TECHNICAL MEMORANDUM ◦ JANUARY 2022

Meadow Creek Lagoon Existing Conditions

PREPARED FOR

San Luis Obispo County Water
Conservation and Flood Control District
County Government Center, Room 206
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Cover photos: Looking upstream at Arroyo Grande Lagoon in January 2021 (top left), Meadow Creek Lagoon adjacent to levee within project area in October 2021 (bottom left), Arroyo Grande Lagoon adjacent to levee within the impact area in October 2021 (top right), and Meadow Creek Lagoon adjacent to levee within project area in January 2022 (bottom right).

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1 INTRODUCTION

Stillwater Sciences was retained by the San Luis Obispo County Flood Control and Water Conservation District (District) to develop and evaluate alternatives to increase connectivity between Arroyo Grande Creek and Meadow Creek lagoons and to restore approximately 8.3 acres of degraded habitat in Meadow Creek Lagoon. The purpose of the project is to increase habitat for growth and survival of smolt and rearing juvenile steelhead (*Oncorhynchus mykiss*), as well as to enhance and protect lagoon wildlife and fisheries habitat in general. In addition to steelhead, the lagoons provide habitat for two other federally listed species: California red-legged frog (*Rana draytonii*) and tidewater goby (*Eucyclogobius newberryi*). The project is a requirement of a Jeopardy Biological Opinion (BO) issued by the National Marine Fisheries Service (NMFS) for the Arroyo Grande Creek Waterway Management Program. The BO includes requirements for implementation of Reasonable and Prudent Alternatives (RPAs) that would avoid the likelihood of jeopardizing the continued existence of, or destruction or adverse modification of critical habitat for, the federally threatened South-Central California Coast Distinct Population Segment of steelhead.

The project goals are to:

1. Increase the hydrologic connectivity between Arroyo Grande Creek and Meadow Creek lagoons;
2. Enhance conditions in approximately 8.3 acres of degraded habitat, including but not limited to increasing habitat complexity, discernible flow, deep-water refugia, and riparian banks for shading; and,
3. Ensure the project does not exacerbate existing flooding conditions in surrounding developed areas.

This project includes four tasks as follows: Task 1 (completed) was to compile existing reports and data and identify data gaps/analyses needed to complete subsequent tasks. Task 2 (in progress) is to support the District in public and stakeholder outreach; Task 3 (in progress) is to synthesize and characterize the existing conditions; and Task 4 is to conduct an alternatives analysis and develop 30% designs for a preferred alternative (task details under development). The specific purpose of this report is to present the results of the existing conditions synthesis and characterization (Task 3) and to lay the foundation upon which restoration alternatives can be effectively evaluated.

2 PROBLEM STATEMENT

The Meadow Creek Lagoon is located in the coastal community of Oceano, California, where the downstream reach of Meadow Creek meets Arroyo Grande Lagoon before draining to the Pacific Ocean (Figure 1). The project area, per RPA3, includes 8.3 acres of Meadow Creek Lagoon. An additional 4.2 acres are within the adjacent impact area within Arroyo Grande Lagoon (Figure 2). Information from outside of the project area and the adjacent impact area are considered within the larger study area (black box as shown in Figure 1) and are included to the extent that it is anticipated to inform the alternatives evaluation or the existing conditions of the project.

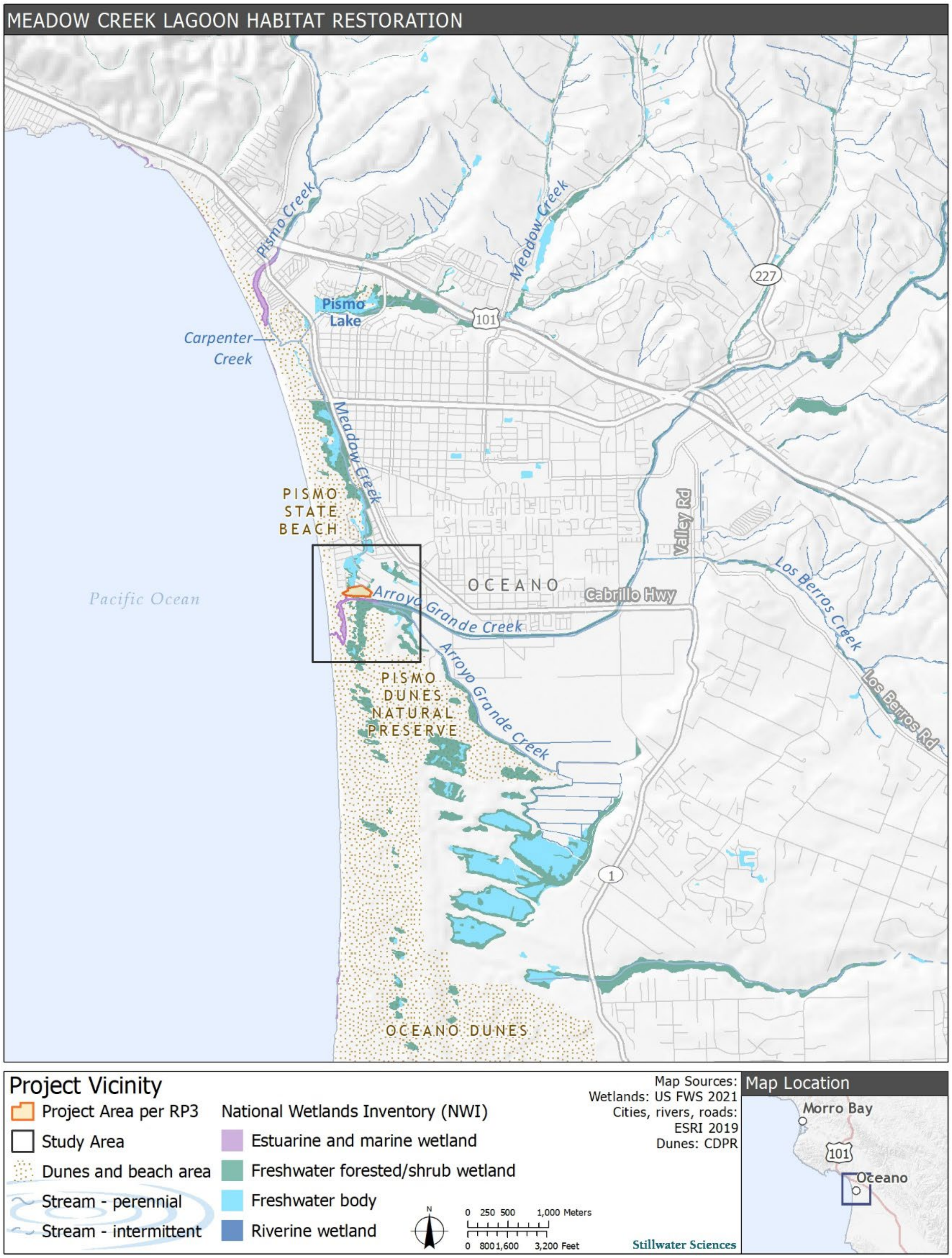


Figure 1. Project vicinity.

Figure 2. The project area per RPA 3 and the adjacent project impact area.

3 WATERSHED CONTEXT

Arroyo Grande Creek is located in west-central San Luis Obispo County (Figure 1). Arroyo Grande Creek upstream of the confluence of Meadow Creek is approximately a 157-square-mile watershed, of which approximately 70 square miles are impounded by Lopez Dam. The construction of Lopez Dam affected all aspects of downstream hydrology and sediment transport, including existing conditions of the study area. Two major tributaries enter Arroyo Grande Creek downstream of Lopez Dam: Tar Springs and Los Berros creeks. Land uses in the watershed downstream of the dam and in these two tributaries include a wide mix of agricultural, rural, residential, urban, open space, recreational and public facility land uses. Meadow Creek is a tributary that joins mainstem Arroyo Grande Creek near its mouth at the Pacific Ocean (Figure 1). Meadow Creek has an approximately 10-square-mile watershed, which drains a primarily urban landscape. Under existing conditions, Meadow Creek has two outlets, one at Carpenter Creek (Figure 1) and one into Arroyo Grande Creek at the Sand Canyon Outlet (Figure 2). Approximately 6.4 square miles of the upper Meadow Creek Watershed are upstream of the Carpenter Creek outlet, and 3.6 square miles are downstream and drain towards the confluence with Arroyo Grande Creek.

4 SITE OVERVIEW AND INFRASTRUCTURE

4.1 Existing Infrastructure

A base map of the project and adjacent impact area is presented in Appendix A, showing existing infrastructure, general alignments of Meadow Creek and Arroyo Grande Creek, and property boundaries. The terrain data is derived from a combination of an aerial survey (Central Coast Aerial Mapping 2021) and bathymetric surveys (Cannon 2012, 2017) to characterize the overland topography and lagoon bathymetry, respectively.

Agricultural development and implementation of the Arroyo Grande Creek flood control project in the late 1950s converted the formerly sinuous creek into a linear channel constrained between earthen levees with riprap protection along both toes of the channel. The terminus of the northern levee extends across the former confluence of Meadow Creek and Arroyo Grande Creek, separating Meadow Creek Lagoon to the north of the levee and Arroyo Grande Lagoon to south of the levee (Appendix A). As a result of sediment removal, vegetation management, and levee improvements as part of the Arroyo Grande Creek Waterway Management Program (WMP), Arroyo Grande Creek currently provides flood protection of up to the 10-year recurrence interval, or 5,400 cubic feet per second (cfs). Prior to WMP completion, the channel capacity was approximated to be around 1,700 cfs, which equates to a recurrence interval between approximately 2 to 5 years (Waterways 2010).

The Meadow Creek and Arroyo Grande lagoons are joined via the Sand Canyon Outlet Structure (Appendix A), which consists of two arch pipe culverts approximately 48 inches (in) wide by 71 in tall in cross section and 65 feet (ft) in length. The inlets of the culverts are equipped with a trash rack. At the outlet of each culvert are iron flap gates (Hydrogate model 50C or similar) that prevent high flows from Arroyo Grande Lagoon, as well as high tides from the Pacific Ocean, from flowing into the Meadow Creek Lagoon. A manually operated winch system is installed to allow opening and closing of the flap gates as needed (i.e., monthly inspection) (CSL RCD 2013, ESA PWA 2013). When the flap gates are not manually operated, a small differential pressure on the back of the gates cause them to open automatically, allowing water to drain from Meadow

Creek Lagoon into Arroyo Grande Lagoon. When the water level on the downstream side of the gates exceeds the water level on the upstream side, the gates close automatically.

Areas surrounding the project site, including the Island, portions of the Strand, the Oceano County Airport, and the SSLOC Wastewater Treatment Facility (Appendix A) are within FEMA's (2021) mapped 100-year flood hazard zone (1% annual flood risk). The Base Flood Elevations (Zone AE) throughout areas surrounding the project site range from approximately 13 to 15 ft NAVD88.

The Island neighborhood to the east of Meadow Creek Lagoon (Appendix A) was constructed in the 1950s by filling the wetlands and lowlands using dredged materials (ESA PWA 2013). The houses are built on ground elevations ranging between elevation 10.4 ft and elevation 15.2 ft North American Vertical Datum of 1988 (NAVD 88) (Cannon 2012). More than half of the houses were flooded during the December 2010 storm event, when the peak lagoon water surface elevation reached about 12.0 ft NAVD 88 (ESA PWA 2013). The Strand neighborhood (Appendix A) was constructed in the 1970s on top of the dunes to the west of Meadow Creek Lagoon. The majority of the houses within the Strand were constructed on higher ground than those within the Island neighborhood (e.g., elevations ranging from 15 to 25 ft NAVD 88, localized areas to 35 ft; ESA PWA 2013). A flood inundation map provided by the District indicates that two properties on the southeastern edge of the Strand neighborhood (approximate elevations between 10 and 15 ft NAVD88) were partially inundated during the December 2010 flood (County of SLO 2021a). The Oceano County Airport (approximate elevations from 10 to 16.5 ft NAVD88) and the South San Luis Obispo County Sanitation District (SSLOC) Wastewater Treatment Facility (elevations from 10 to 13 ft NAVD 88), both located adjacent to the project site, were also flooded during the December 2010 storm event.

Locations of subsurface and overhead utilities within or near the project area are based on data provided by the District, and their approximate alignments are included in the base map presented in Appendix A. A shallow 36-in-diameter asbestos bonded corrugated metal pipe ocean outfall that runs along the north side of Arroyo Grande Creek levee may significantly constrain the restoration design. The centerline of the ocean outfall is indicated to be 8 ft away from the northern toe of the levee, and the cover along Meadow Creek Lagoon ranges between 1 to 2 ft (South San Luis Obispo County Sanitation District 1979, 1997). According to the SSLOC, the outfall is operated mostly as a gravity line but becomes pressurized under rare circumstances, when there are high flow events combined with storm surges at the outlet. To continue operating the outfall mostly as a gravity line, burying the outfall deeper to avoid potential conflict with the project is not a viable option. Realigning the outfall away from the project area while maintaining gravity drainage would be challenging and cost prohibitive as this method would likely lengthen the pipe significantly and require substantial alteration to the existing infrastructure.

Although outside of the project area, a buried 10-in-diameter high-density polyethylene (HDPE) waterline across Meadow Creek Lagoon between Maui Circle and Utah Ave (i.e., around STA 3+30 of the Meadow Creek alignment in Appendix A) may constrain the restoration design. The deepest section of the waterline is indicated to be approximately 10 ft below the Meadow Creek Lagoon flowline (Terra Verde 2018). In the same alignment, there is also an abandoned 8-in-diameter asbestos-cement pipe waterline that remained in place when the 10-in-diamter HDPE waterline was installed. The depth of the abandoned 8-in-diameter waterline is waterline is unknown, thus a typical cover of 3 ft will be assumed for design purposes.

5 GEOTECHNICAL AND GEOLOGICAL HAZARDS

A complete geotechnical and geological hazards assessment in provided in Appendix B. A short summary of key findings is provided here. The project is located within the Coast Ranges geologic and geomorphic province, which extends from the Transverse Ranges in southern California to the Klamath Mountains in northern California and into Oregon. The province is characterized by north-northwest trending mountain ranges (locally the Santa Lucia Mountains) composed of sedimentary, volcanic, and metamorphic rock formations. The rock units are predominantly Jurassic and Cretaceous age with Tertiary to Quaternary age units commonly overlying the older rock along the flanks and foothills of those ranges. Recent sediments are found within the intervening drainages and valleys and coastal areas. The geology within the project area consists of a complex sequence of interbedded unconsolidated sediments resulting from the interaction of multiple geologic environments that are active in the area, including the floodplains of Meadow and Arroyo Grande creeks, eolian (windblown) sand dunes, shallow bay, estuary, marshes, and sandy beaches (Holzer et al. 2004).

Subsurface conditions within the project limits are anticipated to consist of artificial fill (af), estuarine deposits (Qe), stream channel deposits (Qhc), alluvial flood-plain deposits (Qa), beach sand (Qb), dune sand (Qd), and young eolian deposits (Qye) based on surface conditions observed during our site reconnaissance and on subsurface information presented in previous studies performed in the project vicinity (Jenks & Harrison 1979; Kleinfelder 2014; Holzer et al. 2004; Fugro 2009, 2012; Yeh 2019, 2020).

Groundwater measured by previous studies was generally shallow (2 to 7 ft below the ground surface) (Jenks & Harrison 1979, Holzer et al. 2004, Kleinfelder 2014, Yeh 2019). The elevations of groundwater surfaces measured by those studies ranged from approximately 0 to 11 ft relative to mean sea level (MSL). Wet soil conditions should be anticipated and dewatering to lower groundwater levels for construction will likely be needed for excavations, particularly along the margins of Meadow Creek Lagoon. Projects proposed within the study area should assume it will be necessary to develop a robust dewatering plan that identifies how to re-use or properly dispose of a significant volume of water on a daily basis during construction.

Geologic hazards that will likely need to be addressed by the project design include strong ground motion associated with the design earthquake, liquefaction and associated seismic settlement and slope instability of predominantly loose to medium dense sandy alluvial and eolian deposits, and subsidence or settlement of potentially compressible alluvial and estuarine deposits. The preliminary design earthquake is a M6.7 event that would result in an estimated peak ground acceleration of 0.47g. The potential for liquefaction to impact the project alternatives is considered high based on the anticipated subsurface conditions and the findings of previous studies. Liquefaction occurred within the study area in response to the 2003 M6.5 San Simeon Earthquake. The preliminary design earthquake (M6.7 event) is similar to the M6.5 San Simeon Earthquake but would result in an estimated peak ground acceleration two to four times stronger than the acceleration estimated for the San Simeon Earthquake.

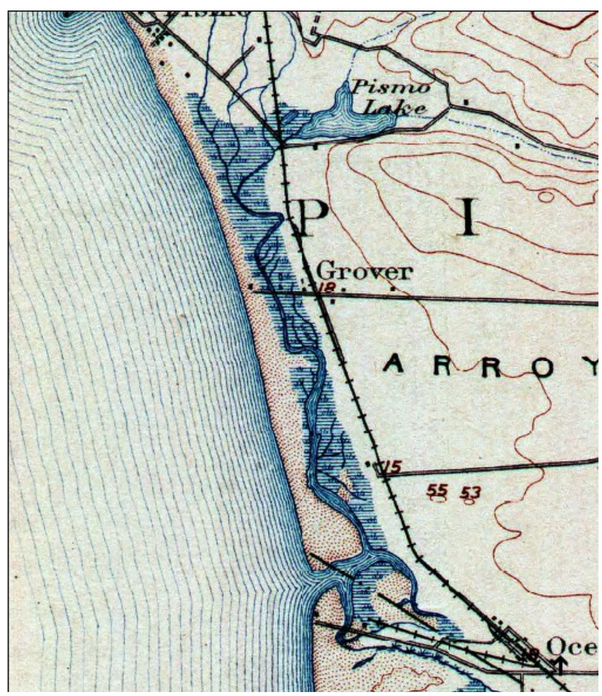
Subsurface conditions associated with each mapped geologic unit are anticipated to be generally similar within the study area, both horizontally and at depth, including those geologic units underlying artificial fill. It is anticipated that the potential for liquefaction will be similar for all project alternatives, including improvements to the existing north levee of Arroyo Grande Creek.

Liquefaction effects that could impact the levee embankments or flood control structures within the embankment (such as culverts and flap gates) include settlement, slope instability, and/or cracking of the levee embankment that could reduce the flood protection provided by the improvements. Typical mitigation methods for liquefaction are discussed in Appendix B Section 4.2 and 4.3 (Draft Geotechnical and Geological Hazards Report) and include removal and replacement of potentially liquefiable soils with properly compacted fill, although potentially liquefiable soil may be deep enough that removal would be considered impractical for the selected project alternative. Alternatively, liquefaction and seismic hazards can be addressed by soft fixes that typically include emergency response and resource planning for seismic events. We understand the County of San Luis Obispo selected a soft fix-approach to seismic hazards for the upstream 2020 Arroyo Grande Creek flood control project (Yeh 2020).

A new levee alignment within and/or along the margins of Meadow Creek Lagoon would likely be founded on relatively soft and compressible alluvial and estuarine deposits that are generally considered susceptible to settlement. The foundation soil underlying the existing north levee is anticipated to consist of alluvial deposits that may be susceptible to settlement if the existing levee were raised or modified such that additional loads were imposed on the foundation soil. Mitigation options for static settlement are provided in Appendix B Section 4.3 and include, for example, pre-construction loading of the foundation soil to accelerate consolidation and reduce the potential for post-construction settlement of foundation soil.

6 GEOMORPHOLOGY AND SEDIMENT SUPPLY

6.1 Coastal and Lagoon Geomorphology



Arroyo Grande Creek and Meadow Creek lagoons are centrally located along the coastline within San Luis Bay (Point San Luis to Point La Sal). The bay contains extensive fine-grained beaches and the most extensive dune field in central California (i.e.., Pismo Dunes Preserve). San Luis Bay from Point San Luis to Point La Sal is what is termed a crenulate bay, a bay with a fish-hook shape and a rocky headland in response to the dominant approach of larger waves and swell. Because of this dominant wave direction from the northeast, the general southerly direction of sand transport along the coast preferentially delivers sand to beaches in mid- and southern portions of the bay, including the study area (top right photo).

The current configuration of Meadow Creek bears little resemblance of its former course (Chipping 1989) (bottom right map). Prior to 1911, Pismo Lake and Meadow Creek drained into lower Pismo Creek, which in turn flowed into lower Arroyo Grande Creek, creating an extensive back barrier (landward of coastal dunes) freshwater lagoon system. The modern-day Arroyo Grande Creek and Meadow Creek lagoons are remnants of formerly extensive back barrier lagoon and wetland habitats that once existed between Pismo Beach and the Oceano Dunes Complex (ESA PWA 2013). Today the remnants of this extensive system include a series of open water areas, including but not limited to Pismo Lake and Meadow Creek Lagoon (Figure 1).

To remain consistent with definitions utilized in previous reports (e.g., ESA PWA 2013), the term lagoon is defined as the “matrix of open water, marsh and floodplain habitats that [form] when waters from a coastal creek are impounded or dammed upstream by the beach”. Thus, the term “lagoon” herein describes all non-marine open water and associated habitats, including the remanent back barrier freshwater wetland system (i.e., Meadow Creek Lagoon) and the lagoon system that is controlled by the presence of a sand bar (i.e., Arroyo

Grande Lagoon) and tidally mixes when either tides and/or waves overtop the sand bar, or the sand bar is breached and scoured. The current Meadow Creek Lagoon within the project area (Figure 1) has mostly filled with sediment and organic matter over time and consists of isolated pockets of open water, which are hydrologically disconnected during the dry season. These habitats within the project area areas are further discussed in Sections 8 and 9.

Arroyo Grande Lagoon near outlet after tidal mixing occurred - high tide on 11/6/21 (6.5 ft NAVD 88).

In contrast to Meadow Creek Lagoon, the sand bar-controlled Arroyo Grande Lagoon system is what is commonly termed a bar-built estuary (BBE). BBEs are typically located along high wave energy coasts, with swell-exposed beaches, and are associated with rivers or streams that have seasonally variable discharge (Haines et al. 2006). The typical BBE formation pattern is (1) high stream flows coupled with strong swells keep the creek mouth open in the winter; (2) low stream flows and a concomitant shift in swells during summers cause a sand bar to form across the mouth, restricting or isolating the stream from the ocean and pooling fresh and marine waters in the estuary, (3) in response to storm flows, water elevation rises behind the bar until water overtops or leads to structural failure of the sand bar and draining of the estuary (Behrens et al. 2013, Rich and Keller 2013). A sand bar is defined as a ridge of sand that forms perpendicular to the lagoon mouth and can result in water impounding behind the bar, providing increased open water and inundated marsh plain habitat during the otherwise dry summer season. Even when closed, tides or waves can overtop the sand bar, delivering salt water and nutrients to the lagoon. The term lagoon mouth is defined as the downstream end of the lagoon as it enters the Pacific Ocean, including that portion either flowing over the sand bar or via a scoured channel. The lagoon mouth is also sometimes called the lagoon outlet (in hydraulic modeling the lagoon outlet is termed an inlet because the perspective is reversed, in Section 7.3 we utilize this convention).

*When closed, a sand bar is present in lieu of the lagoon mouth or outlet.

On the oceanside of both Meadow Creek Lagoon (separated by a housing development) and Arroyo Grande Lagoon is a dune system that generally migrates to the south-east in line with the predominant coastal wave forcing. A previous survey indicates that these oceanside dunes had crests as high as 40 ft NAVD 88 circa 2012 (ESA PWA 2013). A more recent survey indicates a maximum dune crest of 23 ft NAVD 88 adjacent to the Sand Canyon flap gates (Central Coast Aerial Mapping 2021) (Appendix A). A review of historical photography (1939–2021) shows that although the Arroyo Grande Lagoon has previously drained both in line with mainstem lower Arroyo Grande Creek (e.g. when it was being managed to drain straight out to the ocean through the early 1990s) or migrating slightly north when less development existed (e.g., 1963), an elongated open body of water parallel to the beach and extending south is a common orientation for the Arroyo Grande Lagoon (e.g., 1939, 1975, 1993, post-2004). Currently the lagoon mouth is approximately 0.5 mile south of the levee, creating a long open body of water. While the orientation and size of the open body of water fluctuates on a seasonal and interannual basis, the open body of water has generally persisted over the last few decades on the scale of multiple years or decades. Since the lagoon system provides a range of habitats, including upland, estuarine wetlands, and open water habitat for a wide range of aquatic species (including tidewater goby and anadromous steelhead) (Beck et al. 2001, Bond et al. 2008, Hayes et al. 2011), the quantity of these habitats can also fluctuate on seasonal or interannual scales but likewise persist over longer time scales. Key processes that affect the area, depth, and water quality of open-water habitats include the frequency of overtopping tidal events, the frequency of scouring or flushing events, whether the sandbar is intact or breached, and the volume/water quality of freshwater inputs during ecologically critical seasons (e.g., spring and summer) (see Section 9 for a more detailed discussion of habitat).

6.2 Wave Characteristics Impacts on Beach Morphology

The winds that are the most important to beach and dune formation and destruction are those blowing for sufficient duration from a constant direction over a long enough fetch (open water distance) to create wind waves. The wave climate off the central California coast is influenced primarily by atmospheric-ocean interactions over the Pacific Ocean. The primary variables that characterize the wave climate acting on the project beach/dune system are wave height, wave frequency or period, and wind/wave direction. In the study area, predominant winds and wind waves result in a long-term net transport of sand from north to south along the shoreline.

The seasonal beach morphodynamics at the mouth of Arroyo Grande Creek likely follow the typical cycles of beach destruction (winter) and construction (summer) in response to the seasonal wave climate observed and documented along the California coast. Well-established empirical relationships between wave climate and beach/dune morphology indicate that periods of maximum wave height and period have the greatest destructive effect on a beach. Along the central California coast, maximum wave height, period, and power accompany storms, as indicated by the highest observed and calculated wave climate values recorded during the winter months. During storms, sand is moved alongshore and offshore with the net result being erosion of the beach and dunes (Douglass 1990). As a result, beaches experience erosion and narrowing during winter months. Periods of long wave period (swell) and low to modest wave height typically dominate in summer and result in the construction of wider beaches during the calmer summer months (Hapke et al. 2006). The rate and amount of beach erosion can occur rapidly during large storms. Subsequent recovery is less rapid, often requiring several months for the beach to achieve its pre-storm configuration. These seasonal dynamics, in conjunction with seasonal differences in creek flow, contribute to an open lagoon mouth condition during a portion of the winter months and closed condition during the summer, the latter occurring in response to build up of the sand bar.

The hydraulic and sediment transport models developed for this study do not incorporate coastal processes and are not intended for predicting seasonal changes in beach, dune and lagoon geometry. However, the sediment transport model does identify and simulate inlet erosion and breaching caused by high outflow rates during simulated storms. As discussed in greater detail below (Section 7.3.2), sediment transport modeling results indicate the inlet remains in its current southern position during small storm events, with the formation of a second inlet breach further north during larger storm events.

Three years (2019–2021) of tidal data from the nearest tide gage (Port San Luis) (NOAA 2021) and water surface elevation data from Arroyo Grande and Meadow Creek lagoons were examined (gage locations shown in Figure 2) (County of SLO 2021b) and suggest that tides or wave runup can influence water levels in Arroyo Grande and Meadow Creek lagoons from fall to spring. As described by Donnelly et al. (2004), wave overwash begins when the runup level of waves, usually coinciding with storm surge and accentuated by high tide events, exceeds the local beach sand bar crest height. Runup is the maximum elevation of wave uprush above still-water level (SWL) (USACE 2002). Figure 3 shows tidal, Arroyo Grande Lagoon, and Meadow Creek Lagoon water surface elevations (WSE) for 2021, including the high tide on 11 November 2021 (6.5 ft NAVD 88), when tides flowed into the estuary, temporarily raising lagoon levels approximately a foot before draining again without scouring a visible channel. Conversely, in the dry season the lagoon water levels are typically isolated from ocean influence due to the presence of a higher elevation sand bar. Sand bar elevations have been previously reported as ranging from about 6.0 ft NAVD 88 (e.g., winter) to as high as about 13 ft NAVD 88 (e.g., summer) (ESA PWA 2013). Under typical dry season conditions there is no tidal mixing in the lagoon (Figure 3), as the sand bar is higher than the mean higher high water (MHHW), which is at 5.25 ft NAVD 88 (NOAA 2021).

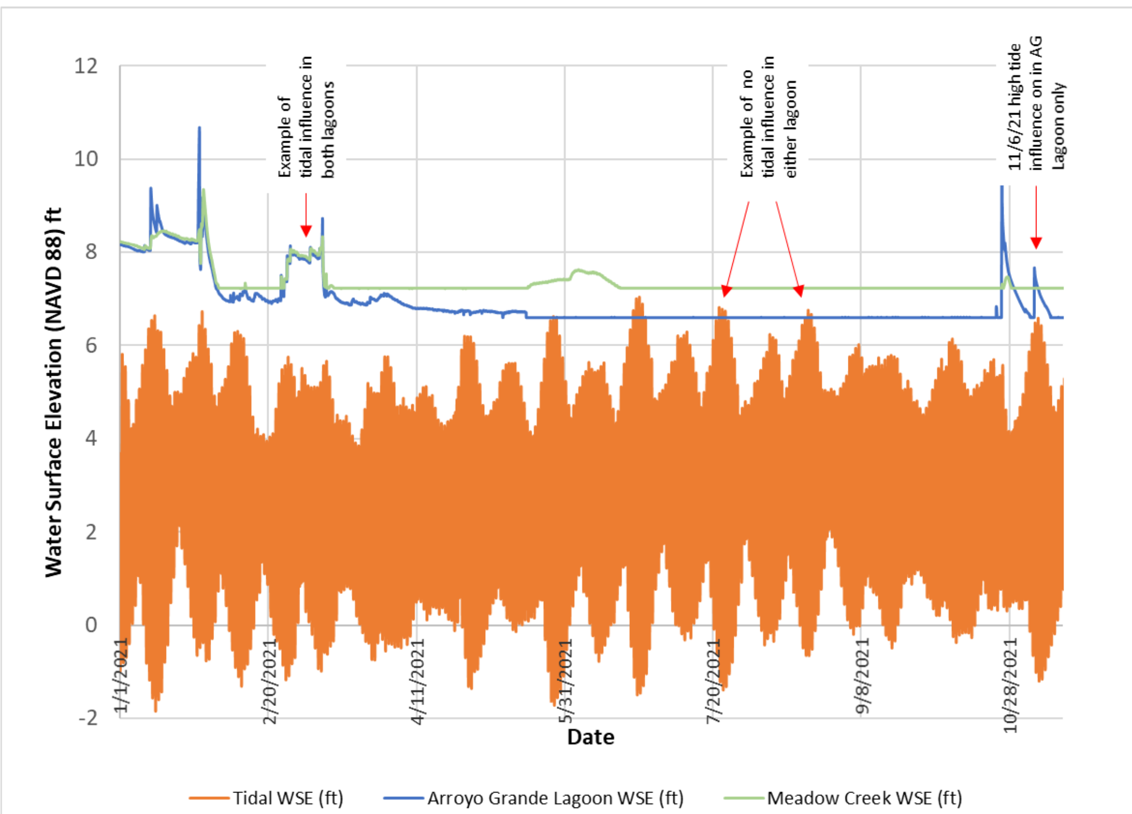


Figure 3. Tidal water surface elevations (WSE) at Port San Luis, Arroyo Grande Lagoon WSE, and Meadow Creek WSE (ft) (NAVD 88) (NOAA 2021, County of SLO 2021b).

Although the above analysis provides some insight into tidal influence on the lagoons, the frequency of tidal influence cannot be quantified using existing data because both gages are situated above ground elevation and do not capture WSE fluctuations at lower water levels (e.g.

ecologically critical dry season) (see Section 7.2.2. for further discussion). To assess the frequency of tidal influence, additional pressure transducers could be installed. An additional point of reference is provided by a FEMA coastal wave hazard analysis study (2017), which calculated selected annual probabilities of occurrence for wave runup elevations (see Table 1). Comparing these results to sand bar elevations (e.g., 6 ft in winter; 13 ft in summer, from paragraph above) provides a sense of the frequency of wave overwash contributions to the lagoon. Storm events are expected to occur more often during the winter, but could result in wave runup overwash if they occurred in either winter or summer.

Table 1. Total wave runup water level (feet NAVD88).

Location	10% Annual Chance	2% Annual Chance	1% Annual Chance
North end Arroyo Grande Lagoon	13.7	14.9	15.4
South end Arroyo Grande Lagoon	14.3	15.4	15.9

6.3 Sea-Level Rise

Based on a review of available literature, warming oceans are leading to rising sea levels. Any scientific debate regarding this subject is related to the rates at which eustatic sea level rise (SLR) (global or regional average) and relative sea level rise (local rate incorporating tectonic activity) are occurring currently and in the future. SLR would raise static water level, increasing elevation of wave runup relative to land-based beach and dune heights. Sea level rise may also change the wave climate (e.g., wave heights and period) by altering regional water depths and fetch. These processes will lead to increased beach and dune erosion as well as dune overwash unless beach/dune accretion can keep pace with rising sea level. Rhind et al. (2013) reports that sea level rise will tend to increase the erosional state of dunes and may lead to increased mobility of dunes over time. Climate change-induced increases in water temperature in the Pacific Ocean could lead to increased frequency/duration/strength of El Niño events, which result in increased wave height and period, leading to increased episodic beach/dune erosion and wave overwash events. At this point in time, the best available information regarding coastal climate change effects is projections of potential ranges of sea level rise under various greenhouse gas emissions scenarios. Projected values for the Port San Luis tide gage range from 0.7 to 9.9 feet by 2100, depending on emissions scenario (low, high) and probability of occurrence (CA OPC 2018). How SLR will be addressed as part of project alternatives analysis is provided below in Section 7.3.4.

6.4 Lagoon and Beach Management

Meadow Creek Lagoon evolved into its current configuration (Figure 2) in part due to the construction of the Sand Canyon Outlet Structure and Arroyo Grande Creek Levee System in 1958. These flood control features limit the connection between Meadow Creek Lagoon and Arroyo Grande lagoons. Historically, sediment has been removed from both Meadow Creek Lagoon (e.g., in 1939 near Pier Avenue), lower Arroyo Grande Creek, and Arroyo Creek Lagoon (ESA PWA 2013). More recently sediment has been removed from lower Arroyo Grande Creek just upstream of the Arroyo Grande Lagoon as part of the Arroyo Grande Creek Waterway Management Program (WMP; Waterways 2010). Prior to 1990s, the mouth (i.e., inlet in Section 7.3 Hydraulic and Sediment Transport Analyses of Arroyo Grande Lagoon was excavated or breached to reduce risk of flooding on an annual basis (ESA PWA 2013). Breaching was halted in 1993/94 in response to the Coastal Commission requiring a Coastal Development permit. The active management of the lagoon mouth resulted in the creek discharging directly to the ocean at a position in line with the upstream creek alignment (ESA PWA 2013). Since the time that active management of the lagoon mouth ceased, the mouth has migrated south, currently forming an approximately 0.5-mile-long open body of water (see photo on page above).

6.5 Sediment Supply

Both Meadow Creek and Arroyo Grande Lagoon are situated in a depositional zone. The primary source of sediment for Meadow Creek Lagoon in small flood events (<10-year recurrence interval) is its watershed, which is predominantly urban with a relatively low sediment yield into the lagoon (0.35 tons per acre per year [tons/ac/yr]) (SGH's 2006 report) which is equivalent of a total average sediment yield of approximately 800 tons per year being delivered to Meadow Creek Lagoon, assuming upstream water bodies such as Pismo Lake (Figure 1) likely capture a portion of sediment produced in the watershed. Inspection of aerial photography of Upper Meadow Creek Lagoon suggest that areas that were previously dredged (e.g., in 1939 near Pier Avenue) have not filled in. Lower Meadow Creek Lagoon may receive higher sediment yields from Arroyo Grande Creek during larger flood flow events that overtop the northern levee.

Arroyo Grande Lagoon has two primary sediment sources: Arroyo Grande Creek where it enters the estuary on the eastern side and wind and wave transported sand from the dunes and beach. Arroyo Grande Creek delivers sediment into Arroyo Grande Lagoon on a time scale from days to centuries, moving sediments from the creek channel, into the estuary, and eventually into the ocean. Historically, Arroyo Grande Creek deposited sediment both north and south of the modern lower Arroyo Grande Creek channel, creating the broad alluvial plain adjacent to the creek that is currently developed to the north and farmed to the south (Figure 1). The presence of a remnant portion of Arroyo Grande Creek south of the modern-day channel location (Figure 1) illustrates the spatial extent to which historical channel migration occurred. This channel migration and adjacent floodplain morphology are relevant to this project because it underscores the vast amount of sediment that was historically transported by Arroyo Grande Creek, which now must be partially transported through the modern channel. Although the historical sediment load is partially captured by Lopez Dam, a substantial amount of sediment is still delivered to lower Arroyo Grande Creek, as discussed below.

It is possible to estimate the average yearly sediment yield produced by Arroyo Grande Creek watershed and delivered into the estuary by plotting average annual total sediment yield (bedload and suspended sediment) data against drainage area from eleven other southern Coast Range watersheds (Knott 1976, Farnsworth and Warrick 2007, Brown 1973, Minear and Kondolf 2009, Stillwater Sciences 2010). The overall results of these studies are depicted on Figure 4 and show a very strong correlation (R^2 of 0.94), indicating that drainage area is a good predictor of sediment production. Using a linear regression of the plotted data in Figure 3 with the drainage area downstream of Lopez dam (87 square miles or 225 square kilometers [km^2]), we can derive an estimated total average sediment yield of approximately 93,340 tons per year [$t\ a^{-1}$] or 1.71 tons/ac/yr. This total annual sediment yield rate agrees well with other watershed study estimates (SHG 2006, Willis 2002, Inman et al. 1998). Studies in coastal California have estimated that the bedload is approximately 8% to 20% of total sediment load (Farnsworth and Warrick 2007, Brown 1973, Minear and Kondolf 2009). Considering these estimates, average annual bedload sediment yield to Arroyo Grande Lagoon adjacent to the project site is expected to be within the range of 7,500 to 18,700 tons per year. However, due to the flashy nature of the river, it is likely that during many dry years the bedload sediment yield is much lower, and in wet years it is much higher. The flux of sediment from the watershed is intermittent and driven mostly by large storm events, with most of this sediment transfer occurring across a relatively short time frame typical of gravel-bed rivers. The sediment entering Arroyo Grande Lagoon from the creek consists of both bed load, typically consisting of gravels and sands, and suspended load, typically consisting of fine sands, silts, and clays. Wind-driven or littoral sediment entering the estuary consists primarily of sand.

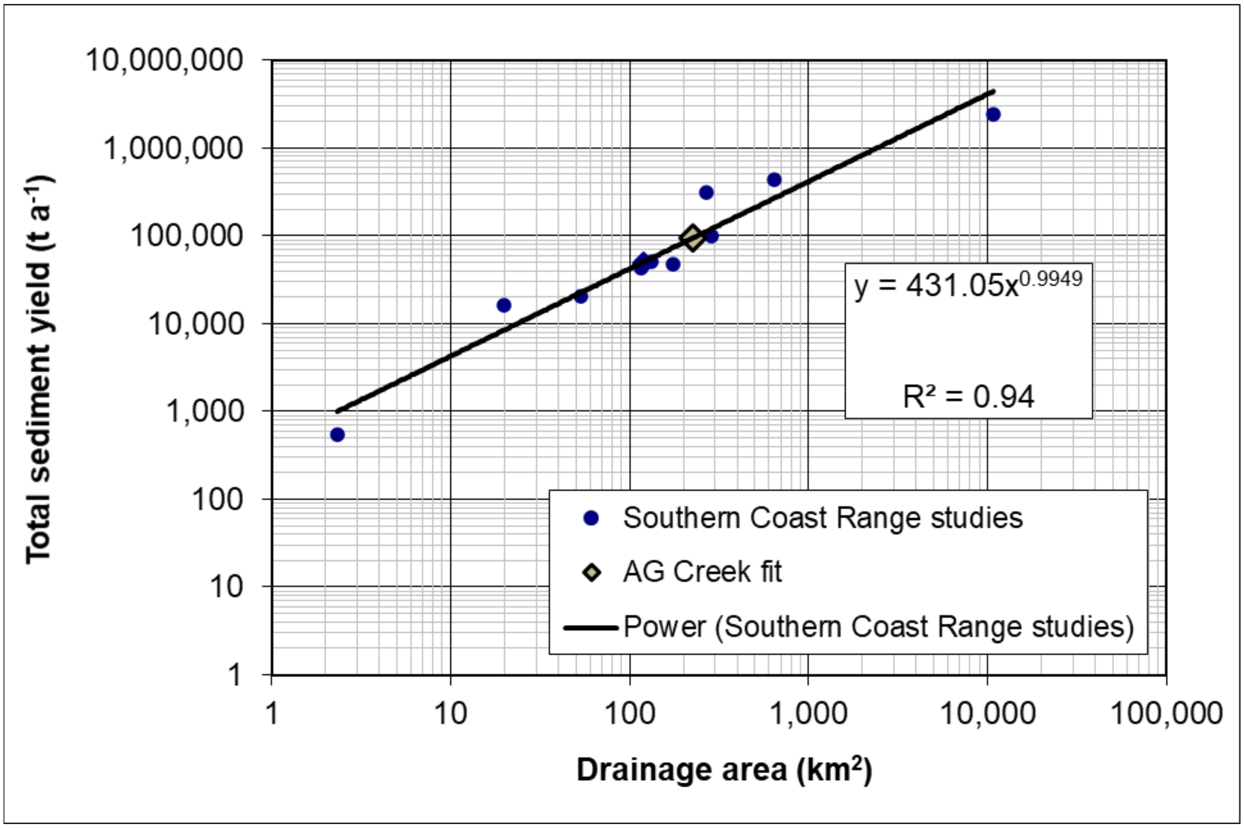


Figure 4. Correlation of estimated sediment yields (in tons per year) [t a^{-1}] from other watersheds in the southern Coast Range region with their drainage areas (Stillwater Sciences 2010). The drainage area of Arroyo Grande Creek downstream from Lopez Dam is watershed is 87 square miles [225 km^2]).

7 HYDROLOGY, HYDRAULICS AND SEDIMENT TRANSPORT

7.1 Arroyo Grande Creek

Characterization of Arroyo Grande Creek flows is relevant for the project because flow conditions dictate upstream steelhead habitat conditions, sediment transport to Arroyo Grande Lagoon, and whether/when Arroyo Grande Creek flow would be available to supplement inflow to Meadow Creek Lagoon.

7.1.1 Dry Season Hydrology

Like most streams in central California, mainstem Arroyo Grande Creek and its tributaries were likely perennial in upper and middle reaches, becoming ephemeral when flowing over deep alluvial valleys (e.g., lower mainstem Arroyo Grande Creek). Dry season releases from Lopez Reservoir for groundwater recharge and municipal uses have increased stream flow rates in mainstem Arroyo Grande Creek below the dam, but the lower mainstem (downstream of Highway 1) remains ephemeral and dries out in the dry season. Previous analysis of available stream flow records of Arroyo Grande Creek indicates that in average and wetter water years, median summer baseflow rates prior to construction of Lopez Reservoir ranged between 1.5 to 2.5 cfs as compared to 3.0 to 4.0 cfs since reservoir construction (Stenson 2004 as referenced in SHG 2004).

7.1.2 Wet Season Hydrology

Winter peak flow events on Arroyo Grande Creek are flashy and tied closely to the duration and magnitude of rainfall and antecedent soil moisture conditions (i.e., the greater the ground is saturated, the greater percentage of rainfall runoff contributions to creek flow) (SHG 2004). The construction of Lopez Reservoir has altered the magnitude of winter storm flows by capturing and storing flows for water supply purposes. A study by the USACE (1999; as cited in Swanson Hydrology + Geomorphology 2006) showed that winter storage in Lopez Reservoir reduced the downstream 2-year flood flow magnitude by 25% and almost 50% for the 100-year event. In addition to modifying the magnitude of peak flow events, dam operations have altered the duration of intervening winter baseflows that would occur naturally by releasing less water during dry years and higher flows as part of flood control operations in wet years (SHG 2004).

SHG's 2004 study evaluated post-dam flood flow estimates on Arroyo Grande Creek and utilized the USACE 2001 values in their modeling and sediment budget calculations. To maintain consistency with prior work, this study adopted the USACE 2001 peak flow estimates and SHG's generated storm hydrographs for hydraulic and sediment transport analyses. Estimates for the 2-, 5-, 10-, 25- and 100-year recurrence interval storms used in this study are provided in Table 2 and Appendix C.

Table 2. Maximum model inflow rates (cfs) for simulated floods.

Model Reach	Flood Recurrence Interval				
	2-year	5-year	10-year	20-year	100-year
Arroyo Grande Creek (AGC)	498	1,744	3,360	5,350	13,114
Los Berros Creek (LBC)	283	992	1,911	3,043	8,133
AGC+LBC	781	2,736	5,271	8,393	21,247
Meadow Creek	38	133	256	408	1,089

7.2 Meadow Creek

7.2.1 General Hydrologic Conveyance

Meadow Creek downstream of Carpenter Creek Outlet.

Meadow Creek has two outlets. One outlet is called Carpenter Creek (Figure 1) and the second outlet is into Arroyo Grande Creek at the Sand Canyon Outlet (Figure 2). While the entire watershed is approximately 10 square miles, only 3.6 square miles of the watershed are downstream of the confluence with Carpenter Creek. Meadow Creek downstream of Carpenter Creek is choked with thick, channel-spanning vegetation (see photo at right) and has limited conveyance (Chipping 1989). In the winter of 2021/2022 stream flows were observed to flow out Carpenter Creek rather than flowing down Meadow Creek towards the golf course or Meadow Creek Lagoon. Runoff from Upper Meadow Creek watershed can flow out Carpenter Creek either directly via the Carpenter Creek channel or by overflowing onto the adjacent Pismo Campground. During larger floods, water may flow via the Meadow Creek channel and/or the adjacent golf course before eventually draining past Grand Avenue and into a series of open water areas that connect to the Meadow Creek Lagoon (Chipping 1989). A series of storm drains underlying this area also direct flows into the lagoon area (Chipping 1989). In 2016 a new pedestrian bridge was installed over Carpenter Creek and two small, perched culverts were removed (County of SLO 2016). According to an engineering drawing of the new pedestrian bridge (County of SLO 2016), the channel top width and depth at the crossing are approximately 18 ft and 4 ft, respectively.

7.2.2 Dry Season

Due to the lack of rainfall and presence of upstream storage (e.g., Pismo Lake), Meadow Creek carries little to no surface water flow during the dry season. The broad interconnected channel and wetland corridor between Carpenter Creek and Lower Meadow Creek Lagoon is choked with vegetation and hosts areas on open water (e.g. upstream and downstream of Pier Avenue), which may be partially sustained by groundwater. Sustained ponding in the project area in Lower Meadow Creek Lagoon is controlled by water levels in Arroyo Grande Lagoon and the Sand Canyon Outlet Structure. Thus in the dry season when water levels drop in Arroyo Grande Creek and Lagoon, that portion of Meadow Creek that is closest to the levee can become desiccated (see Section 9.2).

Mean seasonal water levels in the lagoons recorded in two locations (Figure 2) are reported in Table 3. It should be noted that pressure transducers are prone to report incorrect values when water depths are near zero. A review of gage records indicates that the Meadow Creek and Arroyo Grande lagoons recorded water surface elevations stay constant at around 7.2 ft NAVD 88 and 6.6 ft NAVD 88, respectively, generally around summer and fall. As confirmed in the field by Stillwater Sciences on 21 October 2021 and 18 November 2021, this pattern is indicative of the lagoons' water surfaces being below the measurable gage elevation or due to dry conditions. Table 3 indicates that, on average, there is no hydrologic connection between the two lagoons between July and October, because Meadow Creek Lagoon at the upstream side of the Sand Canyon Structure is dry. There may be more frequent hydrologic connection between the two lagoons in spring (April to June) compared to the dry summer months. Depending on the relative water surface elevations, the hydrologic connections between the two lagoons may be the strongest in winter (November to March).

Table 3. Mean seasonal water levels in Meadow Creek and Arroyo Grande lagoons (2012-2018).

Site	April–June		July–October		November–March	
	Avg WSE[1]	Avg Depth[2]	Avg WSE	Avg Depth	Avg WSE	Avg Depth
Arroyo Grande Lagoon (ID 769)	7.5	0.9 ft[3]	7.0	0.4 ft	8.0	1.4 ft
Meadow Creek Lagoon (ID 770)	7.6	0.4 ft[4]	7.3	dry[5]	7.9	0.7 ft

1 WSE = water surface elevation in ft NAVD 88
2 Average depth of water, where the pressure transducers are installed
3 Surveyed ground or creek bed elevation at Arroyo Grande Lagoon gage is not available; however, the pressure transducer base elevation reading is 6.6 feet.
4 County of San Luis Obispo (2021) reports that the approximate elevation of creek bed, where the Meadow Creek Lagoon gage is installed, is 6.4 ft NAVD 88; however, the pressure transducer base elevation reading is 7.2 feet
5 Confirmed with dry season visual observations

7.2.3 Wet Season Hydrology

Due to the lack of stream flow records, only a qualitative characterization of wet season flows in Meadow Creek is possible. In general, runoff within the Meadow Creek watershed is influenced more by urbanization than flows in mainstem Arroyo Grande Creek. Flood waters in Meadow Creek are made up of stormwater runoff from the cities of Pismo Beach, Grover Beach, and Oceano. Prior to development, these areas were underlain by soils with a high infiltration rate. However, with urbanization and the introduction of more impervious surfaces, the volume of storm runoff increased and drainage time to Meadow Creek Lagoon decreased, both processes that would lead to higher peak flow rates.

The densely vegetated and relatively broad, back-dune depression areas within and extending north of Meadow Creek Lagoon provide considerable flood storage, which attenuates stormwater hydrographs into Meadow Creek Lagoon. There is also a flood control outlet to the Pacific Ocean via Carpenter Creek Channel located immediately north of the Pismo Beach Golf Course and approximately 1 mile north of Meadow Creek Lagoon. It is not known at what flow magnitude the Carpenter Creek outlet is activated, but there are anecdotal accounts that a portion of floodwaters were diverted during the 2010 flood event, and two perched culverts were removed from the upstream portion of Carpenter Creek in 2016 (County of SLO 2016).

Regardless, the primary driver of water levels in lower Meadow Creek Lagoon is water levels in Arroyo Grande Lagoon and precipitation in Meadow Creek watershed (ESA PWA 2013). This stems from the presence of the flap gate-equipped culverts, which restrict drainage from Meadow Creek Lagoon to Arroyo Grande Creek when water levels in Arroyo Grande Lagoon are higher than those in Meadow Creek Lagoon. The mean water levels in Arroyo Grande and Meadow Creek lagoons in the wet season are reported in Table 3. Between April and June and November and March, there appears to be some connection between the two lagoons via shallow flows through the Sand Canyon Structure. However, due to the presence of flap gates, whether the connection exists through the Sand Canyon Structure depends on relative water surface levels between the lagoons and cannot be determined from the seasonal averaged water surface levels.

7.3 Hydraulic and Sediment Transport Analyses

To evaluate existing hydraulic and sediment transport conditions and restoration feasibility within the project and adjacent impact area, cbec eco engineering (cbec) developed a numerical hydraulic (HD) and sediment transport (ST) model pair encompassing Meadow and Arroyo Grande Creek channels and lagoons. Both models were developed using the U.S. Army Corps of Engineers (USACE) HEC-RAS one- and two-dimensional unsteady model code. Utilizing existing data, HD and ST models were developed to characterize existing baseline hydraulic and geomorphic conditions for a suite of peak flow events and lagoon water levels controlled by varying lagoon inlet geometries. Using the models, cbec identified and characterized the primary site features (e.g., grade controls, surface topography/bathymetry, Sand Canyon Outlet Structure, levees, and freshwater flow rates) controlling current inundation area/depth/duration, sediment delivery, and channel stability in the model domain. The existing conditions models will be modified to evaluate associated hydraulic, geomorphic, and wetland habitat conditions within Meadow Creek and Arroyo Grande lagoons within the project and adjacent impact area under selected alternatives. The HD and ST model will also be used to evaluate flood impacts/benefits associated with each of the restoration alternatives. A complete description of HD and ST model development and simulation results is provided in cbec's modeling report (Appendix C). The following sections present findings for existing condition simulations that will aid in alternative development and analysis.

7.3.1 Hydraulic Model Analysis

A suite of baseline existing condition simulations was completed for a range of flood flow events (upstream boundary conditions) under varying inlet and tidal (downstream) boundary conditions. Creek inflow boundary conditions simulated using the HD model included floods having 2-, 5-, 10-, 20-, and 100-year recurrence intervals. In addition, the multi-day historic storm that occurred between 18 January and 25 January 2007 was also simulated. These six storm events are hereafter referred to as the design flows. Three varying combinations of Arroyo Grande Lagoon inlet geometry and tidal conditions were analyzed using the design flows, including: 1) maximum inlet opening and high tide (IO/HT); 2) maximum inlet opening and low tide (IO/LT); and 3) inlet closed and high tide (IC/HT) (see Table 4). Ocean tide levels were held static through each design flow simulation. The high tide simulations used the mean higher high water (MHHW) tidal datum from the National Oceanic and Atmospheric Administration's (NOAA's) Port San Luis tide station of 5.35 ft NAVD 88. Although the mean lower low water (MLLW) tidal datum is equal to -0.08 ft NAVD 88, the low tide simulations used a value of 1.5 ft NAVD 88, which is the minimum elevation of the model terrain. To maintain model stability, tidal elevations could not be lower than the minimum model geometry elevation.

Table 4. Model downstream boundary conditions at Arroyo Grande Lagoon inlet.

Downstream Boundary Condition	Inlet Condition	Inlet Invert Elevation (ft NAVD 88)	Tide Level (ft NAVD 88)
IO/HT	open	5.3	5.25
IO/LT	open	5.3	-0.08*
IC/HT	closed	11.0	5.25

* The lowest points on the tidal timeseries were truncated at a base-stage of 1.5 ft NAVD 88 to account for this and improve model stability.

Simulated water levels in Meadow Creek Lagoon, Arroyo Grande Lagoon, and Arroyo Grande Creek at 22nd Street were evaluated for each HD model simulation. In addition, the maximum inundation area within the model domain was plotted for each simulation. These data will serve as the baseline for comparison to HD model simulations of proposed project alternatives. Additional simulated water level/depth data can be extracted from any location (grid) in the model domain as needed for analysis. All simulated water level elevations are in feet and referenced to the NAVD 88 vertical datum.

In general, the simulation results are as expected. For example, stage heights in Meadow Creek Lagoon, Arroyo Grande Lagoon, and Arroyo Grande Creek at 22nd Street increase as flood magnitude increases. However, there are differences in the lagoon water levels depending on inlet boundary conditions. During the 2-year flood in both the IO/HT and IO/LT simulations, the water levels in Arroyo Grande Lagoon rise from 8.0 ft prior to the storm to 10.0 ft during the peak flood flow, while the stage in Meadow Creek Lagoon remains constant at about 7.0 ft.

During the 2-year flood, there are relatively small amounts of inflow to Meadow Creek Lagoon—baseflow is 3 cfs and the peak is approximately 40 cfs for approximately two hours. There is a sill in the middle of the Meadow Creek Lagoon that must be overtopped before water levels begin to increase in the lower (southern) half of the lagoon. Review of the 2-year flood inundation map suggests that water in the upper (northern) half of Meadow Creek Lagoon does not overtop the sill during the 2-year flow.

When the inlet is closed, the stage in Arroyo Grande Lagoon is much higher, starting at 11.0 ft prior to the storm and rising to about 12.0 ft during the flood flow peak. The stage in Meadow Creek Lagoon remains steady at 7.0 ft. These results indicate that there is no change in Meadow Creek Lagoon water level during the 2-year flood. Apart from the 100-yr flood (i.e., 2- through 20-year event), the simulated water levels in Arroyo Grande Lagoon are always higher than Meadow Creek Lagoon, indicating that the tide gates on the culverts are closed and there is no exchange between Arroyo Grande Lagoon and Meadow Creek Lagoon during passage of the flood. During the 100-year event, the water levels in Meadow Creek Lagoon reach the same elevation and appear to equilibrate with those in Arroyo Grande Lagoon during the flood peak. As the flood flow recedes, the water levels drain faster out of Arroyo Grande Lagoon than Meadow Creek Lagoon, resulting in higher post-peak water levels in Meadow Creek Lagoon than Arroyo Grande Lagoon. Under this condition, Meadow Creek Lagoon may drain through the culverts to Arroyo Grande Lagoon.

During the 5-year event, there is a similar rise in Meadow Creek Lagoon stage from 7.0 ft prior to the storm and peaks at to 9.0 ft under all three inlet boundary conditions. This rise is attributed to stormwater inflow from the upper Meadow Creek Lagoon watershed. When the inlet is open, water levels in Arroyo Grande Lagoon are at 9.0 ft prior to the storm and rise to an elevation of approximately 13.0 ft regardless of tide level. When the inlet is closed, the stage in Arroyo Grande Lagoon starts at just over 11.0 ft due to the backwater effects of a closed inlet and rises to 14.0 ft during the peak flow. These patterns are similar during the 10-, 20-, and 100-year floods, with maximum water levels of about 15.0 to 17.0 ft in Arroyo Grande Lagoon, while the stage in Meadow Creek Lagoon rises to approximately 10.0 ft, 11.0 ft, and 16.5 ft, respectively.

The maximum inundation areas during peak flow events also seem reasonable in comparison to prior modeling completed by Waterways (2010) and ESA PWA (2013) for the District as well as anecdotal accounts. The relative changes in lagoon inundation area also respond as expected relative to inlet boundary conditions. Results indicate that the inundation area of Meadow Creek Lagoon for any given design flow simulation does not change under varying inlet boundary conditions. This makes sense, as water level results indicate Meadow Creek Lagoon is controlled solely by stormwater inflow from the upper watershed and the lagoon does not receive inflow from Arroyo Grande Creek or Arroyo Grande Lagoon (i.e., the flap gates are closed). Similarly, the design storm inundation areas on Arroyo Grande Creek do not change upstream of the lagoon for any given design flow simulation. Only the inundation area of Arroyo Grande Lagoon changes in response to the different inlet boundary conditions, with the maximum inundation and depth for any given design flow occurring when the inlet is closed. When the inlet is open, the lagoon inundation area does not appear to change regardless of tide level.

7.3.2 Hydraulic Model Limitations

Based on HD modeling of existing conditions, the following potential modifications to modeling may be considered. First, the current approach to estimating inflow to Meadow Creek Lagoon is by scaling the Arroyo Grande Creek hydrographs by drainage area. Better estimates of Meadow Creek Lagoon hydrology may improve accuracy of simulated changes. Regardless, model simulation results of project alternatives will be used to quantify water level and inundation area changes in Meadow Creek Lagoon relative to the existing/baseline conditions. Secondly, the actual channel inlet is very dynamic and likely experiences significant changes in geometry during a single storm event. This phenomenon cannot be modeled with the existing simulation tools and approach; however, maintaining consistent inlet boundary conditions between baseline and alternative model scenarios provides a reasonable approach for comparison.

7.3.3 Sediment Transport Analysis

The ST model developed for the project uses the HD model output along with sediment yield and grain size estimates to predict changes in bed surface elevation, sediment load capacity, concentration, and transport rate for a grain-size range of interest. The ST model domain covers lower Arroyo Grande Creek from the east end of the South San Luis Obispo County Sanitation District facility to the Pacific Ocean. MCL is not included in the ST model domain for a few reasons. The location of the lower lagoon is at the terminus of a low gradient complex of heavily vegetated wetlands and intervening ponds. In this type of system all but the finest grained sediment is captured upstream as there is not enough concentrated flow energy to transport sediment through or erode sediment from the system. Field observations of lower MCL also indicate a lack of significant sediment deposition or erosion. Regardless, the lack of creek flow and sediment transport monitoring data on MCL in the vicinity of the project preclude model development.

The Arroyo Grande Creek ST model was developed with existing available sediment yield and grain-size distribution data (SHG 2006). Based on grain-size distribution data collected by SHG (2006), the creek substrate through the modeled reach is dominated by pebble-sized material (0.16–1.26 in) (4–32 millimeters [mm]). There is not sufficient monitoring data for ST model calibration, so the model will only provide a relative comparison of project alternative conditions to baseline (existing conditions) simulation results. Regardless, this tool and approach will be useful in the evaluation of potential bed stability (scour) and channel/lagoon aggradation conditions under potential future conditions.

Simulation results of bed elevation changes for existing conditions design flows under varying inlet boundary conditions reveal where potential scour and deposition will occur over the high flow event. Bed elevation changes for the 2-year design flows indicate changes ranging from 0.0 to 0.12 ft in the Arroyo Grande Creek channel adjacent to Meadow Creek Lagoon and through Arroyo Grande Lagoon. Most scour occurs in major bends in the channel entering and exiting the lagoon, while deposition occurs sporadically within the center of the channel and at the lagoon outfall into the ocean. Withing Arroyo Grande Lagoon, model results indicate a larger degree of erosion than deposition during the 2-year storm under all three inlet and tidal (downstream) boundary condition scenarios. When the inlet is open, there is a net loss of between 174 and 1800 cubic yards (CY) of sediment from the lagoon. The net loss increases to approximately 3800 CY when the inlet is closed. The latter increase in erosion is attributable to scour and opening of the inlet through the barrier beach.

For the 10-year design flow, modeling results suggest much greater erosion within the Arroyo Grande Lagoon channel and at the lagoon mouth, with minor amounts of creek bed level change under the IO/HT and IO/LT conditions. During the 10-year design flows for all lagoon boundary condition scenarios, a second inlet forms approximately 1000 feet north of the original when the sandbar is overtopped and breached during the peak flow period. Erosion of the channel bed and through the secondary outlet can be as much as 3.5 ft, with deposition occurring mostly in the tidal zone or in minor amounts along the lagoon banks. When the inlet is closed (IC/HT), there is less erosion within the main north-south aligned channel through the lagoon, likely due to higher water levels and backwater conditions within Arroyo Grande Lagoon. However, scour and inlet deepening through the barrier beach is greater when starting with an inlet closed boundary condition. Model simulation results result in a net loss of between approximately 11- and 25 thousand cubic yards of sediment from the lagoon and barrier beach, with the greatest losses occurring under the inlet closed scenario.

Simulation results of the 100-year design flows indicate increased extent and magnitude of bed level change, extending upstream of Arroyo Grande Lagoon into the leveed reach of Arroyo Grande Creek adjacent to Meadow Creek Lagoon. Similar to the 10-year design flow, simulation results indicate the development of a second inlet north of the primary southern inlet. As would be expected, the depth of erosion and height of aggradation is greater than the 10-year design flow, with maximum bed level changes of +/- 4.2 ft. Again, channel erosion within Arroyo Grande Lagoon is less in the lagoon under IC/HT conditions versus IO/HT and IO/LT. Similar to the 2- and 10-year design flow simulation results, there is a net loss of material from the lagoon under the 100-year design flow simulations, with 30- to 40-thousand cubic yards being transported into the Ocean.

7.3.4 Proposed Sea-Level Rise Analysis Approach

No sea-level rise scenarios were integrated into the hydraulic model simulations of existing conditions. However, as part of project alternatives analysis, cbec intends to evaluate changes in water levels and inundation area under sea-level rise conditions using the hydraulic models. This section presents the proposed sea-level rise levels that will be simulated and compared to existing conditions model simulation results as part of the upcoming alternatives hydraulic analysis. No wave runup or storm surge will be included in this analysis as the hydraulic model does not have the capability to capture these processes.

Pursuant to NMFS policy (NMFS 2016) as cited in the Arroyo Grande Creek Waterway Management Program Biological Opinion (BO), the sea-level rise analysis should evaluate impacts based on a high emissions scenario for the timeframes 2070 - 2100. The BO and its citations predate the current guidance, the 2018 California Ocean Protection Council (OPC) guidance. The current OPC guidance provides estimates of sea-level rise for low and high emissions scenarios for a range of probabilities of occurrence (50%, 66%, 5%, 0.5%, and extreme scenario). This introduces more choices for project planning purposes. The OPC method recommends considering sea-level-rise related *impacts*, *adaptive capacity*, and *risk tolerance* in determining an appropriate sea-level rise projection, including, for example, the following considerations:

- Consequences of potential impacts,
- What is at stake,
- Adaptive capacity, and
- Economic impacts.

OPC Recommended Policies include:

- Prioritize social equity, environmental justice, and needs of vulnerable communities: involves consideration of, for example, contamination risks, public access, protecting local jobs and housing, economic impacts on agriculture, emergency services and response, social and economic implications.
- Prioritize protection of coastal habitats and public access: including natural solutions for shoreline protection/managed retreat, preserving public access and protecting natural resources.
- Consider the unique characteristics, constraints, and values of existing water-dependent infrastructure, ports, and public trust uses.
- Consider episodic increases in sea-level rise caused by storms and other extreme events.
- Coordinate with federal, state and local planning and projections.
- Consider local conditions to protect communities and the environment.
- Include adaptive capacity in design and planning.
- Assessment of risk and adaptation planning should be conducted at community and regional levels when possible.

The OPC high-emissions-scenario sea-level rise projections for project lifespans from 2070 – 2100 are provided in Table 5 (CA OPC 2018).

Consideration of this information suggests:

- Use of the high emissions scenario, consistent with NMFS guidance, is reasonable.
- Use of the 2070–2100 timeframe, consistent with NMFS guidance, is reasonable.
- The extreme risk aversion scenarios are highly uncertain and at the upper end of the range (8 to 10 feet of sea-level rise) there would be substantial inundation of the project area and vicinity, such that modeling efforts for these scenarios are considered less valuable.
- The Likely Range (66%) probability, 3 feet, captures a reasonably likely, high emissions scenario through 2100.
- There is not expected to be much value in modeling lower sea-level rise scenarios.
- There may be value in modeling a higher sea-level rise scenario, on the order of 5.3 to 6.7 feet, from the Medium-High Risk Aversion scenarios. These values have a low probability of occurrence and would likely occur with other equally uncertain changes, but modeling could be useful from the perspective of adaptive management strategies.

Available geospatial and visualization tools using the best available sea level rise projections are provided in the inundation plots in Attachment 1 to Appendix C.

Table 5. Projected sea-level rise (in feet) for Port San Luis (high emissions scenario).

Year	Low Risk Aversion (66% probability)	Medium–High Risk Aversion (0.5% probability)	Extreme Risk Aversion
2070	1.7	3.3	5.0
2080	2.1	4.3	6.4
2090	2.6	5.3	8.0
2100	3.1	6.7	9.9

8 WETLANDS AND WATERS OF THE U.S.

The study area contains Waters of the U.S., including wetlands (subject to Clean Water Act USACE jurisdiction under Section 404 and Regional Water Quality Control Board jurisdiction under Section 401), Waters of the State (subject to Regional Water Quality Control Board jurisdiction under California's Porter-Cologne Water Quality Control Act), and riparian areas (subject to California Department of Fish and Wildlife [CDFW] jurisdiction). Both the project area and adjacent impact area are entirely within the coastal zone original jurisdiction and are subject to California Coastal Commission jurisdiction. Meadow Creek historically flowed into Arroyo Grande Creek, but the two creeks are currently divided by a levee, connected by the Sand Canyon Outlet (Figure 2). Arroyo Grande Creek is listed as navigable to 2.5 ft MSL on the Los Angeles District of the USACE's list of traditionally navigable waters, but Meadow Creek is not included (USACE 2021).

Information on potential waters and wetlands features of the study area was obtained from the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) *Wetlands Mapper* (USFWS 2021a) online application, as well as previous wetland delineation efforts in the vicinity (SWCA 2009, Terra Verde 2012a). The NWI *Wetlands Mapper* shows multiple wetland types within the study area, including both estuarine areas (i.e., areas with at least occasional access to open ocean with areas of inundated marsh and tidal habitat, including estuarine and marine wetlands and estuarine and marine deepwater) and riverine areas (i.e., including freshwater forested/shrub wetlands, freshwater body, and riverine wetlands) (Figure 5). However, the NWI mapping does not depict connectivity between the estuary and the open ocean, which does occur.

In addition to the NWI data, results from previous wetland delineation field efforts conducted in the study area were reviewed (Terra Verde 2012a, SWCA 2009) and are shown in Figure 6. The area of waters of the US and wetlands contiguous with the project and adjacent impact area up to Air Park Avenue were calculated and contain at least 13.16 acres of waters of the U.S., including wetlands, and an additional 8.68 acres of various wetland types (i.e., state, CDFW, and Coastal Zone) (Table 6). As seen in Figure 6, a portion of the adjacent impact area (1.69 acres) has not been delineated but observed to contain a mix of open water, emergent, and willow wetlands. No major hydrological changes as a result of increased stormwater flow, diversions of water from the channel, or major land use changes surrounding the wetlands are known to have occurred since the 2012 wetland delineation; therefore, that delineation is expected to provide reasonable information for assessing and comparing impacts of various alternatives. The need to revisit the jurisdictional delineation will be considered as the range of potential project alternatives is defined. A current/up-dated determination will likely be required for CEQA and will be required for permit applications.

Figure 5. National Wetlands Inventory map of the study area.

Figure 6. Available wetlands and waters data within the study area.

Table 6. Potential jurisdictional waters contiguous with the project and adjacent impact area up to Air Park Avenue (Terra Verde 2012a) and the associated NWI type.

Feature	Acres
Waters of the U.S. and State, including Wetlands[2,3]	
Not mapped by NWI	0.26
Estuarine and Marine Wetlands	0.55
Estuarine and Marine Deepwater	0.14
Freshwater Forested/Shrub Wetland	1.89
Freshwater Emergent Wetland	6.65
Freshwater Pond	3.68
Total Waters of the U.S. and State, including wetlands[2,3]	**13.16**
Additional Wetlands (State, CDFW, and Coastal Zone)[4]	**8.68**
Unmapped Area (may include additional waters and wetlands)	1.69
Non-jurisdictional Uplands	2.47
Total Project Area and Adjacent Areas	**26.00**

[1] Reported acreage includes the project area and hydrologically contiguous areas up to Air Park Drive. Wetlands mapped north of Air Park Drive and east of Oceano County Airport are shown on Figure 6 but not included in the acreage calculations in this Table.
[2] Subject to jurisdiction under Section 404 of the CWA, Section 401 of the CWA, Porter-Cologne Water Quality Control Act, CDFW, and California Coastal Commission.
[3] Includes both the "Waters of the U.S. and State – Wetlands" and "Waters of the U.S. and State – Other Waters" presented in Figure 6.
[4] Subject to jurisdiction under the Porter-Cologne Water Quality Control Act, CDFW, and California Coastal Commission.

9 BIOLOGICAL RESOURCES

This section presents the results of biotic assessments and synthesis for the project and adjacent impact area, as well as key conditions within a larger study area that may have significant influence on the project or adjacent impact area. Specifically, Section 9 includes a summary of fish and wildlife found within and near the project area (Section 9.1); an in-depth look at two key fish species: steelhead (Section 9.2) and tidewater goby (9.3); an assessment of aquatic habitat conditions within and near the project area as they pertain to steelhead and tide water goby (Section 9.4); known water quality conditions within and near the project area (Section 9.5); an in-depth look at two additional special status species, California red-legged frog (Section 9.6.) and plovers (Section 9.7), and a summary of special-status flora (Section 9.8).

9.1 Fish and Wildlife

As a first step, database queries were conducted to evaluate the potential for special-status fish and wildlife species to occur within and near the project and adjacent impact area to inform project designs. The following resources were queried:

- USFWS's Information for Planning and Conservation (IPaC) portal for federally listed and proposed endangered, threatened, and candidate species (USFWS 2021b);

- CDFW's California Natural Diversity Database (CNDDB) (CDFW 2021a); and
- NMFS's West Coast Region, California Species List Tool (NMFS 2018).

The USFWS, CNDDB, and NMFS database queries were each based on a search of the U.S. Geological Survey (USGS) 7.5-minute quadrangles that surround the project area (Arroyo Grande NE, Guadalupe, Nipomo, Oceano, Pismo Beach, Point Sal, Santa Maria, and Tar Springs Ridge), per standard practice.

Special-status fish and wildlife species included in the database queries included any species that are legally protected under either the federal Endangered Species Act (FESA), the California Endangered Species Act (CESA), or under other regulations or policies, such as the California Fish and Game Code. Special-status species include the following:

- listed, proposed, or under review as endangered or threatened under the FESA or the CESA;
- designated by 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); and/or
- protected under the federal Bald and Golden Eagle Protection Act.

Based on the above databases and queries, 48 special-status fish and wildlife species were identified as having the potential to occur within the Project Region (Table D-3 in Appendix D). Of these, 13 species were determined to have moderate to high potential to occur within the project or adjacent impact area (Table 7). The remaining 35 species are not expected to occur in the project or adjacent impact area because either there is little to no suitable habitat and/or the project and adjacent impact area are outside of the species' known range (Table D-3). General habitat associations and likelihood of occurrence within the project or adjacent impact area are provided for all 48 species in Table D-3 in Appendix D.

Due to the project objectives, the key fish and wildlife species evaluated in this report are South-Central California Coast steelhead, tidewater goby, California red-legged frog, and western snowy plover (*Charadrius nivosus nivosus*) based on their high likelihood of occurrence within the project or adjacent impact area and their federal listing status. These species are discussed in the following sections.

Table 7. Special-status fish and wildlife species with moderate to high potential to occur within the project or adjacent impact area.

Scientific Name	Common Name	Status[1] Federal/State
Danaus plexippus	Monarch, California overwintering population	FC/–
Oncorhynchus mykiss	Steelhead, South-Central California Coast DPS	FT/–
Eucyclogobius newberryi	Tidewater goby	FE/–
Rana draytonii	California red-legged frog	FT/SSC
Actinemys marmorata	Western pond turtle	–/SSC
Phrynosoma blainvillii	Coast horned lizard	–/SSC
Anniella pulchra	Northern California legless lizard	–/SSC
Thamnophis hammondii	Two-striped garter snake	–/SSC
Elanus leucurus	White-tailed kite	–/SFP
Laterallus jamaicenis coturniculus	California black rail	–/ST, SFP
Charadrius nivosus	Western snowy plover	FT/SSC
Sternula antillarum browni	California least tern	FE/SE, SFP
Agelaius tricolor	Tricolored blackbird	–/ST, SSC

[1] Status codes: FE = federally listed as endangered under the Endangered Species Act, FT = federally listed as threatened under the Endangered Species Act, FC = candidate species for federal listing under the Endangered Species Act, SE = Listed as Endangered under the California Endangered Species Act, ST = Listed as Threatened under the California Endangered Species Act, SSC = State Species of Special Concern, SFP = State Fully Protected species. A dash indicates no listing status.

9.2 South Central California Coast Steelhead

9.2.1 Status

Steelhead in the project and adjacent impact area belong to the South-Central California Coast (SCCC) Distinct Population Segment (DPS), which encompasses all naturally spawned steelhead that occur in waterways located between the Pajaro and Santa Maria Rivers (NMFS 1997, 2006). This DPS is listed as threatened under the FESA (NMFS 1997, 2006). NMFS (2021) designated critical habitat within 40 SCCC DPS watersheds throughout central California, including Arroyo Grande Creek (excluding Meadow Creek Lagoon watershed).

9.2.2 Life history

Adult steelhead

Oncorhynchus mykiss can exhibit different life history strategies, including anadromous (steelhead), where juveniles rear in freshwater for two to three years, smolts migrate to the ocean where they mature to adults, and adults (usually at ages four to five) return to freshwater rivers and creeks to spawn. They can also exhibit a resident life history (rainbow trout), where rearing, maturing, and spawning all occur within freshwater. In cases where life history is uncertain, the term *O. mykiss* is used. Based on variability in the timing of their life histories, steelhead are broadly categorized into winter and summer reproductive ecotypes. Only the winter ecotype (winter-run) occurs in the Arroyo Grande and Meadow Creek watersheds. Winter-run steelhead generally enter natal spawning streams from December through March as sexually mature adults and spawn in late winter or spring (Meehan and Bjornn 1991, Behnke 1992). Spawning occurs primarily from January through April (Hallock et al. 1961, Moyle 2002).

Female steelhead construct redds in suitable gravels (0.39–1.18 in) (1–13 centimeters [cm]) diameter [Moyle 2002]), often in pool tailouts and heads of riffles, or in isolated patches in cobble-bedded streams. Steelhead eggs incubate in the redds for 3–14 weeks, depending on water temperatures (Shapovalov and Taft 1954, Barnhart 1991). After hatching, alevins remain in the gravel for an additional two–five weeks while absorbing their yolk sacs, and then emerge in spring or early summer as fry (Barnhart 1991).

After emergence, steelhead fry utilize shallow, low-velocity habitats, typically found along stream margins and in low-gradient riffles (Hartman 1965, Fontaine 1988). As fry grow and improve their swimming abilities in late summer and fall, they increasingly show a preference for higher water velocity and deeper mid-channel areas near the thalweg (the deepest part of the channel) in locations with cover (Hartman 1965, Everest and Chapman 1972, Fontaine 1988). Locations with high water velocity and cover likely provide juvenile steelhead resting locations while they watch for drifting invertebrates being carried by flow. Aquatic invertebrates comprise a key item in the diet of juvenile steelhead.

Steelhead can smolt at a variety of ages[1], but most frequently smolt at age 2+. The duration of time juveniles spend in freshwater appears to be related to growth rate, with larger, faster-growing members of a cohort smolting earlier (Peven et al. 1994). Steelhead in areas with warm water temperatures, where feeding and growth are possible throughout the winter, may require a shorter period in freshwater before smolting, while steelhead in colder, more northern, and inland streams may require three or four years before smolting (Roelofs 1983). Juvenile steelhead rearing in estuaries have been shown to have increased growth rates and grow to be larger than

[1] In this discussion, we follow conventional methods for assigning fish ages to year classes. Age 0+ refers to fish in their first year of life, sometimes called young-of-the-year (YOY); age 1+ to fish in their second year of life, and so on. A fish changes from age 0+ to age 1+ based on the time of hatching, which in the case of steelhead occurs in the spring.

those rearing in upper watersheds (Hayes et al. 2011). Juvenile steelhead outmigration typically occurs from March through June.

Lagoon conditions have an important influence on anadromous fish survival since steelhead must pass through these areas during upstream adult migration and downstream smolt outmigration. Lagoon rearing habitat for juvenile migrants preparing to smolt has been demonstrated to be critically important for other central California coast steelhead populations. Significantly higher growth rates and ocean survival by steelhead that reared in lagoons has been documented, even with lagoon water temperatures as high as 24°C (75°F) (Smith 1990, Hayes et al. 2008, Bond et al. 2008). Depending partly on growing conditions in their rearing habitat, steelhead may migrate downstream to estuaries as fry or juveniles or may rear in streams for up to four years before outmigrating to the estuary and ocean (Shapovalov and Taft 1954). Steelhead migrating downstream as juveniles may rear for one month to a year in the estuary before entering the ocean (Hayes et al. 2008).

In other West Coast estuaries, restored tidal marsh and complex lateral subtidal habitats have been rapidly colonized by juvenile salmonids, demonstrating the reemergence of life history strategies previously thought to have been extirpated (Bottom et al. 2011). Thus restoring habitat connectivity and dynamics may provide juvenile steelhead opportunities to exploit these habitats regardless of present use.

9.2.3 Habitat requirements

Habitat suitability for steelhead in Arroyo Grande and Meadow Creek lagoons is based on literature review of habitat criteria. Juvenile steelhead have been documented within the Arroyo Grande Lagoon and lower Arroyo Grande Creek throughout the year (Rischbieter 2020).

No good data are available on minimum water depths used by steelhead in estuaries, but a minimum depth of 1.6 ft is generally considered suitable for avoiding avian predation—no maximum water depth is believed to apply to this habitat (Daniels et al. 2010). For this assessment, water depths greater than 1.6 ft are considered suitable for rearing juvenile steelhead, while pools with riparian shade and depths between 4–7 ft provide important deep-water refugia for juveniles due to potential thermal stratification anticipated to provide suitable water temperatures.

There have been numerous studies evaluating the relationship between water temperature and growth in steelhead; results regarding optimal and unsuitable temperatures vary depending on the location or population of fish studied. Myrick and Cech (2000) report a maximum water temperature for rearing as 26°C (78.8°F), observing that growth slowed as temperature increased from 19°C (66.2°F) to 25°C (77.0°F), with the greatest reduction at 25°C (77°F). Elevated temperatures, however, in conjunction with high food availability likely contribute to the productivity of lagoons and their value as salmonid rearing habitat (Atkinson 2010). In the Scott Creek estuary along the central California coast, the highest steelhead growth rates were observed at temperatures between 15–24°C (59–75.2°F) (Hayes et al. 2008). Based on these observations, as well as those in Daniels et al. (2010), we define daily average temperatures of less than 26°C (78.8°F) as suitable, as measured at the bottom of the water column.

Although steelhead can withstand high salinity for brief periods, salinities less than 10 parts per thousand (ppt) are generally considered suitable for steelhead rearing in estuaries (Daniels et al. 2010). Therefore, salinity values less than 10 ppt are defined as suitable for this assessment.

No water velocity criterion has been developed for steelhead rearing in estuaries; however, for this study we assumed that velocities less than 1.0 foot per second (ft/s) to be suitable based on research on steelhead rearing in riverine environments.

In lagoon habitats similar to Arroyo Grande and Meadow Creek lagoons, DO concentrations greater than 5 mg/L are considered suitable for rearing steelhead (ISU 2008, as cited in Daniels et al. 2010). Dissolved oxygen concentrations near saturation (9.0 mg/L) are generally required for growth, but they can survive at DO concentrations as low as 1.5–2.0 mg/L at low temperatures (Moyle 2002).

In Arroyo Grande and Meadow Creek lagoons, the following target habitat criteria are proposed for steelhead:

- Water depths >1.6 ft to 4.0 ft;
- Water depths from 4.0 ft to 7.0 ft are considered important deep-water and thermal refugia;
- Daily average temperatures <26°C (78.8°F), as measured at the bottom of the water column; and
- Water velocity <1.0 ft/s.

In addition, habitat suitability will be considered higher if cover is present, particularly in the form of submerged and emergent aquatic vegetation.

9.2.4 Factors affecting abundance

Critical environmental factors affecting adult upstream migration include fish passage past lagoon sandbars, sufficient stream flows to support passage, and access to suitable spawning habitat.

Critical environmental factors affecting spawning and incubation include suitable spawning gravel, which is often limited by fine sediment deposition.

Critical environmental factors affecting rearing steelhead may vary depending on the season. During periods of low flows and high air temperatures that can occur from the late spring through early fall, *water availability, water temperature, and food availability are critical environmental factors* for rearing juvenile steelhead. Nearly all elements of juvenile steelhead summer and fall rearing habitat are strongly influenced by stream flows, which affect rearing habitat area, the depth and volume of pools, connectivity between habitat types (especially between the lagoon and stream habitat), water velocity, and water temperatures.

During periods of high flows and low water temperatures that occur in winter months*, critical environmental factors include low-velocity pool habitats with large rocky substrate or woody debris*, which steelhead use for cover (Hartman 1965, Raleigh et al. 1984, Swales et al. 1986, Fontaine 1988).

Critical environmental factors affecting steelhead rearing in lagoon habitat *include deep-water and thermal refugia habitat and connectivity to upstream habitat* as water quality conditions in the lagoon deteriorate in the late fall (Hayes et al. 2011). Upstream of the project area (e.g. near Pier Avenue), largemouth bass (*Micropterus salmoides*), which prey on juvenile steelhead, have been observed (Terra Verde 2012b).

9.2.5 Occurrence within or near the project area

Steelhead are present near the project area and within the adjacent impact area. Annual surveys conducted by California State Parks have documented steelhead throughout Arroyo Grande Lagoon and lower Arroyo Grande Creek (Rischbieter 2006, 2011, 2021; Table 1 in Appendix E). The most commonly observed life stage in Arroyo Grande Lagoon has been juvenile steelhead, followed by YOY and smolts. In general, juvenile steelhead appear to be utilizing Arroyo Grande Lagoon as rearing habitat, with some smolts likely using the lagoon for rearing prior to migrating to the ocean. Water quality conditions (i.e., dissolved oxygen and temperature) appear to dictate the suitability of habitat for steelhead. The greatest steelhead abundance within the lagoon has been observed to occur in the spring, with a steady decline throughout the summer months as water quality conditions can become less optimal for rearing. Ten dead adult (>20 in) and several juvenile steelhead were observed in Arroyo Grande Lagoon in the summer of 2008 resulting from the dry-back of Arroyo Grande Lagoon and poor water quality conditions (Rischbieter 2008). Similarly dry conditions in 2009 resulted in poor water quality conditions and the dry-back of Arroyo Grande Lagoon, presumably resulting in the mortality of several juvenile steelhead observed rearing in the lagoon (Rischbieter 2009).

Although Sand Canyon flap gates presumably provide access to steelhead when open; no steelhead have been observed in Meadow Creek Lagoon (Terra Verde 2012b, Rischbieter 2014, 2016, 2017).

9.3 Tidewater Goby

9.3.1 Status

Tidewater goby are federally listed as endangered under the FESA (59 FR 5494 5499) and designated as a species of special concern by the State of California. Critical habitat was designated for tidewater goby in some nearby lagoons, including Pismo Creek; however, no critical habitat is designated for the Meadow Creek or Arroyo Grande lagoons (78 FR 8745).

Tidewater goby are an estuarine/lagoon adapted species that are endemic to the California coast, mainly in small lagoons and near stream mouths in the uppermost brackish portion of larger bays (Moyle 2002, USFWS 2005). Tidewater goby historically occurred in at least 134 localities along the California coast, in coastal lagoons, marshes, and estuaries from Tillas Slough in the Smith River of Del Norte County to Agua Hedionda Lagoon in San Diego County (Moyle 2002, USFWS 2005). Tidewater goby still occur within this range, but over half of the population at these localities are extirpated or extremely small with uncertain long-term persistence (USFWS 2005). Populations in very small estuaries (<5 acres) are at risk of extirpation, while populations in intermediate-sized estuaries (5–125 acres) tend to be the most stable (USFWS 2005). With some exceptions (e.g., Lake Tolowa/Lake Earl, 4800 acres), stable tidewater goby populations are not common in very large estuaries (USWFS 2005).

9.3.2 Life history

Tidewater gobies are short-lived (generally one year) and highly fecund fish (females produce 300–500 eggs per batch and spawn multiple times per year) that disperse infrequently via marine habitat but have no dependency on marine habitat for their life cycle (Swift et al. 1989, Lafferty et al. 1999). Tidewater gobies inhabit discrete lagoons, estuaries, or stream mouths separated by mostly marine conditions, and are generally absent from areas where the coastline is steep and streams do not form lagoons or estuaries (USFWS 2005). Tidewater gobies feed mainly on small animals, usually mysid shrimp (*Mysidopsis bahia*), gamarid amphipods (*Gammarus roeseli*), and

Adult tidewater goby

aquatic insects, particularly chironomid midge (Diptera: *Chironomidae*) larvae (Swift et al. 1989, Swenson 1997, Moyle 2002). Swenson and McCray (1996) found that juvenile tidewater gobies are generally day feeders, although adults mainly feed at night (USFWS 2005). Tidewater gobies use three different foraging styles to capture benthic prey: plucking prey from the substrate surface, sifting sediment in their mouth, and mid-water capture (USFWS 2005).

Reproduction begins in spring, usually late April or May, and continues into the fall, although usually the greatest numbers of fish are produced in the first half of this time period. The reproduction period is generally associated with the closure and filling of the estuary (late spring to fall). Breeding occurs in slack shallow waters of seasonally disconnected or tidally muted lagoons, estuaries, and sloughs. Males dig burrows vertically into sand, 4 to 8 in deep and defend the burrows until hatching (SCR Project Steering Committee 1996). The eggs take approximately 6 to 10 days to hatch at about 15 to 25°C (59–77°F), with tidewater gobies reaching a standard length of approximately 0.17 to 0.25 in (Moyle 2002). Larvae are planktonic (unable to swim freely) for up to three days before they become benthic (USFWS 2005), and the larvae apparently spend a day to a few weeks in open water until they reach approximately 0.6 to 0.7 in in length and sink down to the lagoon floor to enter the benthic juvenile life stage until reaching sexual maturity at 0.9 to 1.1 in (Moyle 2002).

The average size of adult tidewater gobies tends to be significantly larger in marshes (1.7 to 1.8 in standard length) when compared to tidewater gobies from lagoons or creek habitats (USFWS 2005, Swenson 1997). This may be because the more stable physical conditions of the marsh foster improved growth or a more consistent or abundant supply of prey (Swift et al. 1997, USFWS 2005).

9.3.3 Habitat requirements

Habitat suitability for tidewater goby in Arroyo Grande and Meadow Creek lagoons is based on extensive literature review of habitat criteria and USFWS (2013) designation of critical habitat. The habitat parameters include a relatively broad range of values representing the range of conditions known to occur in habitats occupied by gobies. Although gobies appear to tolerate a wide range of habitat conditions, they appear to be most abundant and to persist in habitats with a narrower "preferred" range in habitat parameters during specific life stages. Suitable tidewater goby habitat used in this assessment represents this preferred range.

Tidewater goby appear to prefer shallow water (<3 ft) near emergent vegetation, possibly to avoid predation by wading birds and piscivorous fish (Moyle 2002). Reported minimum depths may be associated with foraging depth thresholds for wading birds such as herons; in general, avian predation efficiency decreases with depths >0.7 ft (Gawlik 2002). The literature indicates that juvenile and adult gobies prefer depths ranging from 0.7 to 1.0 ft, based primarily on sampling with beach seines. However, gobies have been captured in Big Lagoon at depths of up to 15.1 ft using a small-frame trawl towed by a small boat (C. Chamberlain, pers. comm., 2006). The

USFWS (2013) includes water depths from 0.3 to 6.6 ft as a primary constituent element (PCE) of tidewater goby critical habitat, and this range is adopted here as a suitable for depth range.

Tidewater goby juveniles and adults can be found year-round, although they are most abundant in summer and fall (Rischbieter 2017). The USFWS (2013) includes sand, silt, and mud substrates suitable for constructing burrows as a PCE of tidewater goby critical habitat, which we will use for this assessment.

Juvenile/adult tidewater gobies are reported to prefer water temperatures of 12.2–23.8°C (54–75°F), within a range of 5.5–25.0ºC (42–77ºF) (Stillwater Sciences 2006). The USFWS (2013) did not designate temperature as a PCE for tidewater goby critical habitat. Based on the above, we define suitable habitat as having daily average water temperatures, as measured at the bottom of the water column, of <23.8°C (<75°F).

Juvenile and adult gobies are reported to prefer salinities of ≤15 ppt within a range of 0–51 ppt, as measured at the substrate surface. The USFWS (2013) includes salinities ≤12 ppt as a PCE of critical habitat. Based on the above, we define suitable habitat as having salinities less than 15 ppt as suitable.

The USFW (2013) did not designate dissolved oxygen as a PCE for tidewater goby critical habitat. While well-oxygenated water is considered optimal habitat, some studies have shown tolerance of low DO levels and ability to survive anoxic events by breathing air. This is supported by the results of State Park's annual fish surveys in Arroyo Grande Creek, Arroyo Grande Lagoon and Meadow Creek Lagoon documenting the greatest abundance in summer and fall (Rischbieter, 2006, 2009a, 2009b, 2010, 2011, 2014, 2016, 2017, 2020, 2021), when DO can be low.

Tidewater gobies are reported to prefer low water velocities. For example, Swenson (1997) found that gobies were absent from the main channel, which had a surface velocity of 0.50 ft/s but were present at high densities in an adjacent backwater pool. Areas with low water velocity are a PCE of tidewater goby critical habitat (USFWS 2013). Without having much quantitative information, we define suitable surface water velocities less than 0.50 ft/s as suitable.

Preferred reproductive/spawning habitat is reported to be very similar to juvenile rearing and adult habitat; 15–23.8°C (59–75°F), within a range of 11.6–26.6°C (53–80°F) (Stillwater Sciences 2006). Preferred salinities for reproduction/spawning were identified as ≤15 ppt within a range of 5–25 ppt. Preferred depths for tidewater goby reproduction/spawning were identified as 0.7–1 ft. Substrate preferences for reproduction appear to be sand, coarse sand, and sand/mud.

In Arroyo Grande and Meadow Creek lagoons, habitat meeting the following criteria are proposed as suitable for tidewater goby:

- Water depths from 0.3 to 6.6 ft;
- Substrate of sand, mud, or silt;
- Daily average temperatures <23.8°C (75°F), as measured at the bottom of the water column; and
- Surface water velocity <0.50 ft/s.

In addition, habitat suitability will be considered higher if cover is present, particularly in the form of submerged and emergent aquatic vegetation such as pickleweed (*Batis maritime*), pondweed (*Potamogeton pectinatus*), widgeongrass (*Ruppia maritime*), bulrush (*Typha latifolia*), and sedges (*Scirpus* spp.) (USFWS 2013).

Generally, if conditions in the lagoon are suitable for steelhead, they should be suitable for tidewater goby too, provided a range of microhabitats are available that include low-velocity and shallow habitats preferred by tidewater goby.

9.3.4 Factors affecting abundance

Tidewater gobies are sensitive to impacts such as lack of fresh water due to diversions, pollution, siltation, and invasion of non-native species, such as the western mosquitofish (*Gambusia affinis*), a competitor, and centrarchids (*Lepomis spp.*), a predator (USFWS, Lafferty et. al 1999). Western mosquitofish are ubiquitous in Arroyo Grande and Meadow Creek lagoons, and a variety of non-native centrarchids and largemouth bass (*Micropterus salmoides*) have been observed in Meadow Creek Lagoon (Terra Verde 2012b).

9.3.5 Occurrence within or near the project area

Annual fisheries surveys have documented a continual presence of tidewater goby in Arroyo Grande Lagoon since 2005 and, occasionally, a smaller population in lower Meadow Creek Lagoon just upstream of the Sand Canyon Outlet Structure. The first known occurrence of tidewater goby in Arroyo Grande Lagoon was in 2005 (Rischbieter 2006); however, there was a presumed extirpation of tidewater goby in Arroyo Grande Creek in the summer of 2008 and 2009 resulting from dry-back and poor water quality conditions (Rischbieter 2010). Tidewater goby recovered in 2010 and have since been captured throughout the Arroyo Grande Lagoon in the "tens of thousands" (Rischbieter 2017). In Meadow Creek Lagoon, sampling efforts have been less frequent but have only occasionally resulted in the captured tidewater goby and in much lower abundance (Rischbieter, 2006, 2009a, 2009b, 2010, 2011, 2014, 2016, 2017, 2020, 2021; Tera Verde 2012; Table 1 in Appendix E).

9.4 Lagoon Aquatic Habitat Conditions

Both Arroyo Grande and Meadow Creek lagoons are remnants of an extensive back barrier (landward of coastal dunes) wetland complex that once existed between Pismo Beach and the Oceano Dunes (Section 6.1). When Meadow Creek Lagoon water levels are higher than Arroyo Grande Lagoon, the Sand Canyon Outlet Structure allows flow from Meadow Creek Lagoon into Arroyo Grande Lagoon.

Habitat conditions for steelhead and tidewater goby within and near the project area (from Air Park Ave to Arroyo Grande Lagoon Mouth) were assessed by inspecting recent aerial photography (2011–2021), reviewing available reports on aquatic habitat and species observations, and by conducting two field visits: one on 21 April 2021, and one on 21 October 2021. During the field visits, water depths were measured in select locations, presence of aquatic vegetation/fish cover was observed, and the hydrological connection between pools was determined.

In general, upper Meadow Creek Lagoon (upstream of the project area to Air Park Avenue) consists of two pools connected by an approximately 500-foot-long channel (Figure 7, Photo 1).

The depth of the upstream-most pool (#1) varies spatially and seasonally but generally provides year-round extensive shallow water (0.3–1.6 ft) habitat for tidewater goby, suitable rearing habitat (>1.6 ft) for steelhead, and seasonal winter and spring deep refugia habitat for steelhead (>4 ft). The second downstream-most pool (#2) provides abundant shallow water habitat suitable for tidewater goby and suitable seasonal winter and spring steelhead rearing habitat and appears to be dry during summer thus providing neither shallow nor deep-water refugia habitat for steelhead (Figure 7, Photo 2).

Lower Meadow Creek Lagoon (project area) is comprised of multiple small pools connected by a series of smaller channels (Figure 7). While in the winter and spring these pools may provide pockets of suitable rearing habitat for steelhead and likely for tidewater goby, pool depths in general appear to be shallow (<1.6 ft), and deep-water refugia do not occur. During the October 2021 field visit, the entirety of lower Meadow Creek Lagoon was dry (Figure 7, Photo 3). In general, Meadow Creek Lagoon has densely vegetated banks and open-water habitats in the center of the pools with extensive cover for aquatic species along channel margins and little cover in the middle of the pools.

In Arroyo Grande Lagoon, both within the project impact area and downstream of it, the extent of aquatic habitat is primarily dependent on whether the lagoon is open or closed to the ocean. Steelhead rearing habitat (>1.6 ft deep) and deep-water refugia habitat (>4 ft) can occur during periods when the lagoon is closed (photo below to left), generally occurring downstream of the project impact area. Closed-bar conditions are defined as those when the sand bar separates the lagoon from the ocean and tidal and lagoon water surface elevations are mostly decoupled, although overwash during high tides and wind wave runup does occur (see Section 6.1). During dry season closed-bar conditions, Arroyo Grande Lagoon is a primarily freshwater lagoon with areas of brackish conditions (ESA PWA 2013). In general, Arroyo Grande Lagoon, both downstream of and within the project impact area, contains primarily open-water habitat with minimal habitat complexity and has sparse vegetative cover along channel margins.

Arroyo Grande Lagoon downstream of the adjacent impact area.

When the lagoon is closed, Arroyo Grande Lagoon within the project impact area can provide both deep refugia habitat for steelhead (>4 ft) and suitable rearing habitat (>1.6 ft) for steelhead and tidewater goby. When the lagoon is open, Arroyo Grande Lagoon within the project impact area contains lotic habitat primarily characterized by shallow (<1.6 ft) run-like habitat, with some localized scour along in-channel vegetation and woody debris. A review of recent aerial photos (2011, 2013, 2018) of Arroyo Grande Lagoon in the dry season indicates that the project impact area can stay wetted in some years (e.g., 2011, 2018) and dry back to small, isolated pools in others (e.g., 2013). During the 21 October 2021 field visit, five shallow pools (max depth = 0.5 ft) were present in Arroyo Grande Lagoon within the project impact area. A photo of one of these pools is shown in Figure 7, Photo 4.

Figure 7. Meadow Creek and Arroyo Grande Lagoons near the project and adjacent impact area. Photos from 21 October 2021 field visit include (1) deep refugia habitat conditions in upper Meadow Creek Lagoon, (2) desiccated habitat conditions in the smaller pool in upper Meadow Creek Lagoon, (3) desiccated habitat conditions in lower Meadow Creek Lagoon, and (4) isolated pool habitat and dry channel conditions in Arroyo Grande Lagoon.

9.5 Water Quality

Water quality measurements in Arroyo Grande and Meadow Creek lagoons have been taken sporadically during fisheries and more targeted water quality monitoring efforts; however, data on current and long-term water quality conditions in the lagoons are unavailable. In general, water quality conditions in the lagoons deteriorates during the summer and fall as water temperature increases and algae proliferates.

In Arroyo Grande Lagoon, available data suggests that summer water quality conditions indicate a brackish nature, with moderate to low dissolved oxygen (<5 milligrams per liter [mg/L]) (Terra Verde 2012b, Rischbieter 2017) and high summer daytime pH levels indicative of lagoons with substantial algal growth (Rischbieter 2016). During periods of drought, Arroyo Grande Lagoon can shrink in size and, during a prolonged period of drought, can become desiccated.

Water quality surveys conducted by Althouse and Meade (2011) found that dissolved oxygen (DO) levels in Meadow Creek Lagoon upstream of the project area were chronically low (<5 mg/L) and water temperatures ranged from a low of 10.3°C (50.5°F) in December to a high of 24.5°C (76.1°F) in September. A subsequent water quality survey on August 16th, 2012 was conducted by Terra Verde (2012b) along Meadow Creek Lagoon from Pier Avenue through the project area. While moderate to high DO values (ranging from 6.78 to 10.48 mg/L) and water temperatures ranging from 21.7°C (71.0°F) to 22.1°C (71.8°F) were measured downstream from Pier Avenue to Air Park Avenue, lower DO values (ranging from 4.24 mg/L to 1.32 mg/L) and water temperatures ranging from 16.7°C (62.0°F) to 21.5°C (70.7°F) were measured downstream of Air Park and downstream through the project area.

As discussed in Sections 9.2 and 9.3, steelhead are expected to be more sensitive to low DO conditions than tidewater goby and annual fish surveys generally support this conclusion.

9.6 California Red-Legged Frog

9.6.1 Status

California red-legged frog (CRLF) is 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). Currently, most CRLF populations are largely restricted to coastal drainages on the central coast of California.

9.6.2 Life history

CRLF breeding occurs between late November and late 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 California red-legged frogs has been documented at non-forested breeding sites (Fellers et al. 2001). California red-legged frogs become reproductively mature frogs at two to four years, with females taking longer to develop (Jennings and Hayes 1994).

Adult California red-legged frog

9.6.3 Habitat requirements

CRLF habitat includes wetlands, wet meadows, marshes, lagoons, ponds, lakes, and low-gradient, slow-moving stream reaches. Breeding occurs between late November and late April (Jennings and Hayes 1994). 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). Suitable salinities are lower than 4.5 ppt and CRLF do not have established temperature thresholds (USFWS 2010a), but in general temperatures less than 23°C (73.4°F) are considered suitable.

In Arroyo Grande and Meadow Creek lagoons, habitat meeting the following criteria are considered suitable breeding habitat for CRLF:

- Water depths greater than 2.3 ft;
- Daily average temperatures <23°C (73.4°F), as measured at the bottom of the water column;
- Salinity less than 4.5 ppt; and
- Very slow surface water velocity (0 ft/s).

9.6.4 Factors affecting abundance

Threats to the species within its remaining range include several human-influenced impacts, including urban encroachment, introduction of exotic predators and competitors, habitat fragmentation, contaminants (including pesticides and fertilizers), and the creation of large reservoirs that may not be properly managed for native species (USFWS 2002). Within Arroyo Grande and Meadow Creek lagoons, threats to CRLF include American bullfrogs (*Lithobates catesbeianus*) and the effects of homeless individuals (Cleveland et al. 2018).

9.6.5 Occurrence within or near the project area

Western snowy plover

Occurrences of CRLF in all life stages have been consistently documented in Arroyo Grande Lagoon during surveys conducted from 2008 through 2020 (Rischbieter 2009a, 2009b; Cleveland et al. 2019, Cleveland Biological 2020; Tera Verde 2012) (Table 1 in Appendix E). In Arroyo Grande Lagoon, surveys as recent as 2020 documented 25 adult CRLF, 44 juveniles, and 3 tadpoles over the course of 6 different survey efforts (Cleveland Biological 2020). In Meadow Creek Lagoon, CRLF have not been observed since 2012, when a single adult CRLF was observed (Terra Verde 2012b), while adult bullfrogs (a documented threat to CRLF) have been observed in high abundances (Cleveland Biological 2020).

9.7 Western Snowy Plover

9.7.1 Status

The Pacific Coast population of western snowy plovers are federally listed as threatened and are a CDFW Species of Special Concern. The species' range occurs from Damon Point, Washington, south to Bahia Magdelenda in Baja California, Mexico (USFWS 2007). Critical habitat for western snowy plovers occurs within the project area and extends from the north side of Arroyo Grande Creek at the south end of Strand Way, south roughly 12 miles, to approximately 0.4 miles north of Mussel Point.
The mapped critical habitat area includes Arroyo Grande Lagoon and the levees within the project and adjacent impact area.

9.7.2 Life history

The Pacific Coast population of western snowy plovers primarily breed on coastal beaches within their range. Breeding occurs from early March through late September and the wintering period occurs from late October through mid-February (USWS 2007). Nesting habitat primarily occurs on sand spits, dune-backed beaches, beaches at the mouths of creeks and rivers, and at lagoons and estuaries. Hatching occurs primarily from early April through mid-August, with fledging occurring approximately one month after hatching (Powell et al. 1995). Western snowy plovers feed on invertebrates on the surface of wet sand, surf-cast kelp, dry sand above the high tide line, salt pans, spoil sites, and the edges of salt marshes, salt ponds, and lagoons.

9.7.3 Habitat requirements

Western snowy plovers are associated with barren to sparsely vegetated dune-backed beaches, barrier beaches, salt-evaporation ponds, and occasionally bluff-backed beaches and gravel bars in rivers with wide flood plains up to 7 miles (straight-line distance) from the nearest ocean beach (USFWS 2007, Page et al. 2009). Nests are situated above the high tide line (USFWS 2010b).

9.7.4 Factors affecting abundance

Threats to the species within its range primarily include habitat loss and degradation resulting from human disturbance and urban development (USFWS 2007). Additional factors affecting the abundance of the species included introduced beachgrass (*Ammophila* spp.*)* and an increase in the predator populations, which have resulted in a decline in active nesting areas and a subsequent decrease in the size of the population.

9.7.5 Occurrence in the Project and Adjacent Project Area

CNDDB results indicate that snowy plovers have been observed within the project and adjacent impact area along the southern edge of the Arroyo Grande Lagoon and have nested in the area around Arroyo Grande Lagoon as recent as 2010 (CDFW 2021) and just south of the lagoon in 2017 (MIG 2020). The density of documented nesting sites increases substantially farther south (MIG 2020). Snowy plovers have also been documented wintering along the foredunes adjacent to the Arroyo Grande Lagoon (Terra Verde 2012b).

9.8 Botanical Resources

Database queries were conducted to evaluate the potential for special-status plant species and sensitive natural communities to occur in the quadrangles which surround the project area, based on habitat suitability (soils, habitat type, elevation, and distributional range). The following resources were queried:

- USFWS's IPaC portal for federally listed and proposed endangered, threatened, and candidate species (USFWS 2021b);
- CDFW's CNDDB (CDFW 2021a); and
- California Native Plant Society's (CNPS's) online Inventory of Rare and Endangered Vascular Plants of California (CNPS 2021a).

The USFWS, CNDDB, and CNPS database queries were each based on a search of USGS 7.5-minute quadrangles which surround the project area (Arroyo Grande NE, Guadalupe, Nipomo, Oceano, Pismo Beach, Point Sal, Santa Maria, and Tar Spring Ridge), per standard practice. The project falls mostly within the Oceano OE W quadrangle, which cannot be queried in CNDDB. Appendix D (Table D-1) provides a summary of special-status plant species and sensitive natural communities documented in the database results.

In addition, the following information sources were reviewed to inform evaluations of special-status species with potential to occur within and near the project area:

- Biological Resources Assessment: Meadow Creek Lagoon (Terra Verde 2012b);
- Pismo State Beach and Oceano Dunes State Vehicular Recreation Area Vegetation Mapping Report (MIG|TRA Environmental Sciences 2015); and
- Arroyo Grande Lagoon Interim Sandbar Management Plan (ESA PWA 2013).

Due to the extended period that has elapsed since the most recent botanical surveys, botanical resources surveys will be updated as part of the CEQA process.

9.8.1 Vegetation Communities

Vegetation mapping surveys within and near the project area were conducted in 2012 (Terra Verde 2012b, MIG|TRA 2015). Eight of the primary vegetation types identified by Terra Verde (2012b) to occur near or within the project area (including three sensitive natural communities[2]) as summarized in Table 8 and mapped in Figure 8.

Table 8. Vegetation types documented within or near the project area up to Air Park Avenue as shown in Figure 8.

Habitat Type	MCV Alliance[1] Common Name	MCV Alliance[1] Scientific Name	Sensitive Natural Community?[2]	Acres
Vegetated land cover				
Upland	Coastal brambles	*Rubus (parviflorus spectabilis ursinus)* Shrubland Alliance	no	0.42
	Sea lyme grass patches	*Leymus mollis* Herbaceous Alliance	yes (S2)	0.01
Wetland	Arroyo willow thicket	*Salix lasiolepis/Rubus* spp. Association of the *Salix lasiolepis* Shrubland Alliance	no	10.16
	California bulrush marsh	*Schoenoplectus californicus* Herbaceous Alliance	yes (S3S4)	7.78
	Pacific silverweed marsh	*Argentina egedii* Herbaceous Alliance	yes (S1)	0.48
Non-native/ disturbed uplands	European beach grass swards	*Ammophila arenaria* Semi-Natural Herbaceous Stands	no	1.98
	Iceplant mat	*Carpobrotus edulis* Semi-Natural Herbaceous Stands	no	0.15
	Ruderal	none	no	0.06
Unmapped				1.82
Non-vegetated land cover				
Developed	n/a	n/a	no	0.29
Open water	n/a	n/a	no	3.08
Total				**26.21**

1 MCV refers to the classification system in "A Manual of California Vegetation," Sawyer, Keeler-Wolf, and Evens, 2008; cited in Terra Verde 2012b.
2 S1 = Critically Imperiled
S2 = Imperiled
S3 = Vulnerable
S4 = Apparently secure (CNPS 2021b)

2 Sensitive natural communities were defined as those natural community types with a state ranking of S1 (critically imperiled), S2 (imperiled), or S3 (vulnerable) as listed in the most recent California Sensitive Natural Communities List (CDFW 2020b) and documented as Holland Types (Holland 1986).

Figure 8. Available vegetation types documented within and near the project area up to Air Park Avenue by Terra Verde 2012b.

In addition to the 2012 field survey results, database queries identified six sensitive natural communities as potentially occurring within or near the project area (see Table D-2 in Appendix D). The potentially occurring communities were reviewed and converted to the vegetation classification system used in Table 8 (CNPS 2021b). Of those, four sensitive natural communities were determined to have no potential to occur within or near the project area; the remaining two sensitive natural communities have both a high potential to occur and previously were documented within or near the project area up to Air Park Avenue (Terra Verde 2012b). Sensitive natural communities documented within or near the project area up to Air Park Avenue are described below.

9.8.1.1 California bulrush marsh

The *Schoenoplectus* (*acutus*, *californicus*) Herbaceous Alliance (Hardstem and California bulrush marshes) is dominated or co-dominated by hardstem and/or California bulrush with other herbaceous species, including *Azolla filiculoides* (American water fern), *Bolboschoenus maritimus* (alkali bulrush), *Euthamia occidentalis* (western goldenrod), *Hoita macrostachya* (California hemp), *Hydrocotyle ranunculoides* (marsh pennywort), and *Typa latifolia* (cattail; CNPS 2021b). Hardstem and California bulrush marshes is a natural community of special concern (S3S4) on CDFW's List of California Terrestrial Natural Communities (CDFW 2021b).

This vegetation type was documented throughout approximately 30% of the area surveyed within and near the project area up to Air Park Avenue as shown in Figure 8 (Terra Verde 2012b).

9.8.1.2 Sea lyme grass patches

The *Leymus mollis* Herbaceous Alliance (Sea lyme grass patches) is characterized by the presence of sea lyme grass (syn: *Elymus mollis* subsp. *mollis*) which can be dominant with other herbaceous species, including *Abronia latifolia* (yellow sand verbena), *Achillea millefolium* (yarrow), *Ambrosia chamissonis* (silver beachweed), and *Calystegia soldanella* (beach morning glory; CNPS 2021b). Sea lyme grass patches are a natural community of special concern (S2) on CDFW's List of California Terrestrial Natural Communities (CDFW 2021b).

This community is documented in less than 1% of the area surveyed within and near the project area up to Air Park Avenue as shown in Figure 8 (in the southwest corner along the beach) (Terra Verde 2012b).

9.8.1.3 Pacific silverweed marsh

The *Argentina egedii* Herbaceous Alliance (Pacific silverweed marshes) is dominated or co-dominated by Pacific silverweed and/or *Festuca rubra* (red fescue), with other herbaceous species, including *Anemopsis californica* (yerba mansa), *Extriplex californica* (California orach), *Bolboschoenus maritimus* (alkali bulrush), *Carex obnupta* (coast carex), *Carex pansa* (sand dune sedge), and *Distichlis spicata* (saltgrass; CNPS 2021b). Pacific silverweed marsh is a natural community of special concern (S1) on CDFW's List of California Terrestrial Natural Communities (CDFW 2021b).

This community is documented in approximately 2% of the area surveyed within and near the project area up to Air Park Avenue as shown in Figure 8 (along the eastern edge adjacent to other marsh and riparian communities) (Terra Verde 2012b).

9.8.2 Special-Status Plants

Special-status plants are species that are legally protected under the FESA or the CESA or under other regulations or policies such as the California Fish and Game Code. Species identified as rare by the CNPS are also considered special status and evaluated during the California Environmental Quality Act (CEQA) environmental review process. The reason an individual taxon (species, subspecies, or variety) is given such recognition is primarily the documented or expected decline in the species' population, limitation of its population size or geographical extent, and/or distribution, resulting, in many cases, from habitat loss/fragmentation. Special-status plant species are defined as those that are:

- listed, proposed, or candidate species for listing as threatened or endangered under the FESA or CESA;
- included on CDFW's most recent Special Vascular Plants, Bryophytes, and Lichens List (CDFW 2020b) with a California Rare Plant Rank (CRPR) of 1, 2, 3, or 4;
- designated as rare under the California Native Plant Protection Act; and/or
- not currently protected by statute or regulation but considered rare, threatened, or endangered under CEQA (Section 15380).

Species-specific surveys that were performed within and near the project area up to Air Park Avenue are shown in Figure 9 (Terra Verde 2012b). In addition, database queries identified 93 special-status vascular plant species as potentially occurring in the study area. Of those species, 50 were considered not likely to occur, resulting in a refined list of 43 special-status plant species with potential to occur within the study area (Table 9). Three special-status plants were documented within freshwater areas within and near the project area up to Air Park Avenue (Terra Verde 2012b) and are assumed to be present; a fourth special-status plant species was documented in 2012 and occurred outside this area but north of the airport runway, within the study area (i.e., *Senecio blochmaniae* [Blochman's ragwort]; not shown in Figure 9). Four other special-status species are documented within large, imprecise polygons which overlap with the study area but were not observed within the study area (CDFW 2021a; Terra Verde 2012b). The three previously documented species within and near the project area are discussed in more detail below.

Figure 9. Special-status plant species documented within the study area.

Table 9. Special-status plant species with potential to occur in the study area.

Scientific Name	Common Name	Status[1] Federal/State/CRPR
Abronia maritima	red sand-verbena	–/–/4.2
Aphanisma blitoides	aphanisma	–/–/1B.2
Arctostaphylos rudis	sand mesa manzanita	–/–/1B.2
Arenaria paludicola	marsh sandwort	FE/CE/1B.1
Astragalus nuttallii var. *nuttallii*	ocean bluff milk-vetch	–/–/4.2
Atriplex serenana var. *davidsonii*	Davidson's saltscale	–/–/1B.2
Calandrinia breweri	Brewer's calandrinia	–/–/4.2
Ceanothus gloriosus var. *gloriosus*	Point Reyes ceanothus	–/–/4.3
Chenopodium littoreum	coastal goosefoot	–/–/1B.2
Chloropyron maritimum subsp. *maritimum*[2]	salt marsh bird's-beak	FE/CE/1B.2
Cirsium occidentale var. *compactum*	compact cobwebby thistle	–/–/1B.2
Cirsium rhothophilum	surf thistle	–/CT/1B.2
Cirsium scariosum var. *loncholepis*	La Graciosa thistle	FE/CT/1B.1
Cistanthe maritima	seaside cistanthe	–/–/4.2
Deinandra increscens subsp. *Villosa*	Gaviota tarplant	FE/CE/1B.1
Deinandra paniculata	paniculate tarplant	–/–/4.2
Delphinium parryi subsp. *blochmaniae*	dune larkspur	–/–/1B.2
Dithyrea maritima	beach spectaclepod	–/CT/1B.1
Dudleya abramsii subsp. *Bettinae*	Betty's dudleya	–/–/1B.2
Dudleya blochmaniae subsp. *Blochmaniae*	Blochman's dudleya	–/–/1B.1
Eleocharis parvula	small spikerush	–/–/4.3
Erigeron blochmaniae	Blochman's leafy daisy	–/–/1B.2
Erysimum suffrutescens	suffrutescent wallflower	–/–/4.2
Horkelia cuneata var. *sericea*	Kellogg's horkelia	–/–/1B.1
Juncus acutus subsp. *Leopoldii*	southwestern spiny rush	–/–/4.2
Leptosiphon grandiflorus	large-flowered leptosiphon	–/–/4.2
Linanthus californicus subsp. *Tomentosus*	fuzzy prickly-phlox	–/–/4.2
Lomatium parvifolium	small-leaved lomatium	–/–/4.2
Lupinus nipomensis	Nipomo Mesa lupine	FE/CE/1B.1
Malacothrix incana	dunedelion	–/–/4.3
Monardella sinuata subsp. *Sinuata*	southern curly-leaved monardella	–/–/1B.2

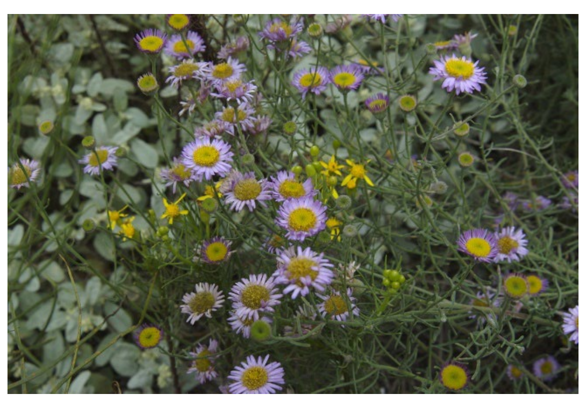
Scientific Name	Common Name	Status[1] Federal/State/CRPR
Monardella undulata subsp. *Crispa*	crisp monardella	–/–/1B.2
Monardella undulata subsp. *undulata*	San Luis Obispo monardella	–/–/1B.2
Mucronea californica	California spineflower	–/–/4.2
Muhlenbergia utilis	aparejo grass	–/–/2B.2
Nasturtium gambelii	Gambel's water cress	FE/CT/1B.1
Nemacaulis denudata var. *denudata*	coast woolly-heads	–/–/1B.2
Orobanche parishii subsp. *brachyloba*	short-lobed broomrape	–/–/4.2
Prunus fasciculata var. *punctata*	sand almond	–/–/4.3
Scrophularia atrata	black-flowered figwort	–/–/1B.2
Senecio aphanactis	chaparral ragwort	–/–/2B.2
Senecio blochmaniae	Blochman's ragwort	–/–/4.2
Symphyotrichum defoliatum	San Bernardino aster	–/–/1B.2

[1] Status:
Federal
FE Federally listed as endangered
– No federal status
State
CE California State listed as endangered
CT California State listed as threatened
– No state status
CRPR (California Rare Plant Rank) List Ranks
List 1B Plants rare, threatened, or endangered in California and elsewhere
List 2 Plants rare, threatened, or endangered in California, but more common elsewhere
List 4 Plants of limited distribution, a watch list
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)
0.3 Not very threatened in California (low degree/immediacy of threats or no current threats known)

[2] Listed as *Cordylanthus maritimus* subsp. *maritimus* in USFWS (2021b).

9.8.2.1 Erigeron blochmaniae

Erigeron blochmaniae (Blochman's leafy daisy) is a perennial rhizomatous herb in the Asteraceae family with a CRPR of 1B.2. It occurs in coastal dunes and coastal scrub habitats at elevations ranging from 10 to 150 ft. It blooms from June through August (CNPS 2021a).



Erigeron blochmaniae (Blochman's leafy daisy) (Creative Commons 2021)

Erigeron blochmaniae was documented in 2012 across multiple patches within freshwater areas within and near the project area (Terra Verde 2012b, CDFW 2021a) on sandy soils in the European beach grass swards habitat.

Approximately 200 individuals were documented; plant associates included *Ammophila arenaria* (European beachgrass), *Carpobrotus* sp. (iceplant), *Ehrharta calycina* (perennial veldt grass), *Ericameria ericoides* (mock heather), and *Lupinus chamissonis* (beach blue lupine) (Terra Verde 2012b).

9.8.2.2 Juncus acutus subsp. leopoldii

Juncus acutus subsp. *leopoldii* (southwestern spiny rush) (Terra Verde 2012b)

Juncus acutus subsp. *leopoldii* (southwestern spiny rush) is a perennial rhizomatous herb in the Juncaceae family with a CRPR of 4.2. Its distribution is limited and occurs in mesic soils in coastal dunes, alkaline meadows and seeps, and coastal salt marshes and swamps at elevations ranging from 10 to 2,955 ft. It blooms from May through June, sometimes as early as March (CNPS 2021a).

Juncus acutus subsp. *leopoldii* was documented in 2012 across multiple patches within freshwater areas within the project area (Terra Verde 2012b, CalTrans 2015, CDFW 2021a) at the edge of the California bulrush marsh habitat, at the transition to arroyo willow thickets. Approximately 20 individuals were documented; plant associates included *Ammophila arenaria*, *Rubus ursinus* (California blackberry), *Schoenoplectus* spp. (bulrushes), *Potentilla anserina* (common silverweed), *Rumex* spp. (dock), and *Salix lasiolepis* (arroyo willow) (Terra Verde 2012b).

9.8.2.3 Mucronea californica

Mucronea californica (California spineflower) (Terra Verde 2012b)

Mucronea californica (California spineflower) is an annual herb in the Polygonaceae family with a CRPR of 4.2. Its distribution is limited (as indicated by its CRPR rating), but can occur on sandy soils in several habitats, including chaparral, cismontane woodland, coastal dunes, coastal scrub, and valley and foothill grassland at elevations ranging from 0 to 4,595 ft. It blooms from March through July or, occasionally, August.

Mucronea californica was documented in 2012 within freshwater areas near the project area (Terra Verde 2012b, CalTrans 2015, CDFW 2021a) in the European beach grass swards and willow riparian habitats, mostly on north-facing dune slopes. Approximately 50 individuals were documented; plant associates included *Carex pansa*, *Ericameria ericoides*, *Erigeron blochmaniae*, and *Juncus breweri* (salt rush) (Terra Verde 2012b).

10 KEY OPPORTUNITIES AND CONSTRAINTS TO INFORM ALTERNATIVES DEVELOPMENT BASED ON EXISTING CONDITIONS

The over-arching goal of the project is to increase habitat for growth and survival of smolt and rearing juvenile steelhead, as well as to enhance and protect lagoon wildlife and fisheries habitat in general. In addition to steelhead, the lagoons provide habitat for two other federally listed species: California red-legged frog and tidewater goby. The project aims to achieve this goal by (1) increasing the hydrologic connectivity between Arroyo Grande and Meadow Creek lagoons; (2) enhancing conditions in approximately 8.3 acres of degraded habitat of Meadow Creek Lagoon, including but not limited to increasing habitat complexity, discernible flow, deep-water refugia, and riparian banks for shading; and, (3) ensuring that the project does not exacerbate existing flooding conditions in surrounding developed areas. Existing conditions indicate that potential key restoration opportunities and constraints to meet the requirements of RPA3 include the following:

Key Opportunities

Opportunity #1: **Improve hydrological connection and fish passage between the project area in Meadow Creek Lagoon and the project impact area in Arroyo Grande Lagoon**. While the existing Sand Canyon Outlet and the levee along Arroyo Grande Creek are necessary for flood protection, they can limit hydrological and tidal connection between the lagoons. Even though the flap gates at the Sand Canyon Outlet can theoretically provide access for steelhead into Meadow Creek Lagoon when open, steelhead have not been observed in the Meadow Creek Lagoon. If there were migratory access between the lagoons, deep-water refugia and suitable rearing habitat for steelhead is available in Meadow Creek Lagoon upstream of the project area and suitable rearing habitat is available in the project area. Furthermore, improved hydrological exchange between Meadow and Arroyo Grande lagoons during non-flood conditions could improve the extent and duration of water inundation and water quality in lower Meadow Creek Lagoon.

Opportunity #2: **Improve the extent and depth of pool habitat in the project area in Meadow Creek Lagoon through excavation**. The estimated amount of sediment delivered to Meadow Creek Lagoon from the watershed is low (~800 tons per year), suggesting that enhancement of pool habitat without extensive long-term sediment maintenance may be feasible. Pool enhancement could be designed to increase habitat complexity, increase suitable steelhead rearing habitat, and provide deep water refugia for rearing steelhead.

Opportunity #3: Improve the hydrological connection between the project area in Meadow Creek Lagoon and Upper Meadow Creek Lagoon through excavation. This could improve fish passage to allow steelhead to take advantage of existing deep-water refugia and suitable rearing habitat upstream of the project area. However additional evaluation of how improved hydrological connection could impact habitat may be needed if this opportunity is pursued. Key issues include how improved hydrological connection could potentially impact Largemouth bass (*Micropterus salmoides*) distribution (see Constraint #3 below) and dry season water levels in both the project area and Upper Meadow Creek Lagoon.

Opportunity #4: Improve habitat conditions in the adjacent project impact area in Arroyo Grande Lagoon. While Arroyo Grande Lagoon both within and downstream of the adjacent impact area can provide some deep-water refugia habitat and suitable rearing habitat for steelhead when the sandbar is closed, the lagoon contains primarily open-water habitat with minimal habitat complexity and has sparse vegetative cover along channel margins. Providing habitat elements (e.g., engineered large woody debris structures) that increase cover and hydraulic complexities may improve steelhead rearing and aquatic habitat conditions. However potential impacts of the engineered habitat structures on floodwater levels and sediment transport should be evaluated if this opportunity is pursued. Within Arroyo Grande Lagoon downstream of the adjacent impact area, an open body of water generally persists through the dry season and limited water quality data suggests that water is brackish, with moderate DO conditions (<5 mg/L).

Key Constraints

Constraint #1: **Surface inflows from Meadow Creek Watershed into the project area in Meadow Creek Lagoon during non-flood periods is generally absent, especially in the dry season**. This reduces wetted area and may constrain restoration opportunities. During the dry season, the project area within Meadow Creek Lagoon can become completely desiccated.

Constraint #2: In the dry season Arroyo Grande Lagoon generally lacks surface inflows and tidal exchange with the ocean. Within the adjacent project impact area, Arroyo Grande Lagoon can dry back, with only small, isolated shallow pools remaining.

Constraint #3. **Largemouth bass which can prey on juvenile steelhead trout have been identified in Meadow Creek Lagoon upstream of the project area.**

Constraint(s) #4-9 Several physical and engineered features may also constrain potential restoration opportunities. These include:

- A shallow 36-in-diameter ocean outfall runs along the north side of Arroyo Grande Creek levee and could limit excavation and habitat restoration options. The outfall would be subject to increased exposure/risk from levee setback.
- An 8-in-diameter waterline runs across Meadow Creek Lagoon. The waterline could limit excavation or need to be relocated.
- There is a high potential for liquefaction and seismic hazards, for which associated mitigation measures involving in-situ ground improvement or engineering design solutions would be costly and take up restoration space. Cost effective soft fixes may be considered to address liquefaction and seismic hazards but depend on the nature of the risks to surrounding land uses.
- There is shallow groundwater and wet soil conditions, for which dewatering will likely be needed during construction.
- Extensive sensitive habitat areas and residential neighborhoods are present, resulting in limited access points and space for staging during construction.
- There are houses, a water treatment facility, and an airport located adjacent to the project site which have low ground elevations and are prone to flooding under existing conditions, including from relatively frequent storm events. The area around the project is mapped within FEMA's 100-year flood hazard zone. Proposed alternatives cannot increase flood risk.

Restoration alternatives for the project area will also be evaluated for their ability to enhance habitat for other special-status species, primarily tidewater goby and CRLF. Tidewater goby are generally found in the project area and could benefit from improvements targeted at steelhead. While CRLF are generally found on the Arroyo Grande Creek side, they are potentially limited on the Meadow Creek side by invasive bullfrogs and any efforts to reduce bullfrogs or their habitat will benefit CRLF.

The existing conditions synthesis and assessment lays the foundation upon which alternatives analysis can be effectively conducted and are summarized herein to guide future alternatives development discussions. Consideration of these opportunities and constraints, as well as any additional opportunities identified by the Science Panel, will be integrated into the future alternatives' development and analysis phase.

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