Stillwater Sciences

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TECHNICAL MEMORANDUM

DATE:	4 August 2021
TO:	Eric Laurie, P.E. (San Luis Obispo County Flood Control and Water Conservation District)
FROM:	Aleksandra Wydzga, Ethan Bell, and Nami Tanaka, P.E., (Stillwater Sciences); Gresh Eckrich, P.E., C.E.G. (Yeh and Associates); Greg Kamman, P.G., C.H.G. (cbec)
SUBJECT:	Meadow Creek Lagoon Restoration Project – Task 1

1 INTRODUCTION

The Meadow Creek Lagoon is located in the coastal community of Oceano, CA, where the downstream reach of Meadow Creek meets Arroyo Grande Lagoon before draining to the Pacific Ocean. Meadow Creek evolved into its current state 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 Lagoon/Pacific Ocean and therefore lead to a number of environmental issues in the Meadow Creek Lagoon, including significant sediment accumulation, encroachment of invasive vegetation, and Meadow Creek fish passage impediment.

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 Meadow Creek Lagoon and Arroyo Grande Lagoon to improve aquatic habitat conditions of approximately 8.3 acres of Meadow Creek Lagoon (Figure 1), while ensuring that the project does not exacerbate existing flooding conditions in surrounding developed areas.

The purpose of this technical memorandum is to identity and prioritize data gaps and additional analysis required for the existing conditions synthesis (Proposed Task 3) and the alternative's analysis/conceptual design development (Proposed Task 4). The focus of the existing conditions synthesis is on 8.3 acres of Meadow Creek Lagoon (Figure 1, purple polygon) and that portion of Arroyo Grande Creek Lagoon immediately adjacent to Meadow Creek Lagoon (Figure 1, green polygon). Data from upstream or downstream of these project areas will be included in the existing conditions assessments to the extent that it is anticipated to inform alternatives evaluation within the project area. This information is vital to understand the connection between the lagoon and upstream riverine habitat, as well as, to understand geomorphic and hydraulic processes and conditions which affect the project area. The bibliography of reports and documents provided by the District as of June 2021 is included in Section 4 and will be periodically updated with new information during the course of the project.

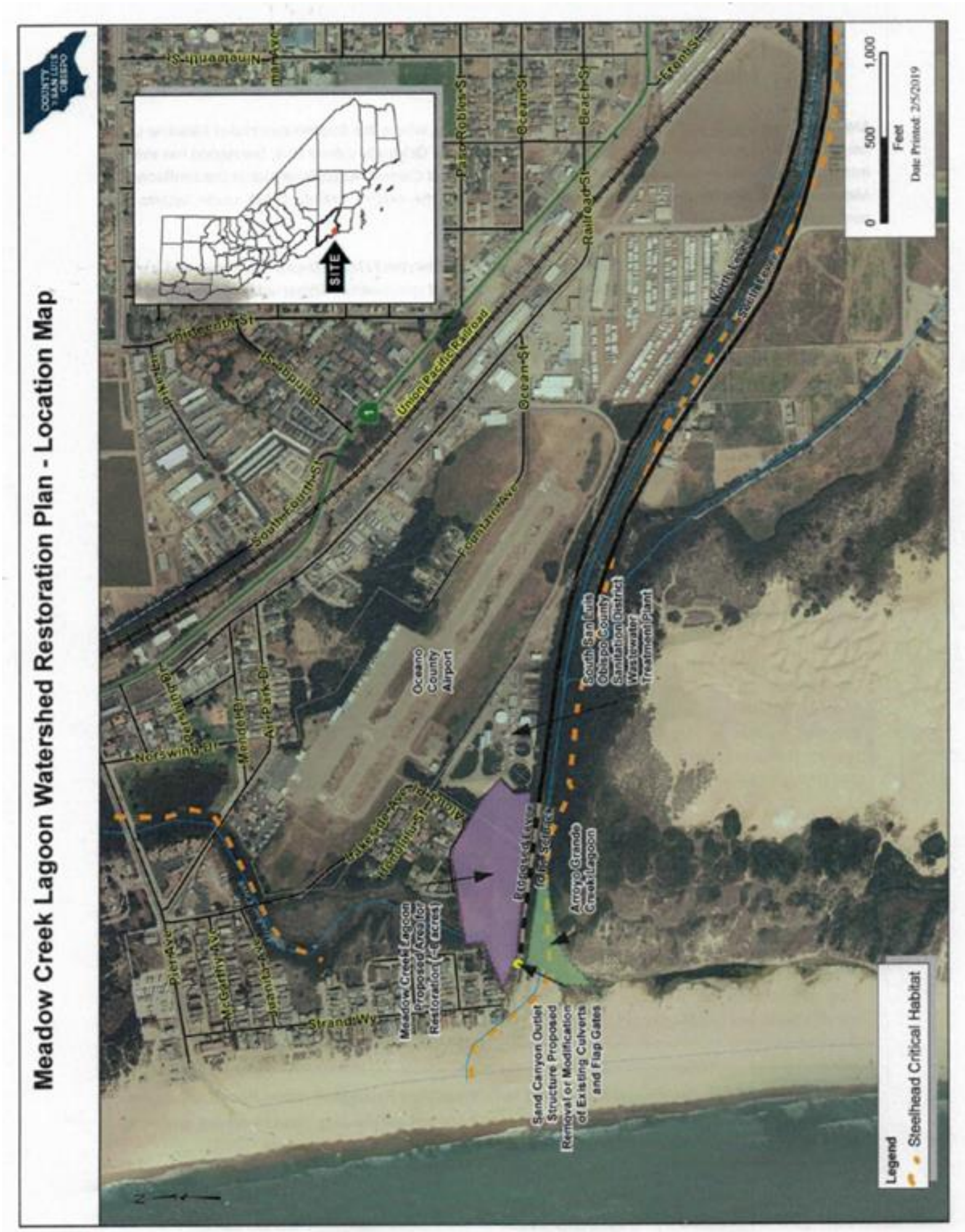

Figure 1. Project area.

2 COMPILED INFORMATION

Numerous studies and reports completed by other agencies and consultants on the Arroyo Grande – Meadow Creek system have been obtained and reviewed by the Stillwater Sciences team.

Information relevant to the project and data gaps identified during this review are summarized below.

2.1 Biological and Habitat Assessments

2.1.1 Aquatic resources

Biological and habitat data will help inform the project design and can be directly used in permit applications and associated impact analyses (e.g., to estimate the project's temporary construction-related impacts on native wetland and riparian vegetation). Based on available scientific literature, the habitat preferences (physical and water quality) of the key focal species at the project site, including steelhead, tidewater goby, Western snowy plover, and California red-legged frogs can be synthesized. Furthermore, the best available information on the current distribution of these species (and wetland vegetation) within the Arroyo Grande and Meadow Creek Lagoons (e.g., Rischbieter 2006–2021, Terra Verde 2012, Cleveland et al. 2019) and a discussion of the environmental dynamics that affect their distribution and resiliency under existing conditions will be summarized with existing data under proposed Task 3.

Fisheries surveys and California red-legged frog surveys have been conducted annually (Table 1); however, the surveys are primarily focused on Arroyo Grande Creek and Arroyo Grande Creek Lagoon with limited surveys occurring in Meadow Creek Lagoon. Fisheries surveys have documented a continual presence of tidewater goby in Arroyo Grande Creek Lagoon and, occasionally, a smaller population in lower Meadow Creek Lagoon just upstream of the flap gates. The fisheries surveys have also documented a continued presence of steelhead in Arroyo Grande Creek Lagoon, without any observations in the Meadow Creek Lagoon. Surveys for California red-legged frogs have detected tadpoles, juvenile, and adult life stages in Arroyo Grande Creek and Meadow Creek Lagoons. Water quality conditions dictate the suitability of habitat particularly for both steelhead and tidewater goby. Water quality measurements have been taken sporadically during fisheries and more targeted water quality monitoring efforts; however, data on current water quality conditions in the lagoons are unavailable. A summary of the existing biological and habitat data for Arroyo Grande Creek Lagoon and Meadow Creek Lagoon is presented in Table 1.

Table 1. Existing California red-legged frog, tidewater goby, steelhead, and water quality data for the Arroyo Grande – Meadow Creek system.

Assessment/ Species	Year	Season	Notes	Location[1]	Source
Tidewater goby	2005	Spring	First known AG Creek occurrence	AG Creek Lagoon*	Rischbieter 2006
	2006	Summer, Winter	Low abundance, captured in summer only	AG Creek Lagoon*	Rischbieter 2007
	2007	Spring, Summer, Winter	Most abundant in summer and winter, lowest in Spring	AG Creek Lagoon*	Rischbieter 2008
	2008	Spring, Summer, Fall	Low abundance in spring and summer, not present during fall surveys	AG Creek Lagoon*	Rischbieter 2009
	2010	Spring, Summer, Fall	Low abundance overall, with most individuals captured in summer; however, report states “noteworthy recolonization following apparent extirpation in 2008”	AG Creek Lagoon*	Rischbieter 2010
	2011	Spring, Summer, Fall	Only captured during fall surveys	AG Creek Lagoon*	Rischbieter 2011
	2012	Spring	Snorkel and beach seine surveys did not detect TWG, captured TWG in AG Creek Lagoon	Meadow Creek Lagoon	Tera Verde 2012
	2012	Spring, Summer, Fall	Most abundant in summer	AG Creek Lagoon	Rischbieter 2012
	2013	Spring, Summer, Fall	Most abundant in summer	AG Creek Lagoon	Rischbieter 2013
	2014	Summer, Fall, Winter	Two captured in summer, subsequent surveys did not capture TWG	Meadow Creek Lagoon	Rischbieter 2014
	2014	Spring, Summer, Fall, Winter	Most abundant in summer	AG Creek Lagoon	Rischbieter 2014
	2015	Spring, Summer, Fall, Winter	Most abundant in summer, not captured in winter. Not captured in seine nets in Meadow Creek Lagoon.	AG Creek Lagoon	Rischbieter 2015
	2016	Spring, Summer, Fall, Winter	Most abundant in spring and summer	AG Creek Lagoon	Rischbieter 2016
	2017	Spring, Summer, Fall	Most abundant in summer	Meadow Creek	Rischbieter 2017
	2017	Summer	Most abundant in summer and fall	AG Creek Lagoon	Rischbieter 2017
	2018	Winter, Spring, Summer, Fall	Most abundant during late summer and fall surveys	AG Creek Lagoon*	Rischbieter 2018
	2019	Winter, Spring, Summer	Most abundant in summer	AG Creek Lagoon*	Rischbieter 2020a
	2020	Winter, Spring, Summer, Fall	Most abundant in summer	AG Creek Lagoon*	Rischbieter 2020b
	2021	Winter	Low abundance	AG Creek Lagoon*	Rischbieter 2021

Assessment/ Species	Year	Season	Notes	Location[1]	Source
Steelhead	2004	Fall, Winter, Spring, Summer	Two adults stranded on beach December 2003, March 2004. Juvenile steelhead captured upstream of lagoon head. Similar abundance throughout each season, though not captured during fall surveys	AG Creek Lagoon*	Rischbieter 2004
	2005	Spring, Summer	Juveniles and smolts found throughout AG Creek lagoon	AG Creek Lagoon*	Rischbieter 2005
	2006	Winter, Spring, Summer	Juveniles most abundant upstream of AG Creek lagoon head, only captured in lagoon in the winter and in low abundance	AG Creek Lagoon*	Rischbieter 2006
	2008	Spring, Summer, Winter	Adult steelhead observed in lagoon during June. Juveniles most abundant in summer, low abundance in spring. Large fish kill occurred in June	AG Creek Lagoon*	Rischbieter 2009
	2009	Spring, Summer, Fall	Juvenile steelhead highest abundance in spring, lowest abundance in late summer	AG Creek Lagoon*	Rischbieter 2009b
	2010	Spring, Summer, Fall	No individuals captured in lagoon; 1 juvenile observed upstream	AG Creek Lagoon*	Rischbieter 2010
	2011	Summer	79 YOY steelhead captured in single beach seine hull, likely redd site at gravel bar just downstream of Meadow Creek confluence	AG Creek Lagoon*	Rischbieter 2011
	2012	Spring, Summer, Fall	2 dead/spent adults seen in April. YOY fish in AG Creek Lagoon in summer	AG Creek Lagoon*	Rischbieter 2012
	2013	Spring, Summer	13 juvenile fish in lagoon. 2 individuals in beaver pond appeared in poor health	AG Creek Lagoon	Rischbieter 2013
	2014	Spring, Summer, Winter	Juveniles most abundant in early summer, not present in late summer fall or winter. Not captured in Meadow Creek Lagoon	AG Creek Lagoon	Rischbieter 2014
	2017	Summer	2 YOY fish captured in June-July	AG Creek Lagoon	Rischbieter 2018
	2018	Winter, Spring, Summer, Fall	1 220mm FL smolt captured in spring	AG Creek Lagoon*	Rischbieter 2018
	2019	Winter, Spring, Summer	3 captured in winter, 6 in spring. Smolts/juveniles (95-175 mm FL). No steelhead captured in Summer	AG Creek Lagoon*	Rischbieter 2020a
	2020	Winter, Spring, Summer, Fall	1 smolt captured in spring	AG Creek Lagoon*	Rischbieter 2020b

Assessment/ Species	Year	Season	Notes	Location[1]	Source
California red-legged frog	2008	Summer	Observed in upper AG Creek lagoon	AG Creek Lagoon	Rischbieter 2009a
	2009	Spring	Adults and tadpoles observed in AG Creek Lagoon	AG Creek Lagoon*	Rischbieter 2009b
	2010	Summer	2 juveniles observed in AG Creek Lagoon	AG Creek Lagoon	Cleveland et al. 2019
	2011	Spring	2 tadpoles observed in AG Creek Lagoon	AG Creek Lagoon	Cleveland et al. 2019
	2012	Summer	1 adult CRLF identified in Meadow Creek Lagoon and 1 in AG Creek Lagoon	AG Creek Lagoon, Meadow Creek Lagoon	Tera Verde 2012
	2013	Summer	3 juveniles observed in AG Creek Lagoon	AG Creek Lagoon	Cleveland et al. 2019
	2017	Spring, Summer	8 adults, 18 juveniles observed, highest abundance in Spring	AG Creek Lagoon	Cleveland et al. 2019
	2019	Spring, Summer	3 juveniles observed in AG Creek Lagoon	AG Creek Lagoon	Cleveland et al. 2019
	2020	Summer	25 adults, 44 juveniles and 3 tadpoles observed in AG Creek Lagoon over 6 survey efforts	AG Creek Lagoon*	Cleveland Biological 2020
Water Quality	2004	Winter, Spring, Summer	Hourly water temperature	AG Creek Lagoon	Rischbieter 2004
	2012	Summer	DO/Temp/Conductivity *DO low during surveys	Meadow, AG Creek Lagoon	Tera Verde 2012
	Monthly – Sept. 2010 through April 2011	Fall, Winter, Spring	DO, Temp, Conductivity, Turbidity, Nutrients “Dissolved oxygen in Meadow Creek Lagoon was chronically low. Additional monitoring would be required to determine seasonal trends and to determine if poor dissolved oxygen concentrations are limited to sampling locations or are more widespread in Meadow Creek.”	Meadow Creek Lagoon	Althouse and Meade, Inc. 2011
	2016	Summer	Salinity: 3.45 ppt; pH: 9.3; DO: 2.7 mg/l	AG Creek Lagoon	Rischbieter 2017
	2020-2021	Year-round	Temperature and turbidity data in lower AG Creek being collected by County as part of WMP or HCP efforts	Lower Arroyo Grande Creek	In-progress

[1] Specific locations provided in source reports
* Indicates Meadow Creek Lagoon was not sampled

2.1.2 Other sensitive species

Surveys for bird, mammals, and reptiles and CNDDB database info exists and is summarized in Terra Verde (2012a) and MIG (2020a-c). The Terra Verde (2012a) report utilizes a CNDDB database review from 2012, while the MIG (2020a-c) report relies on a database review from 2017. Updated database review for sensitive species occurrences will be conducted under Task 3.

2.1.3 Vegetation and wetland

Waters and wetlands are present within the proposed Project area, including Waters of the U.S., Waters of the State, and Coastal Zone wetlands. Two documents identifying jurisdictional waters have been identified (SWCA 2009; Terra Verde 2012b). These documents are assumed to be sufficient for use in developing and comparing project alternatives. Updates to water and wetland delineations may need to occur once the final alternative is selected. Furthermore two documents with vegetation mapping have been identified (Terra Verde 2012a) and MIG (2020a-c), both of which rely on field efforts done in 2012.

2.2 Hydraulics and Hydrology

2.2.1 Hydraulics

The Waterways Consulting (2011, 2021) and ESA (2016a) HEC-RAS models have been provided by the District. The domain and geometry for both Waterways models only cover lower Arroyo Grande and Los Berros Creeks. The 2011 Waterways Consulting model is a 1D model that includes pre- and post-project channel geometries developed in association with the sediment management and levee raise project. Waterways Consulting developed a 2D model (2021) covering the same domain as their earlier 1D model, capturing project design conditions. It is our understanding that this model will be refined in the future using the most recent ground survey data to reflect as-built conditions.

The ESA HEC-RAS model (2016b) is a 1D model that includes lower Arroyo Grande and middle-lower Meadow Creek lagoon. It was originally developed in 2011 using the Waterways Consulting 1D model geometry for Arroyo Grande, and subsequently modified in 2013. A summary of the existing 1D and 2D HEC-RAS models for the Arroyo Grande - Meadow Creek system is presented in Table 2. The models may be used to extract boundary conditions and terrain data; updated to reflect current conditions; or modified to include features that will be proposed under various alternatives.

Table 2. Existing 1D HEC-RAS models.

Consultant	Year	Domain	Geometry	Purpose and notes
USACE	2001	Arroyo Grande and Los Berros Creeks	• Updated of geometry provided by San Luis Obispo County Update based on field investigation	Channel capacity analysis
Swanson Hydrology and Geomorphology	2006	Arroyo Grande Creek	• 2005 photogrammetry survey • Channel cross sectional survey	Evaluation of flood improvement alternative
Waterways Consulting	2011	Arroyo Grande and Los Berros Creeks	• 1D Domain: lower Arroyo Grande and Los Berros Creeks • Geometry captures the pre- and post-project conditions • Neither Arroyo Grande nor Meadow Creek lagoons included in model domain	• 1D HEC-RAS model obtained • Documentation unavailable • Steady state upstream flow boundary conditions: 2-, 3.5-, 4.8-, 5-, 10-, 12-, 15-, 16.6-, 17-, 20-, and 50-year floods per USACE 1999 estimates. • Downstream boundary condition set to constant water level (5.4 ft)

ESA	2013	Arroyo Grande Creek, Meadow Creek Lagoon, and Arroyo Grande Lagoon	• Expanded the Waterway 2011 model geometry to eliminate Los Berros Creek and include both lagoons based on:
			  ○ 2011 Arroyo Grande and 2012 Meadow Creek Lagoon topography survey
			  ○ 2012 Meadow Creek Lagoon bathymetry survey
			  ○ 2009–2011 NOAA LiDAR
				• Modification of Waterways Consulting (2011) model
				• Assessment of lagoon flood dynamics to inform sand bar management plan

ESA	2016	Meadow Creek Lagoon	• Modified the ESA PWA (2013) model geometry to eliminate Arroyo Grande Lagoon and expand Arroyo Grande Creek channel geometry based on:
			  ○ 2016 WWTF topographic survey
			  ○ 2009–2011 NOAA LiDAR
			• 1D Domain: lower Arroyo Grande Creek channel and Meadow Creek lagoon up to Pismo State Beach Road
			• Arroyo Grande Creek lagoon not included in model geometry
				• 1D HEC-RAS model obtained
				• Modification on ESA PSA (2013) model
				• Development of synthetic Meadow Creek inflow hydrographs under climate change scenarios
				• Unsteady flow boundary condition for the 1/18/16 through 1/25/16 period (max. flow of

Consultant	Year	Domain	Geometry	Purpose and notes
				61.11 cfs on Arroyo Grande and 43.64 cfs on Meadow Creek) • Downstream boundary condition set to constant water level (5.4 ft)
Waterways Consulting	2021	Arroyo Grande Creek	• 1D Domain: lower Arroyo Grande and Los Berros Creeks • 2D Domain: right and left bank floodplains downstream of Los Berros Creek to the water treatment plant • Geometry captures pre- and post-project conditions • Neither Arroyo Grande nor Meadow Creek lagoons included in model domain.	• Mixed 1D/2D HEC-RAS model obtained • Documentation unavailable • Unsteady flow boundary condition for the 20-year design flow with peak flow rates of 5344 cfs on Arroyo Grande and 3057 cfs on Los Berros Cr.) • Downstream boundary condition set to constant water level (5.4 ft)

2.2.2 Hydrology

The hydrologic data will be used for design flow estimates, and if needed, for calibration and validation of the hydraulic model. The watershed hydrologic descriptions are provided in Waterways Consulting (2010) and Swanson Hydrology + Geomorphology (2006) for Arroyo Grande Creek, and Chipping (1989) for Meadow Creek. ESA (2013) provide detailed descriptions of the Arroyo Grande Lagoon fluvial hydrology and fill-breach-drain cycles, highlighting recent rainfall events.

The USACE (1999a,1999b) performed a comprehensive hydrologic analysis of Arroyo Grande Creek and its tributaries using a HEC-1 rainfall-runoff model and developed regression equations to approximate peak discharges for a range of frequency events based on 29 stream gage records located within San Luis Obispo County. FEMA FIS (2007) also provides the estimates of peak flood flows for Arroyo Grande Creek and Meadow Creek. Table 3 summarizes peak flood discharges published by USACE and FEMA. The Arroyo Grande Creek flood control improvement project that is currently under construction is designed based on the USACE estimates. The steady state design flows and hydrographs are also available for Arroyo Grande Creek and Meadow Creek from HEC-RAS models provided by the District.

The historical flow records may be necessary to execute an event-based simulation or model calibration/validation. These data may be available for Arroyo Grande Creek and Meadow Creek from HEC-RAS models or generated from stage data as described in the following section.

Table 3. Summary of peak flood flows (cfs) for various recurrence intervals (years).

Source	Year analyzed	5	10	20	50	100	Comments
Arroyo Grande							
USACE	1999	2,800	5,400	8,600	13,600	19,200	Basis of the on-going flood control project
FEMA	1989	-	5,200	-	17,700	26,800	Sum of Los Berros and Arroyo Grande at Arroyo Grande
Meadow Creek							
FEMA	1983	-	760		2,400	3,500	At Pier Ave

2.2.3 Water level

The District maintains a network of gages that monitor rainfall and water levels throughout the Arroyo Grande – Meadow Creek system. Table 4 lists the gauges that will be required for hydraulic model development and calibration for this project. The District provided a link to download instantaneous (15-minute interval) data for each gage. The District has also provided historic mean daily stage data, but instantaneous stage data is required for model development and simulations, which will be obtained from the County's website.

The District has provided rating curves for Arroyo Grande Creek at 22nd Street (#734) and Los Berros Creek, which will be used to convert instantaneous stage data to associated flow rates.

Table 4. Stream water level gauges for the Arroyo Grande - Meadow Creek system relevant to the project.

ID	Location
731	Arroyo Grande at Valley Road
734	Arroyo Grande at 22nd Street Bridge
736	Arroyo Grande at Highway 101
769	Arroyo Grande Lagoon
770	Meadow Creek Lagoon
4615	Pier Avenue

2.3 Geotechnical Engineering

A review of the existing data by Yeh and Associates (Yeh) indicates that the geotechnical data were not collected within the limits of the proposed restoration area. Although the existing data may be leveraged for developing and evaluating alternatives, it is recommended that the site-specific geotechnical data (e.g., drilling borings and advancing cone penetration testing) be collected for the three selected alternatives in proposed Task 4, once the existing conditions assessment is completed.

The proposed restoration area is located within the margins of an estuary/lagoon and adjacent to coastal dunes. The surficial geology was mapped by Holland (2013) as late Holocene-aged unconsolidated sandy, silty, and clay soil younger alluvium. Subsurface conditions are anticipated to consist of saturated, young, and loose to medium dense sand or sensitive fine-grained soil based on the subsurface conditions encountered by previous studies and mapping by Holzer et al. (2004) and Holland (2013). Those soil types are typically susceptible to liquefaction when subjected to strong ground motion. Estuarine deposits typically consist of compressible soil prone to settlement due to changes in loading and/or groundwater levels. The restoration project design will need to consider the potential impacts of liquefaction to the modified levees, and the potential for static and seismically induced settlement of modified levees relative to the design flood event and the minimum freeboard for flood protection. In addition, Yeh anticipates shallow groundwater will be a constructability challenge for the restoration project. Construction excavations will likely encounter loose, sandy soil below the groundwater table. The existing geotechnical data are summarized in the following sections.

2.3.1 U.S. Geological Survey (Holzer et al. 2004)

The U.S. Geological Survey (Holzer et al. 2004) previously performed a geotechnical study in the project vicinity. The study focused on evaluating liquefaction and liquefaction-induced lateral spreading that occurred in Oceano in response to the 2003 San Simeon Earthquake. As part of that study, the USGS performed Cone Penetration Test (CPT) soundings at the South San Luis Obispo County Sanitation District (SSLOCSD) and along streets in the residential neighborhood located approximately 1,400 feet northwest of the proposed levee alignments. The soundings were performed in those areas, because the USGS observed evidence of liquefaction and lateral spreading along the limits of the Meadow Creek Lagoon. The logs of CPT soundings performed by the USGS are included with the Fugro (2009) report (Section 2.3.2). Holzer et al. (2004) also included a figure showing a portion of an 1873–1874 coastal survey sheet (a.k.a. T-sheet) prepared by the U.S. Coast Survey. The figure shows the approximate limits of an estero that was present in 1873–1874 relative to existing roads and surface water features. The estero area was subsequently "subdivided and turned into developable lots by leveling dunes and filling in swamp areas with dune sand in March 1927", according to Holzer et al. (2004). The limits of the pre-development estero encompass the Meadow Creek Lagoon Habitat Restoration project area. Holzer et al. (2004) also infer that the surficial geologic units prior to development consisted of fields of active to inactive sand dunes, marsh and tidal estuarine deposits, floodplain sediments deposited by Arroyo Grande and Meadow Creeks, and beach deposits in the existing residential neighborhood west of the project area.

2.3.2 Fugro (2009)

Fugro (2009) performed a preliminary geotechnical investigation of the Arroyo Grande Creek north and south levees. The investigation evaluated the potential for the site to be impacted by geologic hazards, analyzed static and seismic stability of levee slopes, and discussed geotechnical considerations for proposed levee raise alternatives. Field exploration activities included CPT soundings advanced along the crest of the north and south levees. CPT soundings were located approximately 1,700 feet or farther east of the Meadow Creek Lagoon Habitat Restoration project. The logs of the CPT soundings are presented in the report. Fugro (2009) concluded that the levee could be impacted by liquefaction and slope instability in response to an earthquake.

2.3.3 Geocon (2009)

Geocon (2009) performed a geotechnical investigation for the Visitor Center building at the Oceano Dunes State Vehicular Recreation Area (SVRA) located on Pier Avenue, approximately 2,200 feet north of the Meadow Creek Lagoon Habitat Restoration project. Field exploration activities included advancing three CPT soundings and drilling one hollow-stem-auger boring. The logs of the borings and CPT soundings are presented in the report. Laboratory testing for the project consisted of index tests for classification of the soil types encountered. Geocon (2009) reported that the site could be impacted by liquefaction and lateral spreading to a depth of approximately 25 ft below the ground surface and provided alternatives that included deep dynamic compaction, stone columns, vibro-compaction, deep soil mixing, and pre-fabricated earthquake drains for mitigating adverse impacts associated with those hazards.

2.3.4 Fugro (2012a)

Fugro (2012a) prepared a limited geotechnical report addressing seepage conditions along the existing north levee of Arroyo Grande Creek. The report included an evaluation of the potential for steady-state flow conditions to result in seepage through (i.e., through seepage) and under the levee (i.e., underseepage), instability of the levee slopes, the need for mitigation to address seepage conditions, and construction considerations relative to existing residences and land uses along the north levee. Field exploration activities consisted of three hollow-stem-auger borings drilled along the crest of the north levee. Borings were located approximately 750 feet or farther east of the Meadow Creek Lagoon Habitat Restoration project. The logs of borings are presented in the Fugro (2012a) report. Laboratory testing for the project included tests for triaxial compressive strength using consolidated undrained (CU) loading, direct shear strength (DS), and hydraulic conductivity. Fugro (2012a) reported that a section of the south levee was damaged by liquefaction of the alluvium underlying the levees during the 2003 San Simeon Earthquake. Fugro (2012a) noted that consideration of seismic hazards was not a part of the evaluation, and the County's goal for the project was to improve the north levee relative to flood control only.

2.3.5 Fugro (2012b)

Fugro (2012b) prepared a geotechnical report to further characterize subsurface conditions along the existing north levee of Arroyo Grande Creek and perform seepage and slope stability analyses as a basis for providing geotechnical recommendations for the design of previously proposed levee improvements. Field exploration activities consisted of five hollow-stem-auger borings drilled along the crest of the north levee. Borings were located approximately 5,400 feet or farther east of the Meadow Creek Lagoon Habitat Restoration project. The logs of the borings are presented in the Fugro (2012b) report. Laboratory test results presented in the report included tests for triaxial compressive strength using consolidated undrained (CU) loading, direct shear strength (DS), and hydraulic conductivity. Fugro (2012b) noted that the scope of the improvements was for flood protection only, per the direction of the County, and no seismic criteria were considered in evaluating the stability of the levee slopes.

2.3.6 Yeh and Associates (2019)

Yeh and Associates (2019) prepared a geotechnical report to provide recommendations for the design of a new clarifier, aeration basin, blower building, equipment pads and associated piping as part of the improvements to the SSLOCSD Wastewater Treatment Facility Redundancy Project. The project is located 450 feet NE of the Meadow Creek Lagoon Habitat Restoration Project. Field exploration activities included advancing CPT soundings and drilling borings within the limits of the SSLOCSD property. The logs of the CPT soundings and borings are presented in the report. The report also included geotechnical data collected by previous studies for the facility within the limits of the SSLOCSD property. Laboratory testing for the project included tests for triaxial compressive strength using consolidated undrained (CU) loading, direct shear strength (DS), and constant rate of strain (C) consolidation. Yeh and Associates (2019) reported that the site could be impacted by liquefaction to a depth of approximately 35 feet below the ground surface and provided alternatives that included deep soil mixing, driven piles, and vibro-stone columns for mitigating adverse impacts associated with those hazards. The project is under construction as of early 2021. Vibro-stone columns are being installed to mitigate the adverse impacts of liquefaction.

2.4 Geomorphic Assessment

2.4.1 Historical aerial photographs

The District provided historical aerial photographs of Arroyo Grande Creek and Meadow Creek near the confluence taken in 1939, before the construction of flood control infrastructure and development of the beachside residential areas (San Luis Obispo County Flood Control and Water Conservation District 1939). Aerial photographs of Dune Lakes and vicinity with unknow dates were also provided, but it is unlikely that the project area is covered in these photographs.

The Arroyo Grande Lagoon Interim Sandbar Management Plan (ESA PWA 2013) includes a sequence of historical aerial photographs of Meadow Creek Lagoon area from 1939 to 2013. The report also provides T-sheets (historical topographic mappings) of the areas from 1884 before the Southern Pacific Railroad was constructed through the valley; and from 1897 before intensive development of the valley began but after the construction of the railroad.

2.4.2 Sediment Management

Sediment loading information for Arroyo Grande and Meadow Creeks will be used to assess the relative sediment performance among the alternatives. For Arroyo Grande Creek, the sediment loading may be calculated from cross-sections measured as part to the sediment management plan and provided by the District (Cannon 2021a). Sediment yield estimates for Meadow and Arroyo Grande Creeks are also presented in Swanson Hydrology + Geomorphology (2006).

To facilitate sediment transport modeling, cbec will collect bedload samples at up to four locations on Arroyo Grande Creek to determine the particle size distribution required for modeling. Representative sediment samples (up to four) will be processed by a lab for grain size distribution. Suspended sediment concentrations will be derived from the suspended sediment rating curve presented in Swanson Hydrology + Geomorphology's 2006 report.

2.5 Topographic and Bathymetric Mappings

The terrain and bathymetry information of Meadow Creek and Arroyo Grande Lagoons and surrounding areas will be used to create a project base map and, if needed, a geometry input file for the hydraulic model. The terrain information surrounding both lagoons and channel geometry for Arroyo Grande Creek will be taken from Cannon's 2021 aerial survey DTM (Cannon 2021b), as-built drawings (2021c), or Central Coast Aerial Mapping's 2021 aerial survey topographical mapping (CCAM 2021). The bathymetric survey data for Arroyo Grande Lagoon (Cannon 2017a, 2017b) and Meadow Creek Lagoon (Cannon 2012a, 2012b) were provided by the District in both DWG and PDF formats. The Arroyo Grande Lagoon bathymetry extends from the mouth of the lagoon to Sand Canyon Outlet Structure. The Meadow Creek Lagoon bathymetry extends from Sand Canyon Outlet structure to Pier Avenue bridge. However, a large portion of Meadow Creek Lagoon is indicated to be inaccessible due to dense vegetation and therefore, the contours shown on the map were developed from an aerial survey performed in 2005 by Central Coast Aerial Mapping. Inc. The District also provided DWG, PDF, and Excel formats of the finished floor elevations of the low-lying residences within "The Island" neighborhood and along Fountain Avenue (Cannon 2011a) and an estimate of Meadow Creek Lagoon volume (Cannon 2011b). The horizonal and vertical controls used for the surveying efforts are as follows:

- Horizontal: CA State Plane Zone V, Epoch date 1991.35 at NGS Monument "HPGN CA 05 05" PID FV2048, San Luis Obispo County, CA.
- Vertical: NGS monument X 532 PID FV 0421, San Luis Obispo County, CA. Published Elevation of 13.5 ft NGVD 88.

The terrain and bathymetry information that is not covered in the above survey efforts may be based on a one-meter resolution raster digital elevation model (DEM) of costal topobathy data that is publicly available from NOAA website (NOAA 2013). The DEM was created in by merging topobathy Lidar and multibeam data obtained between 2009–2011. Bathymetry of Meadow Creek Lagoon between Pier Avenue and Pismo State Beach Road bridges will be based on cross-sections provided in the 2013 ESA HEC-RAS model. The 2013 NOAA topobathy DEM will be used to extend the Meadow Creek Lagoon model geometry upstream of Pismo State Beach Road, if necessary.

2.6 Civil Data

2.6.1 Utility

Utility mappings will be used to identify spatial constraints and opportunities when developing project alternatives. Engineering drawings (South San Luis Obispo County Sanitation District 1979, 1997) show a 36-in diameter ocean outfall buried along the north Arroyo Grande Creek levee. The centerline of the outfall is indicated to be 8 ft away from the northern toe of the levee, and the minimum cover is approximately 1 ft. Based on the additional utility mappings provided by the District, the underground utilities that are located near the project site and may potentially impact the alternatives design include: Water lines within Meadow Creek Lagoon, and across Pier Ave and Air Park; SoCalGas lines across Pier Ave and Lakeside Avenue; AT&T cables across Pier Ave and Air Park Ave; and Charter cables across Lakeside Avenue and Air Park Avenue.

2.6.2 Property and ROW

Property and ROW boundaries will be used to set spatial constraints and opportunities for the alternatives. Pertinent data in possession by Stillwater Sciences (Real Estate Portal USA 2018) will be used.

2.6.3 Engineering drawings

The as-built drawings of Arroyo Grande Creek (US Department of Agriculture Soil Conservation Services 1958) were provided by the District. The drawings show the alignments, profiles, typical cross sections for Arroyo Grande Creek and the levee system from Arroyo Grande Lagoon to about 900 ft upstream of its confluence with Los Berros Creek; and about a 3,600 ft long segment of Los Berros Creek. These drawings do not show updates to the levee system per the on-going flood control improvement project along Arroyo Grande Creek upstream of Delta Lane (Waterways Consulting 2010).

The as-built drawings of Arroyo Grande Creek upstream of Delta Lane and Los Berros Creek with improved levee (Cannon 2021c), as well as the DTM file developed from an aerial survey (Cannon 2021c), have been provided by the District.

The flap gates installed at the Sand Canyon Outlet Structure are called out, but the details are not provided in the drawings (discussed more in Section 2.6.5).

Engineering drawings of the pedestrian bridge across Carpenter Creek (County of San Luis Obispo Public Works Department) were also provided by the District.

The engineering drawings (South San Luis Obispo County Sanitation District 1979, 1997) of the ocean outfall along the north Arroyo Grande Creek levee have been provided by the District.

2.6.4 Levee improvement or maintenance records

The District is implementing in stages the flood control improvements along Arroyo Grande Creek upstream of Delta Lane and a portion of Los Berros Creek. Once completed, the project will provide protection up to the 20-year flow recurrence interval (Waterways Consulting 2010). During the 21 April 2021 kickoff meeting, the District clarified that the Arroyo Grande Creek levees upstream of Delta Lane have been raised as part of the project, and portions downstream of Delta Lane have not been altered. The improved levee profiles are included in the as-built drawings (Cannon 2021c) and DTM (Cannon 2021b) prepared from a recent aerial survey.

According to ESA (2016a), critical facilities have been protected with flood barriers and gates to approximately 14.4 ft NAVD 88 since the December 2010 flood event. Locations and details of these additional flood improvement features are unknown and should be provided to the Stillwater Sciences team so that the existing flood condition can be better characterized.

2.6.5 Sand Canyon Outlet Structure

The Sand Canyon Outlet Structure Alternative Analysis (CSL RCD 2013) report provides descriptions of the Sand Canyon Outlet structure. The structure consists of two arch pipe culverts approximately 48 inch by 71 inch in cross section and 65 ft long in length. The inlets of the culvers are equipped with a trash rack. At the outlet of each culvert are iron flap gates (Hydrogate model 50C or similar) that prevent flows from Arroyo Grande Creek from entering 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).

Based on the bathymetry survey data (Cannon 2012a, 2012b) the invert elevations of the two flap gates are 6.44 ft and 6.46 ft NAVD 88 on the inlet side; and 5.36 ft and 5.83 ft NAVD 88 on the outlet side. Another map (source and date unknown) provided by the District indicates the inlet and outlet invert elevations to be 7.13 ft NAVD 88 for both flap gates. The discrepancies in the invert elevations may be due to potential settling and/or sediment accumulation. The District's input is needed to better estimate the invert elevations of the flap gates under current conditions.

3 DATA GAPS

The purpose of this technical memorandum is to identity and prioritize data and information gaps and additional analysis required for the existing conditions synthesis (Proposed Task 3), and the alternative's analysis/conceptual design development (Proposed Task 4). Critical data and information gaps identified are summarized in Table 5.

Table 5. Data an information gaps.

Information gap	Specific action	Priority	Why data is needed
Annual water quality data	Obtain existing unpublished temperature data in lower AG Creek immediately upstream of Lagoon Collect conductivity/salinity, dissolved oxygen (D.O.), and temperature data within project footprint (Figure 1) and within Arroyo Grande Creek adjacent to the project	Medium (not currently included in proposed Task 3 scope)	Water quality data will allow for evaluation of habitat suitability for target species (e.g. D.O. for steelhead) under existing conditions, which in turn will inform the alternatives opportunities and constraints for maintaining or improving water quality
Arroyo Grande Creek bedload sediment grain-size distribution	Collect data	High (included in proposed Task 3 scope)	Sediment data is needed as an input for sediment transport modeling
Data on flood control improvements implemented around critical facilities per ESA (2016)	Obtain information and data regarding flood control improvements implemented around critical facilities (Section 2.6.4)	High	To develop a base map and to characterize existing flood hydraulic performance at the project site using HEC-RAS
Sand Canyon Outlet Structure flap gates invert elevations	Obtain as-built elevations	High	Correct flap gate invert elevations are needed for HEC-RAS modeling to characterize existing hydraulic conditions
Geotechnical Data	Collect site-specific boring and CPT data for three selected alternatives in proposed Task 4	High (to be included Task 4 scope)	Geologic hazards including liquefaction risk could impact levee placement selection and inform design requirements

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