpose | Sustainable GDE indicators | Sustainable GDE indicator target values |
|---|---|---|---|---|---|
| ***Existing county stage gage and proposed groundwater monitoring locations*** | | | | | |
| 1) Stenner Creek | Nipomo Street | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE indicators | Flow rate (cfs) | 0.85 cfs (late spring);<br>0.33 cfs (dry season)[A] |
| | | | | Depth to groundwater below ground surface (ft) | TBD |
| 2) Mainstem SLO Creek | Andrews Street | 1) Stage (ft)<br>2) Flow rate (ft/sec) | 1) Flow into the basin for water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE indicator | Depth to groundwater below ground surface (ft) | TBD |
| 3) Mainstem SLO Creek | Marsh Street | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE indicators | Flow rate (cfs) | 1.20 cfs (late spring);<br>0.90 cfs (dry season)[A] |
| | | | | Depth to groundwater below ground surface (ft) | TBD |
| T4) Mainstem SLO Creek | Elks Lane | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE indicator | Depth to groundwater below ground surface (ft) | TBD |
| 5) East Fork SLO Creek | Jespersen Road | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE Indicators | Water depth (ft) | 2.3 feet[B] (late spring and dry season) |
| | | | | Depth to groundwater below ground surface (ft) | TBD |
| 6) Prefumo Creek | Madonna Road | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Water budget<br>2) Surface-groundwater connectivity<br>3) Laguna Lake study<br>4) Sustainable GDE indicator | Depth to groundwater below ground surface (ft) | TBD |

| Water Body | Location | Proposed monitoring parameters | Purpose | Sustainable GDE indicators | Sustainable GDE indicator target values |
|---|---|---|---|---|---|
| ***New proposed stage gage and groundwater monitoring locations*** | | | | | |
| 7) Stenner Creek | Stenner Creek Road | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Flow into the basin for water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE indicator | Depth to groundwater below ground surface (ft) | TBD |
| 8) Mainstem SLO Creek | Old bridge, near Higuera Street | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Flow out of the basin for water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE indicator | Depth to groundwater below ground surface (ft) | TBD |
| 9) Pismo Creek | Railroad Crossing | 1) Stage (ft)<br>2) Flow rate (ft/sec)<br>3) Groundwater elevation (ft) | 1) Water budget<br>2) Surface-groundwater connectivity<br>3) Sustainable GDE indicators | Flow rate (cfs) | 1.50 cfs (late spring)/;<br>0.50 cfs (dry season)<br>(Stillwater 2016) |
| | | | | Depth to groundwater below ground surface (ft) | TBD |
| ***New proposed groundwater monitoring locations*** | | | | | |
| 10) Tank Farm Wetlands | Near Tank Farm Rd | Groundwater elevation (ft) | GDE indicator | Groundwater depth below surface (ft) | TBD |
| 11) Davenport Creek | Crestmont Road | Groundwater elevation (ft) | GDE indicator | Groundwater depth below surface (ft) | TBD |
| 12) East Corral de Piedra | Orcutt Road | Groundwater elevation (ft) | GDE indicator | Groundwater depth below surface (ft) | TBD |
| 13) West Corral de Piedra | Orcutt Road | Groundwater elevation (ft) | GDE indicator | Groundwater depth below surface (ft) | TBD |
| 14) Canada de Verde | Corbett Canyon Rd | Groundwater elevation (ft) | GDE indicator | Groundwater depth below surface (ft) | TBD |

[A] In 2014 Stillwater Sciences completed a county-wide instream flow study for steelhead trout during their two most flow sensitive periods for minimum instream flows (late spring and later summer). A predictive model, based on watershed area, was developed to estimate minimum instream flows during these time periods. Values reported here are based on this model assuming that Stenner Creek at the Nipomo Street bridge has a watershed area of 11.0 square miles and SLO Creek at the Marsh Street Bridge has a 24.5 square mile watershed area

[B] Jennings and Hayes 1994

[C] Stillwater Sciences 2016

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# Appendices

# Appendix A

# Basin Sediment Thickness Map (GSI 2017)

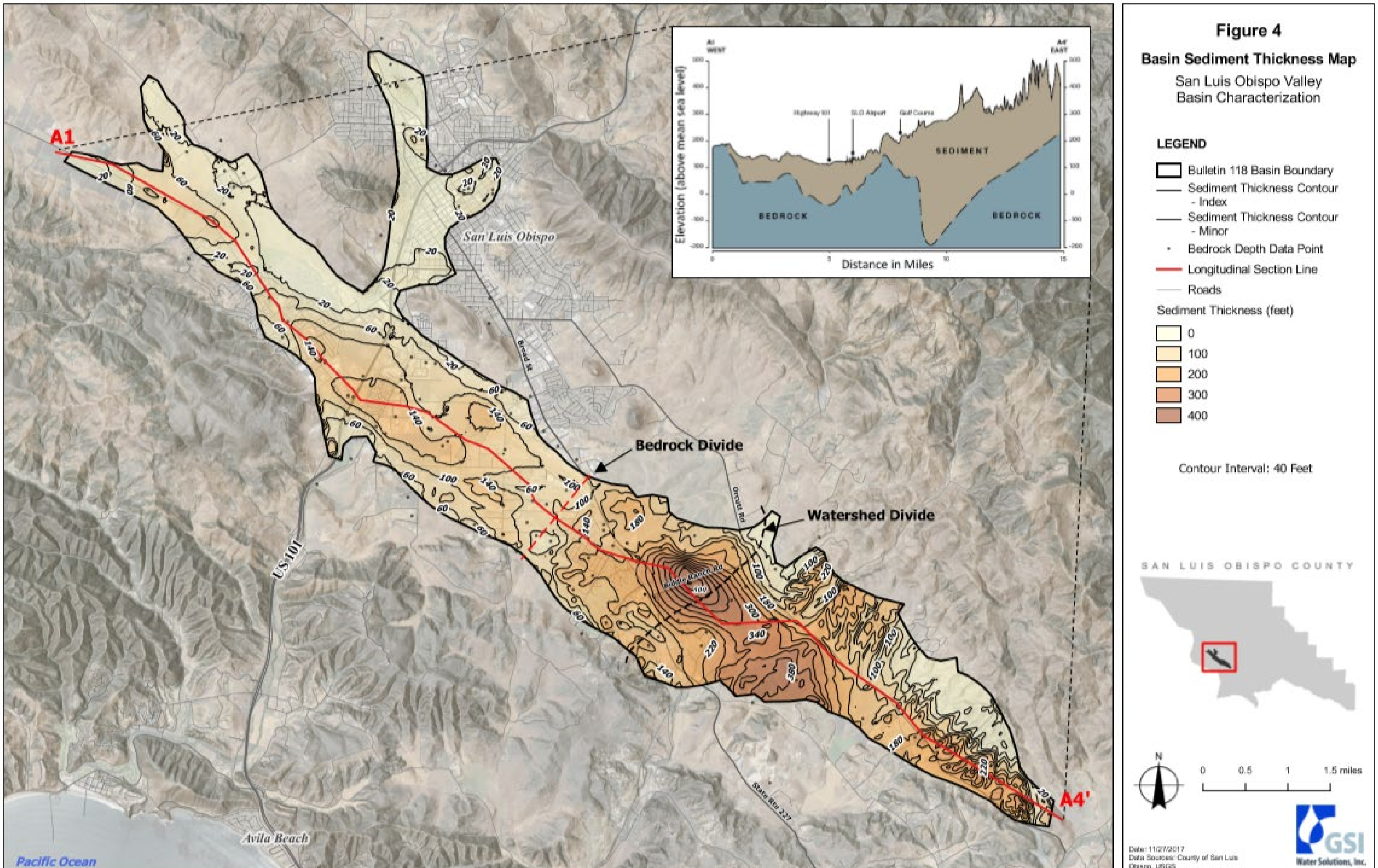


Figure A-1. SLO Groundwater Valley Basin Sediment Thickness Map (GSI 2017).

# Appendix B

# Fall 1954 Water Level Map
# (GSI 2017)

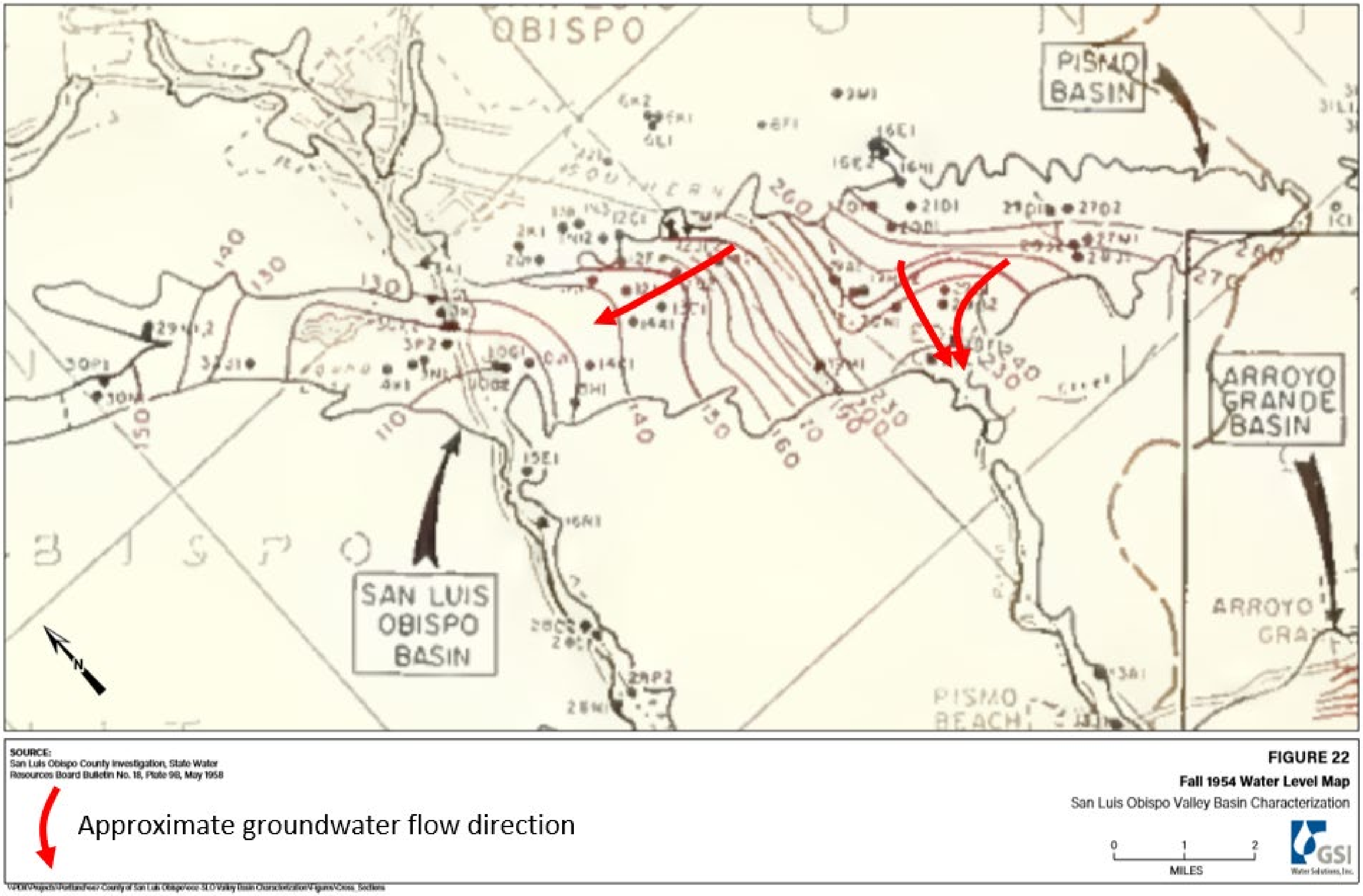


Figure B-1. SLO Groundwater Valley Basin 1954 Water Level Map (Data from DWR, Figure from GSI 2017; direction of groundwater flow (red arrows) added by Stillwater Sciences)

# Appendix C

# Map of Gaining and Losing Instream Flow Conditions, Stenner Creek, September 2020 (Creek Lands Conservation, unpublished data)

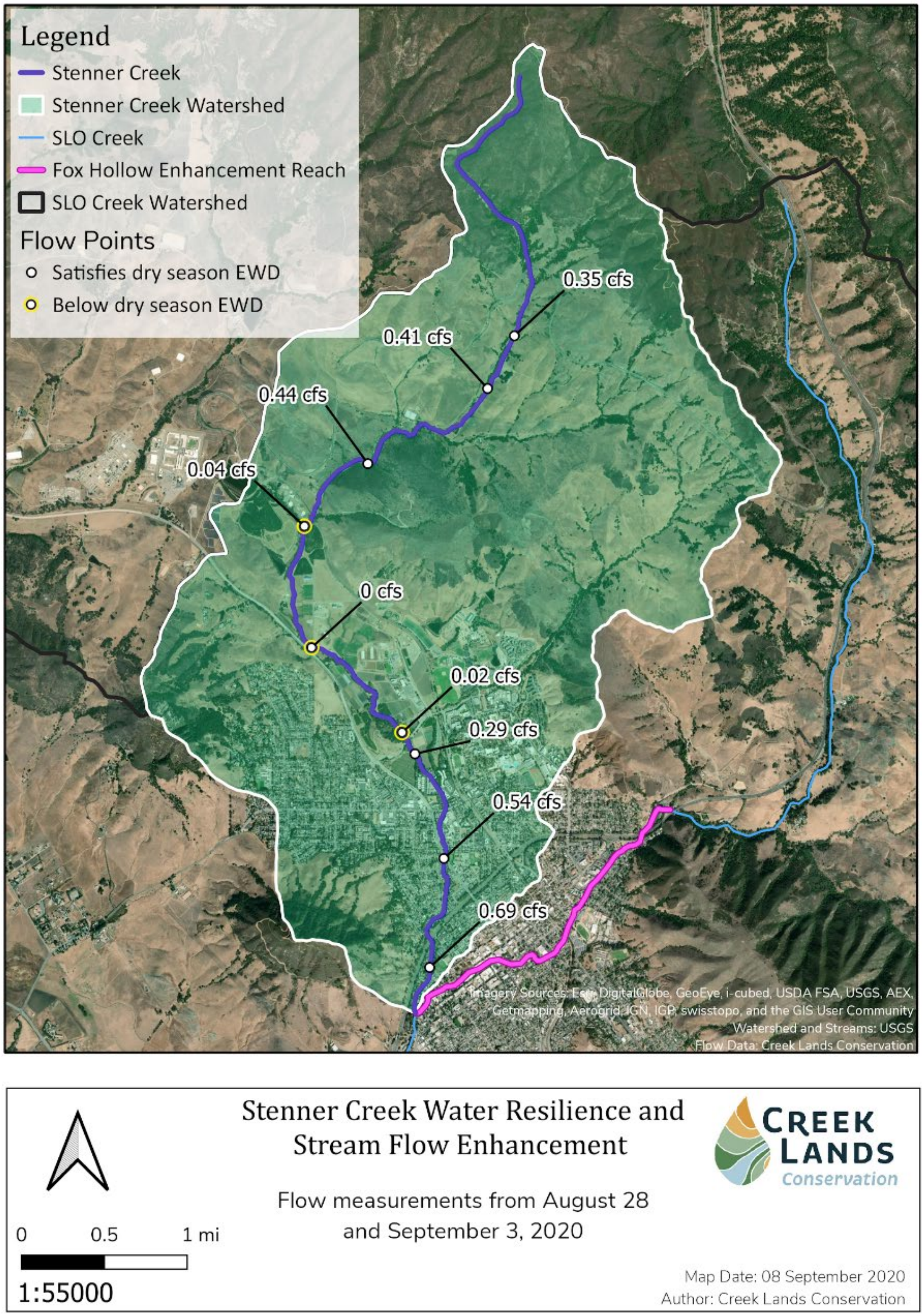


Figure C-1. Stenner Creek flow rate (cfs) as measured by Creek Lands Conservation (CLC) in late August/early September 2020 showing losing and gaining hydrologic conditions. Flow is also compared to environmental water demand (EWD) as defined by Stillwater Sciences (2014). (Figure by CLC)