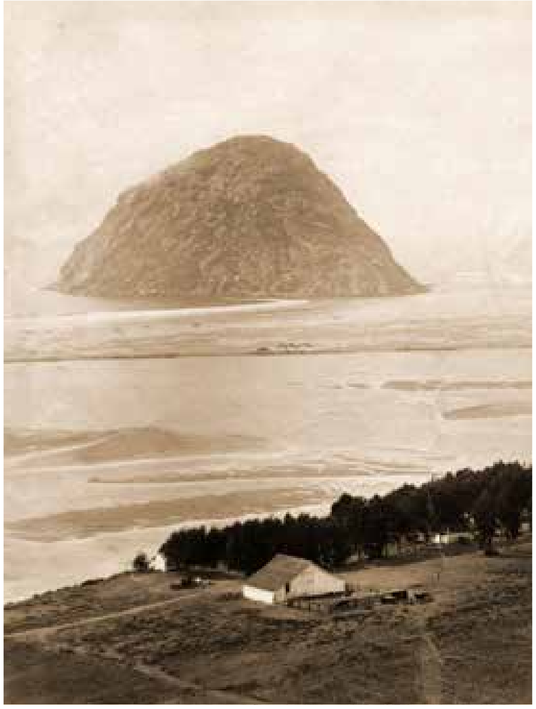
MORRO BAY HISTORICAL ECOLOGY STUDY

SFEI San Francisco Estuary Institute



MORRO BAY HISTORICAL ECOLOGY STUDY

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PROJECT PARTNERS
The Morro Bay National Estuary Program

FUNDED BY
United States Environmental Protection Agency

SFEI PUBLICATION #1291

June 2026

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SUGGESTED CITATION
Satzman BP, Baumgarten SA, Casendino H. 2026. *Morro Bay Historical Ecology Study.* Prepared for the Morro Bay National Estuary Program by SFEI's Resilient Landscape Program. Publication #1291, San Francisco Estuary Institute, Richmond, CA.

Version 1.0 (June 2026)

REPORT AVAILABILITY
Report is available at https://www.sfei.org/projects/morro-bay-historical-ecology

COVER CREDITS
Front: ***[top left] Modern photograph looking southwest from Black Hill:*** SFEI 2024, photograph by Sean Baumgarten; ***[middle left] Land Case Map of Rancho Cañada de Los Osos y Pecho y Islay:*** U.S. District Court ca. 1940, courtesy of The Bancroft Library; ***[middle right] Photograph of Morro Rock:*** SoCA Digitization Project 1880, courtesy of California State Library; ***[bottom left] U.S. Coast Survey map of "Moro [sic] Bay to Toro Point":*** Forney 1883, courtesy of NOAA; ***[bottom right] Modern photograph of Morro Bay from paleodunes:*** courtesy of the Morro Bay National Estuary Program. Back: ***Photograph looking north toward Morro Bay:*** Wieslander 1936, courtesy of University of California, Berkeley Digital Collections.

SFEI PUBLICATION
#1291

FUNDED BY
This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreements CE-98T25101 and 4T-98T47301 to the Bay Foundation of Morro Bay. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

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Introduction

Morro Bay and the Pacific Ocean seen from Black Hill • Photograph by Sean Baumgarten, SFEI.

STUDY GOAL AND OBJECTIVES

As one of the largest estuaries on the Central Coast of California, Morro Bay ("Bay") is a vital connection between the region's marine and terrestrial ecosystems and is recognized as a nationally significant estuary under the U.S. Environmental Protection Agency's National Estuary Program. The Bay and its watershed support an abundance of natural and cultural resources, with large areas of remnant and protected open space home to a range of native plants, fish, wildlife, and invertebrates. Eighteen state and federally listed species and nearly 100 sensitive species have been documented in the Morro Bay Watershed ("Watershed"), including South-Central California Coast steelhead trout *(Oncorhynchus mykiss)*, Southern sea otter *(Enhydra lutris nereis)*, California seablite *(Suaeda californica)*, and Morro shoulderband snail *(Helmithoglypta walkeriana)* (Sims 2010, Fields et al. 2024).

Ecosystems around Morro Bay face a number of threats, including habitat loss and fragmentation, erosion and sedimentation, water quality degradation, freshwater diversion, invasive species, wildfire, and sea level rise. Urban and agricultural development have directly contributed to substantial loss of sensitive habitat types such as freshwater marsh and maritime chaparral. Watershed erosion driven by ranching and other land use changes has resulted in increased rates of sediment deposition in the Bay and tributary streams, reducing tidal prism volumes and contributing to loss of eelgrass habitat in the Morro Bay Estuary ("Estuary") and impairment of steelhead spawning habitat upstream (Haltiner and Thor 1991, MBNEP 2022). Straightening of stream channels, along with groundwater pumping and other water diversions, has resulted in loss of riparian and wetland habitat, reduced floodplain connectivity, and altered streamflow patterns (MBNEP 2022).

Land managers seeking to enhance the health and resilience of ecosystems in and around Morro Bay need information about historical landscape functioning, in addition to intentional engagement with Native communities who are the original caretakers of this land, to guide management, planning, and design of habitat restoration and improvement projects. This study aims to support ecosystem management and restoration efforts in the region by synthesizing archival data to document and map historical landscape conditions in Morro Bay and surrounding areas. The primary objective of the study was to map the spatial configuration of habitat types and channels in the region prior to major Euro-American modification. Limited research was also conducted on topics such as historical hydrologic patterns, wildlife presence, and land use history, though further research will be needed to fully investigate these and other topics.

SETTING AND STUDY AREA

Morro Bay lies at the western-most extent of the Morro Bay Watershed (~197 km^2 or ~76 mi^2) in San Luis Obispo (SLO) County on the Central Coast of California. The Bay formed 10,000-15,000 years ago, as rising sea levels following the last glacial period flooded the river valley at the mouths of Chorro and Los Osos creeks (Haltiner and Thor 1991). Morro Bay is bordered by a sandspit along most of its length, except for a narrow inlet at its northwest corner where tidal exchange occurs. Chorro Creek and Los Osos Creek are the two largest tributaries to the Bay. Chorro Creek originates in the foothills of the Santa Lucia Mountains and flows westward through Chorro Valley. Los Osos Creek originates in the Irish Hills of the San Luis Range and flows north through Los Osos Valley. Chorro Creek and Los Osos Creek drain approximately 112 and 68 km^2 (43 and 26 mi^2), respectively. The lower portion of Morro Creek, also within the limits of the study area, flows southwest from the Santa Lucia Mountains, before draining into the Pacific Ocean just north of the entrance to the Estuary.

> "As one of the largest estuaries on the Central Coast of California, Morro Bay is a vital connection between the region's marine and terrestrial ecosystems and is recognized as a nationally significant estuary under the US EPA National Estuary Program"

Habitats in the Morro Bay Estuary include salt and brackish marshes, intertidal mud flats, eelgrass beds and subtidal habitats (MBNEP 2022). The rest of the Watershed includes a varied assemblage of pioneer dunes, coastal dune scrub, maritime chaparral, oak woodland, California prairie ("prairie") and riparian woodland (MBNEP 2018). Most of the Watershed is open space that is utilized for agriculture, ranching, parks, golf courses, nature preserves, a military base, and California Polytechnic State University-owned rangeland (MBNEP 2022). The developed portions of the Watershed include the City of Morro Bay, Los Osos/Baywood Park communities, Cuesta College, the California Men's Colony, and a number of facilities operated by the County of San Luis Obispo (MBNEP 2022).

The study area encompasses approximately 59 km^2 (23 mi^2) of the Morro Bay Watershed (Fig. 1). It extends from Morro Creek on the north to six miles south of the creek, approximately following the extent of the old wind-blown (eolian) deposits of the late to middle Pleistocene (known as "paleodunes") in the Los Osos/Baywood Park area (Wiegers 2021). The western boundary of the study area includes Morro Rock and the Morro Bay sandspit. The eastern extent of the study area corresponds approximately to the alluvial valley deposits of the Holocene and late Pleistocene found in Chorro and Los Osos valleys (Wiegers 2021). The study area does not include the surrounding hillslopes outside of the valley floor areas.

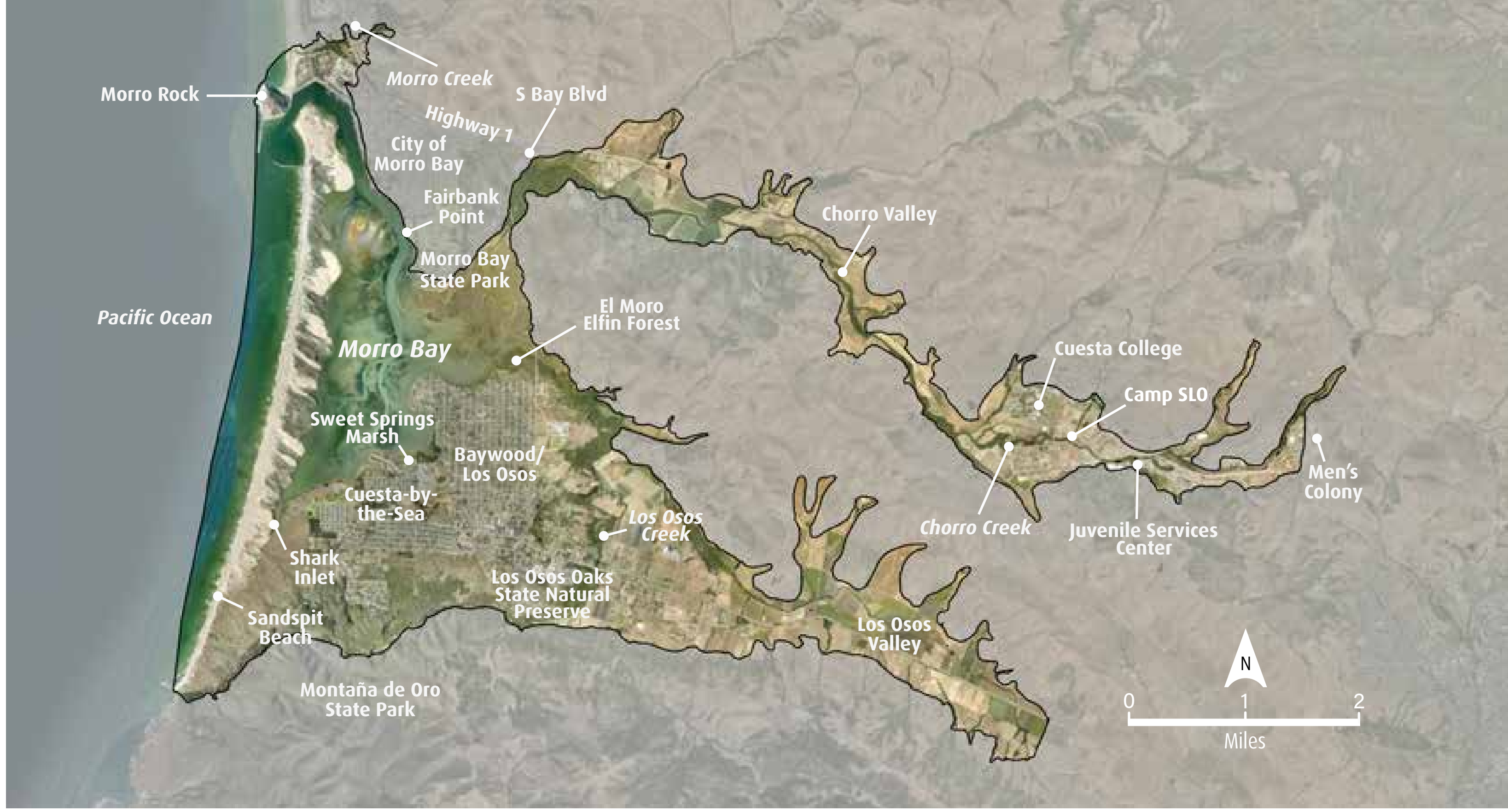


Figure 1. The project study area, which includes the Morro Bay Estuary, Morro Rock, the sandspit, the young alluvial deposits of Chorro Valley and Los Osos Valley, and the old eolian deposits in the Baywood/Los Osos area. The study area encompasses 59 km^2 (23 mi^2) of the Morro Bay Watershed (197 km^2 or 76 mi^2).

NATIVE LAND MANAGEMENT

Since time immemorial, San Luis Obispo County and the Central Coast region have been the ancestral territory of yak tityu tityu yak tiłhini (ytt) Northern Chumash and the Salinan people, who continue to steward their cultural and ecological heritage.* Prior to European colonization, the Central Coast had been home to a Native American population for at least 10,000 years (Miller 1988). The Morro Bay area has supported human habitation for thousands of years, with archeological evidence documenting a continuous presence of Native peoples along the Estuary and surrounding landscapes (Hoover 1976, Jones et al. 2019). Native inhabitants of Morro Bay had numerous seasonal settlements along the rim of the Estuary and the lower reaches of Morro Creek, as well as shell middens on the sandspit (Hoover 1976, Sullivan 1994). Some estimates suggest Native populations peaked in Central California sometime around 1500-1600 C.E. At the time of European contact, it is estimated that roughly 4-5 Native villages were in the Morro Bay area, totaling approximately 280 individuals (Milliken and Johnson 2005).

The native wildlife and plants of the Central Coast served as important cultural resources for the Northern Chumash and Salinan people. Native inhabitants made beads from olivella shells (*Olivella* spp.) and other animal bones (Miller 1988), and hunted for nearshore fish (e.g., rockfish [*Sebastes* spp.], Pacific sardine [*Sardinops sagax caerulea*], cabezon [*Scorpaenichthys marmoratus*], and herring [*Clupea pallasii*]) in the Estuary and ocean and anadromous fish (e.g., steelhead [*Oncorhynchus mykiss*]) in the major streams (Angel 1883, SLOCAS 2000, K. White pers. comm.). Tule reeds (*Schoenoplectus* spp.) were woven into sleeping mats

*The historical boundary between ancestral territories is a matter of ongoing disagreement. Statements in this report are not intended to support any particular claims.

(K. White pers. comm.) and used to make canoes, while peeled willow trees (*Salix* spp.) were often used to construct dwellings (Hoover 1976, Sullivan 1994, Miller 1988, SLOCAS 2000), spears, and baby cradles (K. White pers. comm.). California sawgrass (*Cladium californicum*), rushes (*Juncus* spp.), and tule roots were commonly used to weave baskets (K. White pers. comm.). Acorns, fish, and deer served as culturally-important staple food resources (Miller 1988), alongside saltgrass (*Distichlis spicata*; adding a salty flavor to meat), seaweed (roasted or dried), berries from toyon (*Heteromeles arbutifolia*; dried and eaten raw or cooked), and manzanita (*Arctostaphylos* spp.; both berries and leaves eaten) (K. White pers. comm.).

Native peoples were direct stewards of the land and carefully managed it for provisioning and cultural enrichment through practices such as intentional burning and seed dispersal with plant-specific care (K. Shaffer pers. comm.). For example, the Northern Chumash burned prairies and chaparral to curb the succession of brushy vegetation and to amass the kinds of seeds and bulb plants that were important to their economy (Hoover 1976, Jones et al. 2019). Juan Crespí's 1769 journal from the Portolá Expedition documented cultural burning just outside the project's study area, describing "dry grasses that had been burned off in some spots but not in others" (Crespí and Brown 2001).

The Morro Bay region continues to be a vital place supporting Indigenous lifeways and traditional practices. Native peoples are still here today living with and caring for the many species that rely on this vital connection of freshwater and saltwater habitats (K. Shaffer pers. comm.). ytt Northern Chumash tribal members, for instance, have been actively returning intentional low-intensity burns to their ancestral homelands for the restoration and cultivation of seeds and grasslands (R. Lucas pers. comm.).

HISTORY OF LAND USE CHANGES

Changes to the Morro Bay Watershed have occurred since the late 18th century, beginning with the arrival of Spanish colonizers, the decimation and displacement of Native peoples, and establishment of the nearby Mission San Luis Obispo de Tolosa in 1772. The mission era marked a shift from Native American stewardship of the landscape to intensive livestock grazing, agriculture, and fire suppression (Gamble 2011, Broadman et al. 2022). Despite the collapse of Spanish rule and the California mission system, the 19th century saw even greater land use changes. Between 1822 and 1846 the Mexican Government granted ranchos to wealthy private citizens across San Luis Obispo County, including seven that covered nearly the entirety of the project study area (Mandeville 1858a, Mandeville 1858b, Mandeville 1860, Mandeville 1861, Drummond 1871, Rollins 1877, Mandeville 1888, Hoover 1976; Fig. 2). One estimate suggested "three thousand head of cattle" were grazing the Rancho Cañada de Los Osos y Pecho y Islay in 1852 (USDC 1852). By the late 1850s, homesteading, farming, dairy production, and the widespread seeding of non-native plants (most prominently, invasive grasses) became common practices by American settlers in the area (Shinn 1901, McKennon 1959, Tognazzini 1995). The late 19th and early 20th centuries saw increased dredging of the entrance to Morro Bay, quarrying of Morro Rock, and the plotting of localities such as the towns of Morro Bay, Baywood Park and Los Osos (Hoover 1976, Bailey 1982, CA Dept. Parks and Rec 1988, History of Morro Bay n.d.). Notably, the Works Progress Administration filled in the northern channel to Morro Bay in 1933 to facilitate access to Morro Rock and manage tidal currents within the harbor (CA Dept. Parks and Rec 1988; Fig. 3). Around the same time, Lower Morro Creek, historically a source of freshwater input for the Bay, was diverted to drain into the Pacific Ocean (McKennon 1959).

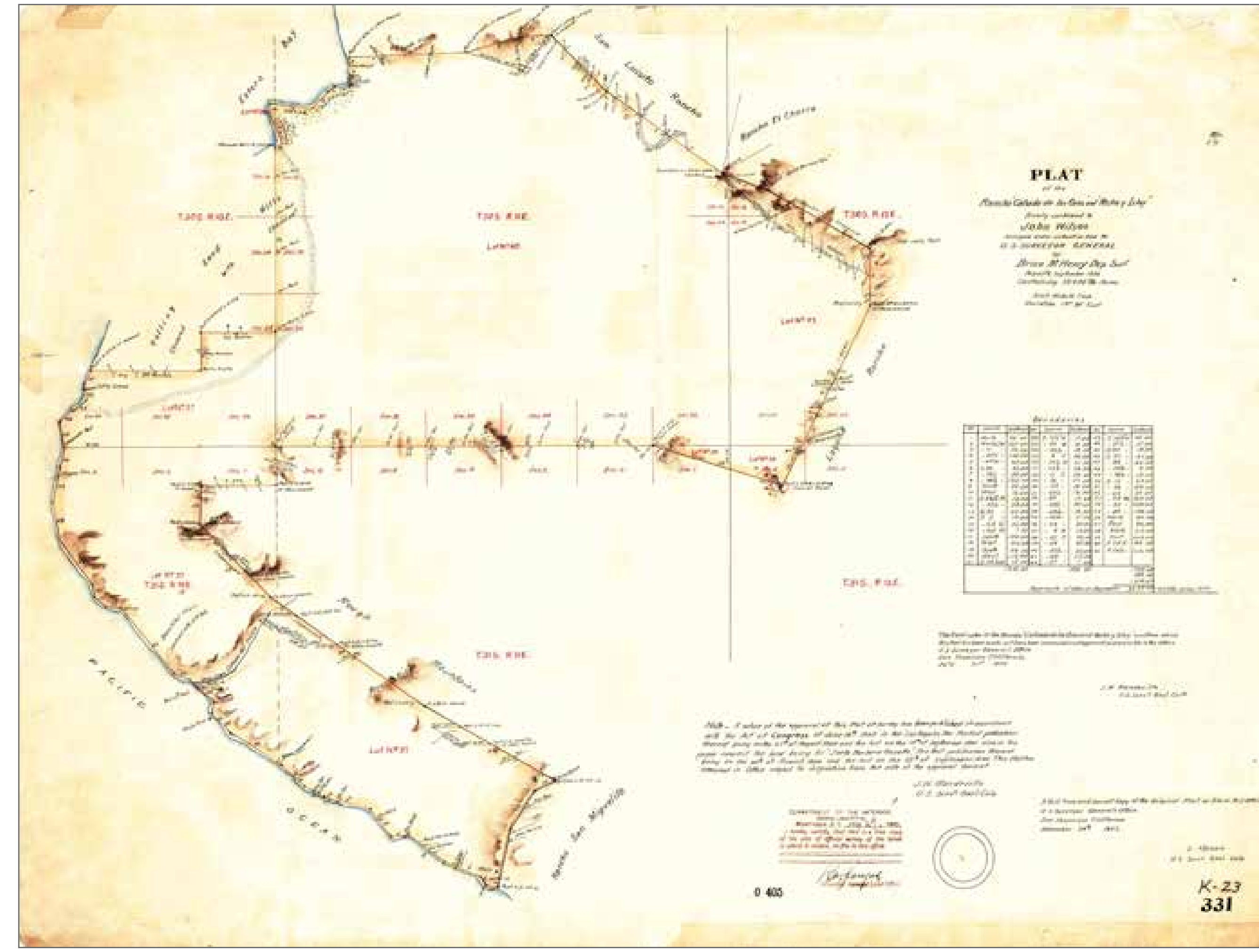


Figure 2. Plat of the Rancho Cañada de Los Osos y Pecho y Islay, one of seven ranchos that covered the study area. Ranchos were granted for the primary purpose of raising livestock. *(Mandeville 1860, courtesy of the Bureau of Land Management [BLM])*

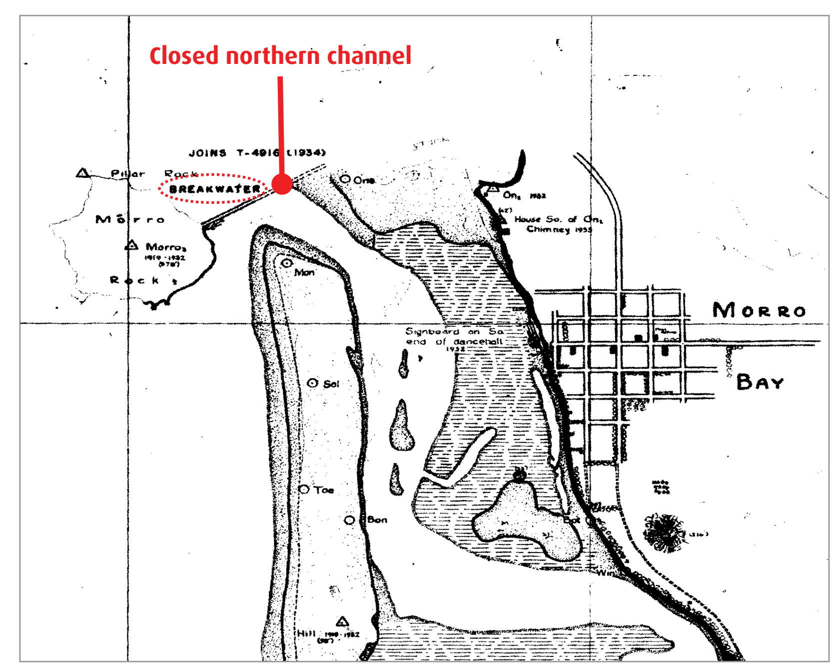


Figure 3. U.S. Coast Survey T-Sheet from 1935 depicting the closed northern channel to Morro Bay, completed by the Works Progress Administration just two years earlier. (*Prudomes 1935, courtesy of NOAA*)

Picture yourself at the mouth of Morro Bay in 1769. In every direction, the Bay presents a busy tableau of life, with thriving ecosystems under Indigenous stewardship. Sea otters hunt and play in the surf. Sharks, rays, and a myriad of fish dart beneath the surface of the water, weaving through dense stands of eelgrass. In the distance, a family of grizzly bears ambles across the sand dunes, hunting for prey and digging for edible bulbs. Songbirds flit through a dense willow grove bordering the salt marsh, looking for a sheltered place to build a nest. As the tide flows out, you hear the calls of thousands of shorebirds arriving to forage on the expanses of mudflats emerging throughout the Bay. Each species responds to daily and seasonal variations in the environment, and in turn contributes to the complex and interconnected ecosystems of this rich Estuary.

Birds foraging in nearshore habitat near State Park Marina • Photograph by Morro Bay National Estuary Program.

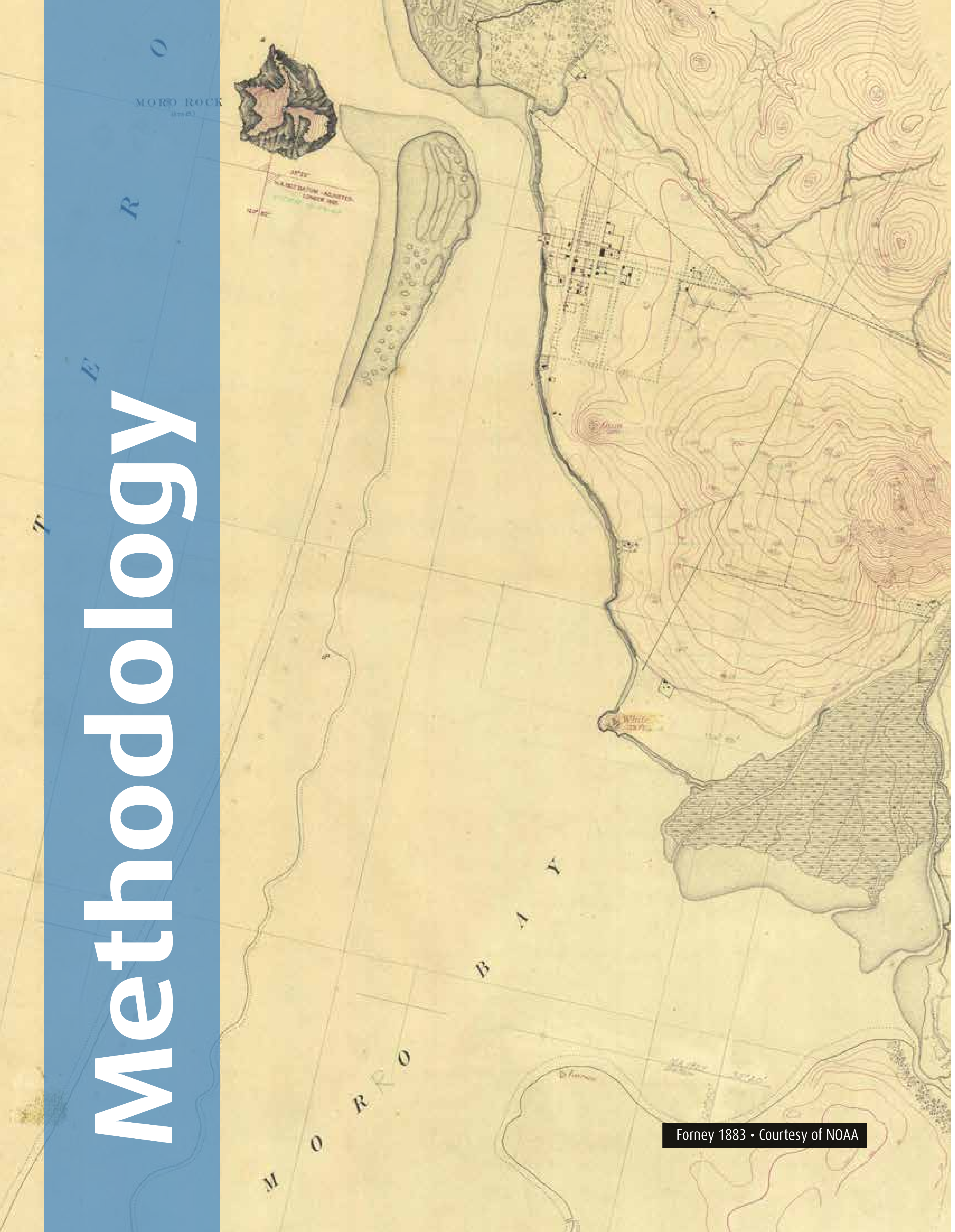
Cumulatively, these land use changes have had wide-ranging effects on the distribution, composition, and structure of habitats in the Watershed and have altered support for wildlife and other ecological functions. For instance, increased sediment inputs in the Watershed from ranching, farming, and other land uses decreased the volume of Morro Bay by an estimated 21% in the 114-year period between 1884-1998 (PWA 2002), and increased the area of tidal marsh by an estimated 80 ha (200 ac) in the 104-year period between 1884 and 1988 (Haltiner and Thor 1988, Haltiner and Thor 1991). Other documented impacts of sedimentation on the Estuary include decreased water quality and habitat richness, reduced circulation, and lower light penetration, which can threaten endemic species' habitats (Broadman et al. 2022). Meanwhile, clearing of the upland areas for ranching and agriculture has resulted in the loss of freshwater marshes, seasonal wetlands, and riparian forests, and promoted the conversion of native prairie and oak woodlands to grasslands dominated by non-native species (Broadman et al. 2022).

SUMMARY OF KEY FINDINGS

This section presents a brief summary of key findings from the historical research. A more detailed discussion of historical landscape conditions is presented in on pages 22-57.

- **The Morro Bay Estuary was historically dominated by shallow open water, extensive intertidal mudflats, and a mix of salt and brackish tidal marsh** concentrated near mouths of the creek valleys. A tidal connection to Morro Bay existed both to the north and south of Morro Rock.
- **The Morro Bay sandspit supported a mix of sparsely vegetated mobile dunes and denser coastal dune scrub, while the extensive paleodunes** south of Morro Bay supported a dynamic mosaic of maritime chaparral and coastal dune scrub.
- **Creeks in the surrounding valleys were generally characterized by single-threaded channels and were lined by riparian forests dominated by willows, oaks, and sycamores.** Chorro Creek was multi-threaded in its lowest reaches. Some channels such as Chorro and San Bernardo creeks likely supported perennial streamflow, while others such as Warden and Los Osos creeks may have experienced intermittent flow, according to late 19th and early 20th century sources.
- **While the configuration of Lower Morro Creek varied in response to flood events**, it typically directed flows into the northern end of Morro Bay, where it emptied onto the tidal flat just opposite the entrance to the Bay.
- **Several large willow groves** bordered Lower Morro Creek, Warden Creek, and the lower portion of Chorro Creek.
- **Chorro and Los Osos valleys were characterized by expansive prairie across most of the valley floor.** Northern Chumash managed prairie and other habitat types in the area through cultural burning and other practices.
- **A large freshwater marsh known as Warden Lake occupied the floor of Los Osos Valley at the confluence of Warden and Los Osos creeks**, while a smaller freshwater marsh known as the "Ciénega de Romualdo" existed just south of the Chorro Creek channel near the present-day Juvenile Services Center.

Methodology



Forney 1883 • Courtesy of NOAA

HISTORICAL ECOLOGY OVERVIEW

The use of historical data to study past ecosystem characteristics is an interdisciplinary field called historical ecology (Swetnam et al. 1999, Rhemtulla and Mladenhoff 2007). Research in historical ecology can provide foundational information about historical landscape patterns (e.g., habitat distribution and channel configuration), processes (e.g., streamflow variability), and functions (e.g., wildlife use), and provides the basis for evaluating landscape change over time. Findings can help identify contemporary management opportunities and constraints and provide critical context when setting restoration goals and targets (Beller et al. 2020).

Constructing an accurate picture of historical landscape patterns requires the integration, comparison, and interpretation of many independent sources (Grossinger et al. 2007). Where possible, historical landscape features in the study area were documented using multiple sources from varying years and authors to ensure accurate interpretation. The following section details how these sources were collected, interpreted, and used to create maps of historical habitat types and channels.

DATA COLLECTION AND COMPILATION

Archival data used to reconstruct the historical landscape of Morro Bay were collected from numerous online databases as well as local, regional, county, and state archives (History Center of SLO, Cal Poly Kennedy Library, SLO Public Library, UC Berkeley Bancroft Library and Earth Science and Map Library, Huntington Library, UC Riverside Water Resources Collections & Archives, California State Library, California Historical Society, California State Parks, Bureau of Land Management, and others). Using a list of local search terms, data collection efforts focused on information related to channel configuration and habitat extent, distribution, and composition. Limited information about other topics, such as hydrology, wildlife presence, and land use changes, was collected incidentally where relevant, but not searched for systematically.

The assembled dataset includes a variety of historical data types, including maps (e.g., U.S. Coast Survey T-Sheets and H-Sheets, Mexican land grant maps, General Land Office [GLO] survey plats, U.S. Geological Survey [USGS] topographic quads, a U.S. Department of Agriculture [USDA] soil map, parcel and subdivision maps, Wieslander Vegetation Type Mapping and plots), photographs (landscape and aerial), and textual documents (e.g., early explorer accounts, GLO field notes, newspaper articles, specimen records). Also included are contemporary technical reports and Geographic Information Systems (GIS) data layers such as a preliminary geologic map of SLO County (Wiegers 2021), National Hydrography Dataset (USGS 2023), California Aquatic Resources Inventory (SFEI 2025), and LiDAR (NOAA 2018). Altogether, the dataset includes approximately 320 landscape and aerial photographs, 140 textual documents, and 100 unique map sources.

Sources with sufficiently high spatial accuracy and/or detailed descriptions of landscape features were compiled and georeferenced in a GIS database. The georeferenced data

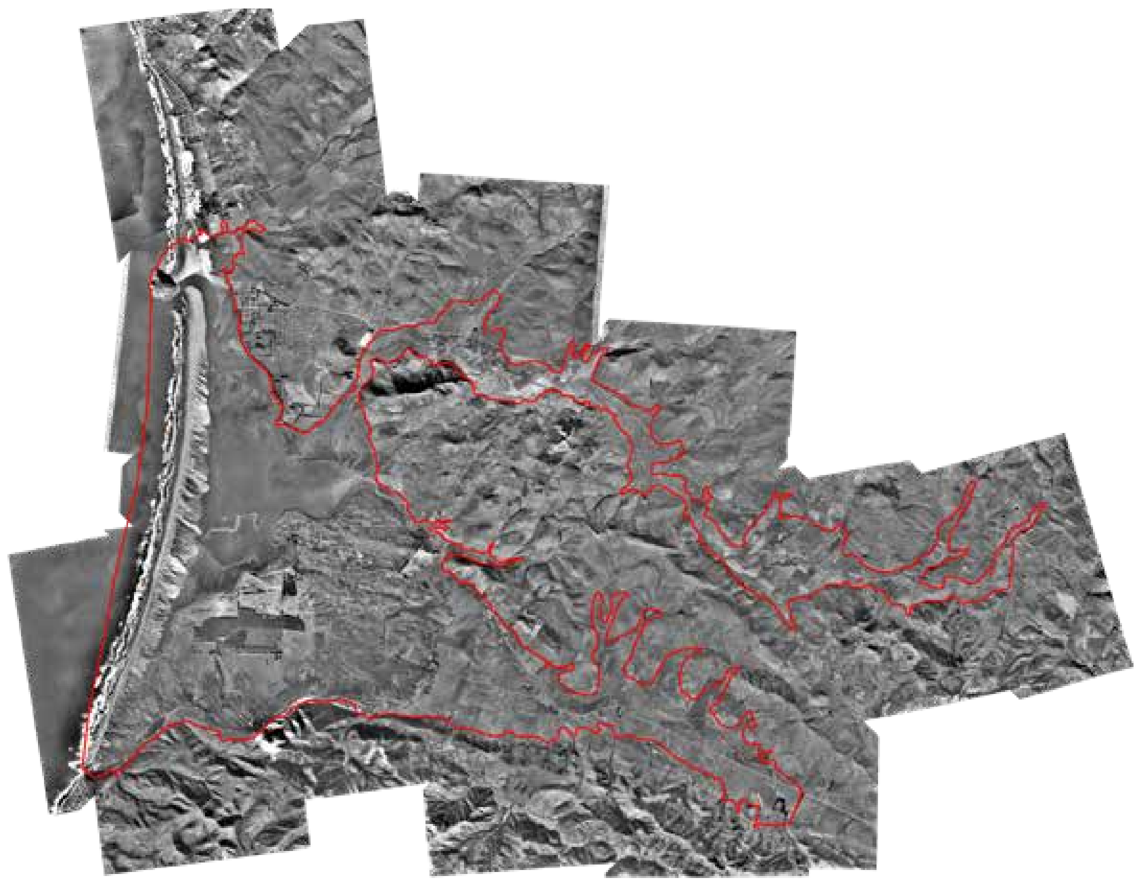


Figure 4. Photomosaic of historical aerial imagery, flown in 1937, of San Luis Obispo County. The study area boundary is outlined in red. (*United States Army 1937, courtesy of UCSB*)

includes approximately 40 historical maps, as well as spatially explicit narrative data such as early explorer accounts, GLO field notes, and records from species databases such as the Consortium of California Herbaria (CCH) and the Global Biodiversity Information Facility (GBIF). Thirty-six historical photographs, taken between the 19th to mid-20th centuries, were also geolocated. A key data source for the study is a historical aerial photomosaic of the entire study area consisting of mosaicked aerial photos from 1937, created by the San Francisco Estuary Institute (SFEI) for the purpose of this study (United States Army 1937; Fig. 4).

DATA SYNTHESIS AND MAPPING

The collected data were synthesized and interpreted to develop two GIS layers representing the prevailing historical distribution of estuarine, marine, palustrine, riparian, and terrestrial habitat types and the configuration of the drainage network during the mid-19th century. Habitats were mapped as polygon features and assigned to one of 18 habitat types, defined by a combination of vegetation cover,* substrate and hydrology characteristics (Table 1). Drainage features, including mainstem channels, key tributaries and tidal sloughs, were mapped as line features. Channels in the valleys were classified as "stream channels," while those in the Estuary were classified as "tidal channels."

*This study only addresses the presence of vascular plants.

Habitat polygons and drainage features were mapped from the most spatially accurate sources believed to be representative of historical landscape condition and configuration. In most cases, marine, dune, and estuarine features were digitized from either the U.S. Coast Survey T-Sheets, H-Sheets, or a combination of both. Mapping of estuarine habitats (e.g., deep bay/channel, shallow bay/channel, and tidal flat/channel) is consistent with tidal elevation ranges used in prior SFEI historical ecology studies (Grossinger et al. 2011, Safran et al. 2017). The 1.8 m (6 ft) and 3.6 m (12 ft) below mean lower low water (MLLW) contours were also mapped, but are not differentiated in the included maps. Palustrine, riparian, and terrestrial features were largely digitized from spatially accurate historical sources such as the 1937 aerial photographs, 1928 USDA soil map, or 19th century subdivision and tract maps. A variety of early sources (i.e., mid-late 19th and early 20th century maps, textual data, and photographs) were used to confirm the historical presence of features and establish their approximate shape, size, location, and classification. Mapped features were attributed in the GIS with supporting sources as well as certainty levels for shape, location, and interpretation (i.e., classification; Table 2). Riparian forests greater than ~20 m (~66 ft) wide were mapped directly from the historical aerial photos, rancho subdivision maps, and T-Sheets. For creek segments where the available evidence suggested riparian corridors were narrower than ~20 m (~66 ft) wide, riparian forest was mapped by applying a uniform 20 m (66 ft) buffer to the applicable channel segment.

View looking southeast over Morro Bay State Park and Chorro Marsh • Courtesy of Jeff Ebner, CA State Parks.

Table 1. Nineteen habitat and channel types, defined by a combination of landscape position, vegetation cover, substrate, and hydrology, were used to capture historical landscape patterns in the GIS mapping.

The list of characteristic plants reflects some of the dominant or characteristic plant species likely associated with each habitat type that were documented in historical botanical records (data from CCH) or other historical sources, though is not a comprehensive list of plant community composition. Historical taxonomic names were standardized in accordance with the Integrated Taxonomic Information System (www.itis.gov). Habitat associations were determined through descriptions in the CCH data, modern botanical references (Calflora.org, Keil and Hoover 2022), and expert knowledge (D. Keil, W. Ferren pers. comm.). Additional species not explicitly documented in the historical record were added to the list of characteristic plants based on expert knowledge, and are indicated with an asterisk. In some cases the historical classes include multiple plant communities that would likely not have occurred in direct association with each other in the wild.

Due to limitations of the historical data sources, many of the historical habitat types are more general than classes used in modern classification systems. The table includes crosswalks to corresponding classes used in modern classification systems for wetland and deepwater habitats (Cowardin et al. 1979), riparian habitats (USFWS 2019), and vegetation alliances (CNPS 2025). The Manual of California Vegetation alliances listed here are intended to capture most of the major corresponding alliances, though may not be comprehensive.

* Species not documented in historical records.

** California Prairie refers to historical terrestrial habitats dominated by native forbs and grasses. Most modern grasslands in the area are dominated by non-native vegetation.

System	Class	Description	Characteristic Plants	Substrate	Hydrology	Cowardin et al. (1979)/USFWS 2019	Manual of California Vegetation Classes (CNPS 2025)
Riverine	**Stream Channel**	Non-tidal, perennial or intermittent rivers or creeks.	**Herbs:** Horned pondweed (*Zannichellia palustris*),* *Potamogeton* spp.,* mosquito fern (*Azolla filiculoides*),* duckweed (*Lemna* spp.)*	Alluvium.	Perennial or intermittent surface flow.	Riverine Perennial Unconsolidated Bottom Riverine Perennial Aquatic Bed Riverine Intermittent Unconsolidated Bottom Riverine Intermittent Unconsolidated Shore Riverine Intermittent Nonpersistent Emergent Riverine Intermittent Aquatic Bed	*Stuckenia (pectinata) - Potamogeton* spp. Herbaceous Alliance, *Azolla (filiculoides, microphylla)* Herbaceous Alliance
Estuarine/ Marine	**Beach**	Ocean and bay shoreline dominated by sandy substrate.		Well-drained sands.	Frequent tidal flooding.	Estuarine Intertidal Unconsolidated Shore Marine Intertidal Unconsolidated Shore	
	Shallow Bay/ Channel	Subtidal estuarine areas between the elevation of Mean Lower Low Water (MLLW) and 5.5 m (18 ft) below MLLW.	**Herbs:** Eelgrass (*Zostera marina*)	Mud or sand.	Permanently tidally inundated.	Estuarine Subtidal Unconsolidated Bottom Estuarine Subtidal Aquatic Bed	*Zostera (marina, pacifica)* Pacific Aquatic Herbaceous Alliance
	Deep Bay/ Channel	Subtidal estuarine areas deeper than 5.5 m (18 ft) below below MLLW.		Mud or sand.	Permanently tidally inundated.	Estuarine Subtidal Unconsolidated Bottom Marine Subtidal	
	Tidal Flat/ Channel	Intertidal habitat exposed between low and high tides.	**Herbs:** Eelgrass (*Zostera marina*)	Mud or sand.	Daily tidal flooding.	Estuarine Intertidal Unconsolidated Shore Estuarine Intertidal Aquatic Bed	*Zostera (marina, pacifica)* Pacific Aquatic Herbaceous Alliance
	Tidal Salt Marsh	Vegetated, tidally influenced saline wetlands.	**Herbs:** Pickleweed (*Salicornia pacifica*), alkali heath (*Frankenia salina*), marsh jaumea (*Jaumea carnosa*), Watson's saltbush (*Atriplex watsonii*), sticky sandspurry (*Spergularia macrotheca*), dodder (*Cuscuta pacifica* var. *pacifica*), California saltbush (*Extriplex californica*), California sealavender (*Limonium californicum*), Point Reyes bird's-beak (*Chloropyron maritimum* ssp. *palustre*),* alkali bulrush (*Bolboschoenus maritimus*), Leopold's rush (*Juncus acutus* ssp. *leopoldii*), arrow grass (*Triglochin concinna*), saltgrass (*Distichlis spicata*) **Shrubs:** California seablite (*Suaeda californica*)	Organic soils.	Frequent tidal flooding.	Estuarine Intertidal Emergent Estuarine Intertidal Scrub/Shrub (possible for *Suaeda*-dominated wetlands)	*Sarcocornia pacifica* Herbaceous Alliance, *Distichlis spicata - Frankenia salina* Coastal Herbaceous Alliance
	Tidal Brackish Marsh	Vegetated, tidally influenced brackish wetlands.	**Herbs:** Alkali bulrush (*Bolboschoenus maritimus*), sturdy bulrush (*Bolboschoenus robustus*), tule (*Schoenoplectus acutus* var. *occidentalis*), California bulrush (*Schoenoplectus californicus*), chairmaker's bulrush (*Schoenoplectus americanus*), common threesquare bulrush (*Schoenoplectus pungens* var. *longispicatus*), slough sedge (*Carex obnupta*), slim sedge (*Carex praegracilis*), salt rush (*Juncus lesueurii*),* saltgrass (*Distichlis spicata*), Nevada goldenrod (*Solidago confinis*), tall coastal plantain (*Plantago subnuda*), Pacific silverweed (*Potentilla anserina* ssp. *pacifica*), low bulrush (*Isolepis cernua*), low barley (*Hordeum depressum*), sago pondweed (*Stuckenia pectinata*)	Organic soils.	Frequent tidal flooding.	Estuarine Intertidal Emergent	*Bolboschoenus maritimus* Herbaceous Alliance, *Carex obnupta - Oenanthe sarmentosa - Scirpus microcarpus* Herbaceous Alliance, *Juncus (effusus, patens) - Carex (pansa, praegracilis)* Herbaceous Alliance, *Schoenoplectus (acutus, californicus)* Herbaceous Alliance
	Tidal Marsh Panne/Pond	Shallow depressions that form within the marsh plain and often develop higher salinities than the surrounding marsh	**Herbs:** Ditch grass (*Ruppia maritima*)*	Organic soils.	Frequent tidal flooding.	Estuarine Intertidal Unconsolidated Shore Estuarine Intertidal Aquatic Bed	*Ruppia (cirrhosa, maritima)* Herbaceous Alliance

System	Class	Description	Characteristic Plants	Substrate	Hydrology	Cowardin et al. (1979)/USFWS 2019	Manual of California Vegetation Classes (CNPS 2025)
Palustrine	Valley Freshwater Marsh	Temporarily to permanently flooded nontidal wetlands dominated by tules (*Schoenoplectus* spp.) and other emergent vegetation. May include areas of unvegetated open water.	**Herbs:** Bulrushes (*Schoenoplectus* spp.), broadleaf cattail (*Typha latifolia*), Santa Barbara sedge (*Carex barbarae*), Harford's sedge (*Carex harfordii*), slough sedge (*Carex obnupta*), rushes (*Juncus* spp.), water parsley (*Oenanthe sarmentosa*) **Shrubs/Trees:** California wax myrtle (*Morella californica*), Western dogwood (*Cornus sericea* ssp. *occidentalis*)	Poorly drained clay and clay loam soils.	Semi-permanently to perennially flooded; subsurface perennially saturated.	Palustrine Emergent	*Schoenoplectus (acutus, californicus)* Herbaceous Alliance, *Typha (angustifolia, domingensis, latifolia)* Herbaceous Alliance, *Carex obnupta - Oenanthe sarmentosa - Scirpus microcarpus* Herbaceous Alliance
	Wet Meadow/ Seasonal Wetland	Wetland dominated by herbaceous cover on poorly drained soils that are seasonally flooded.	**Herbs:** Brown-headed rush (*Juncus phaeocephalus*), spreading rush (*Juncus patens*),* salt rush (*Juncus lesueurii*),* pale spikerush (*Eleocharis macrostachya*), *Carex* spp., saltmarsh bulrush (*Bolboschoenus maritimus* ssp. *paludosus*), common threesquare bulrush (*Schoenoplectus pungens* var. *longispicatus*), California meadow barley (*Hordeum brachyantherum* subsp. *californicum*), creeping wild rye (*Elymus triticoides*),* roundleaf leather-root (*Hoita orbicularis*), cows clover (*Trifolium wormskioldii*),* pacific silverweed (*Potentilla anserina* var. *pacifica*), water parsley (*Oenanthe sarmentosa*), lesser water-parsnip (*Berula erecta*),* broadleaf cattail (*Typha latifolia*), bur-reed (*Sparganium eurycarpum*), *Schoenoplectus* spp., seep monkeyflower (*Erythranthe guttata*),* fringed willowherb (*Epilobium ciliatum*), Western goldentop (*Euthamia occidentalis*), Southern goldenrod (*Solidago confinis*), bugle hedgenettle (*Stachys ajugoides*), adobe snakeroot (*Sanicula maritima*), Hoover's button-celery (*Eryngium aristulatum* var. *hooveri*), Congon's tarplant (*Centromadia parryi* subsp. *congdonii*), saline clover (*Trifolium hydrophilum*)*	Poorly drained clay soils.	Temporarily to seasonally flooded; soils seasonally saturated.	Palustrine Emergent	*Juncus (effusus, patens) - Carex (pansa, praegracilis)* Herbaceous Alliance, *Typha (angustifolia, domingensis, latifolia)* Herbaceous Alliance, *Deschampsia cespitosa - Hordeum brachyantherum - Danthonia californica* Herbaceous Alliance, *Carex obnupta - Oenanthe sarmentosa - Scirpus microcarpus* Herbaceous Alliance
	Willow Grove	Woodland dominated by willow (*Salix* spp.), often associated with areas of emergent groundwater	**Shrubs/Trees:** Arroyo willow (*Salix lasiolepis*), Pacific willow (*Salix lasiandra*),* red willow (*Salix laevigata*), straggly gooseberry (*Ribes divaricatum*)	Alluvium.	Temporarily to seasonally flooded from surface runoff; access to shallow groundwater in the hyporheic zone	Palustrine Scrub-Shrub Palustrine Forested Riparian Lotic Forested	*Salix lasiolepis* Shrubland Alliance, *Salix lucida* ssp. *lasiandra* Forest & Woodland Alliance
	Pond	Non-tidal depressional areas supporting seasonal or perennial standing water.	**Herbs:** Horned pondweed (*Zannichellia palustris*),* sago pondweed (*Stuckenia pectinata*),* *Potamogeton* spp.,* mosquito fern (*Azolla filiculoides*),* duckweed (*Lemna* spp.)*	Mud.	Seasonally or perennially inundated.	Palustrine Unconsolidated Bottom Palustrine Aquatic Bed	*Stuckenia (pectinata) - Potamogeton* spp. Herbaceous Alliance, *Azolla (filiculoides, microphylla)* Herbaceous Alliance
	Riparian Forest	Community of trees and shrubs associated with flowing water bodies.	**Shrubs/Trees:** Arroyo willow (*Salix lasiolepis*), Pacific willow (*Salix lasiandra*),* red willow (*Salix laevigata*), serpentine willow (*Salix breweri*), Western sycamore (*Platanus racemosa*), coast live oak (*Quercus agrifolia*), black cottonwood (*Populus trichocarpa*), California wax myrtle (*Morella californica*), California blackberry (*Rubus ursinus*), California wild rose (*Rosa californica*), spreading gooseberry (*Ribes divaricatum* var. *pubiflorum*), twinberry honeysuckle (*Lonicera involucrata* var. *ledebourii*), Pacific poison oak (*Toxicodendron diversilobum*) **Herbs:** California hedgenettle (*Stachys bullata*), figwort (*Scrophularia californica*)	Mixed alluvium, poorly to well drained soils.	Temporarily flooded from surface runoff; access to shallow groundwater in the hyporheic zone.	Palustrine Scrub-Shrub Palustrine Forested Riparian Lotic Forested	*Salix lasiolepis* Shrubland Alliance, *Salix lucida* ssp. *lasiandra* Forest & Woodland Alliance, *Platanus racemosa - Quercus agrifolia* Woodland Alliance, *Populus trichocarpa* Forest & Woodland Alliance


Arroyo willow (*Salix lasiolepis*) • Courtesy of Jim Morefield (Flickr), CC BY-SA 2.0.


Morro manzanita (*Arctostaphylos morroensis*) • Courtesy of Elaine with Grey Cats (Flickr), CC BY-SA 2.0.

System	Class	Description	Characteristic Plants	Substrate	Hydrology	Cowardin et al. (1979)/USFWS 2019	Manual of California Vegetation Classes (CNPS 2025)
Terrestrial	California Prairie**	Low herbaceous communities composed of annual and perennial forbs and grasses.	**Forbs:** Fiddleneck (*Amsinckia* spp.), tarweed (*Deinandra* spp.), clovers (*Trifolium* spp.), mariposa lilies (*Calochortus* spp.), lupines (*Lupinus* spp.), owl's clover (*Castilleja* spp.), *Clarkia* spp., *Gilia* spp., *Acmispon* spp., common goldenstar (*Bloomeria crocea*), variable linanthus (*Leptosiphon parviflorus*), Jones' tidytips (*Layia jonesii*), johnny-jump-up (*Viola pedunculata*), baby blue-eyes (*Nemophila menziesii* var. *menziesii*), dwarf checkbloom (*Sidalcea malviflora* ssp. *laciniata*), Western blue-eyed grass (*Sisyrinchium bellum*), hayfield tarweed (*Hemizonia congesta* ssp. *luzulifolia*), grassland stebbinsoseris (*Stebbinsoseris heterocarpa*), hairy gumplant (*Grindelia hirsutula*), johnny-tuck (*Triphysaria eriantha* ssp. *eriantha*), California goldfields (*Lasthenia californica*), bluedicks (*Dipterostemon capitatus*), California poppy (*Eschscholzia californica*) **Grasses:** Purple needlegrass (*Nassella pulchra*), California melicgrass (*Melica californica*), spike bentgrass (*Agrostis exarata*), California barley (*Hordeum brachyantherum* ssp. *californicum*)	Well-drained soils.	Infrequent flooding.	N/A (Terrestrial)	*Nassella spp. - Melica spp.* Herbaceous Alliance, *Amsinckia (menziesii, tessellata) - Phacelia* spp. Herbaceous Alliance, *Eschscholzia (californica) - Lupinus (nanus)* Herbaceous Alliance, *Lasthenia californica - Plantago erecta - Vulpia microstachys* Herbaceous Alliance
	Oak Woodland/ Savanna	Oak (*Quercus* spp.)-dominated communities with sparse to dense cover (10-65% cover) and an herbaceous understory.	**Shrubs/Trees:** Coast live oak (*Quercus agrifolia*), California bay (*Umbellularia californica*),* canyon gooseberry (*Ribes menziesii*), California buckthorn (*Frangula californica*), California blackberry (*Rubus ursinus*), coyotebrush (*Baccharis pilularis*), poison oak (*Toxicodendron diversilobum*) **Herbs:** California figwort (*Scrophularia californica*), brackenfern (*Pteridium aquilinum*), coastal woodfern (*Dryopteris arguta*), valley manroot (*Marah fabacea*), blue wildrye (*Elymus glaucus*),* desert fiestaflower (*Pholistoma auritum*)	Deep, well-drained alluvial soils.	Infrequent flooding.	N/A (Terrestrial)	*Quercus agrifolia* Forest & Woodland Alliance, *Umbellularia californica* Forest & Woodland Alliance, *Baccharis pilularis* Shrubland Alliance
	Coastal Bluff Scrub	Low-growing scrub and succulents on rocky headlands and coastal bluffs.	**Shrubs:** California goldenbush (*Ericameria ericoides*), seacliff buckwheat (*Eriogonum parvifolium*), California sagebrush (*Artemisia californica*), poison oak (*Toxicodendron diversilobum*), Coastal goldenbush (*Isocoma menziesii* var. *sedoides*) **Herbs:** Deerweed (*Acmispon glaber* var. *glaber*), giant wildrye (*Elymus condensatus*), Island morning glory (*Calystegia macrostegia*), California saltbush (*Extriplex californica*), seaside woolly sunflower (*Eriophyllum staechadifolium*), coast dudleya (*Dudleya caespitosa*)	Rock, shallow soils.	Surface runoff.	N/A (Terrestrial)	*Artemisia californica - (Salvia leucophylla)* Shrubland Alliance, *Eriophyllum staechadifolium - Erigeron glaucus - Eriogonum latifolium* Herbaceous Alliance, *Isocoma menziesii* Shrubland Alliance
	Maritime Chaparral	Shrubland dominated by evergreen, sclerophyllous shrubs.	**Shrubs/Trees:** Morro manzanita (*Arctostaphylos morroensis*), buckbrush (*Ceanothus cuneatus*), hollyleaf cherry (*Prunus ilicifolia*), coast live oak (*Quercus agrifolia*), chamise (*Adenostoma fasciculatum*), black sage (*Salvia mellifera*), California buckthorn (*Frangula californica*), purple nightshade (*Solanum umbelliferum* var. *xanti*), golden yarrow (*Eriophyllum confertiflorum*), sand almond (*Prunus fasciculata* var. *punctata*), California huckleberry (*Vaccinium ovatum*), bush monkeyflower (*Diplacus aurantiacus*), Pecho manzanita (*Arctostaphylos pechoensis*), brittleleaf manzanita (*Arctostaphylos crustacea*), Santa Cruz island oak (*Quercus parvula* var. *parvula*),* coyote bush (*Baccharis pilularis*) **Herbs:** Western bracken fern (*Pteridium aquilinum* var. *pubescens*), branched woolly sunflower (*Eriophyllum multicaule* var. *multicaule*), wedge leaf horkelia (*Horkelia cuneata*), hawkweed layia (*Layia hieracioides*), suffretescent wallflower (*Erysimum suffrutescens*), greenspot nightshade (*Solanum douglasii*)	Baywood Fine Sands.	Excessively well drained; no flooding	N/A (Terrestrial)	*Arctostaphylos morroensis* Shrubland Alliance, *Arctostaphylos (crustacea, tomentosa)* Shrubland Alliance, *Ceanothus cuneatus* Shrubland Alliance, *Adenostoma fasciculatum - Salvia spp.* Shrubland Alliance, *Quercus agrifolia* Forest & Woodland Alliance
	Mobile Dunes	Unstable dune sands, either unvegetated or supporting early-successional shrubs or forbs.	**Herbs:** Silver burr ragweed (*Ambrosia chamissonis*), American dunegrass (*Elymus mollis*), beach saltbush (*Atriplex leucophylla*), beach evening primrose (*Camissoniopsis cheiranthifolia*), pink sand verbena (*Abronia umbellata*), red sand verbena (*Abronia maritima*), coastal sand verbena (*Abronia latifolia*), California croton (*Croton californicus*), dunedelion (*Malacothrix incana*), beach morning glory (*Calystegia soldanella*)	Well-drained sands, with low organic matter and nutrients.	Variable; infrequent flooding.	N/A (Terrestrial)	*Abronia latifolia - Ambrosia chamissonis* Herbaceous Alliance, *Leymus mollis* Herbaceous Alliance
	Coastal Dune Scrub	Shrub-dominated community occuring on older, stabilized dune soils.	**Shrubs:** Chamisso beach lupine (*Lupinus chamissonis*), California sagebrush (*Artemisia californica*), California goldenbush (*Ericameria ericoides*), black sage (*Salvia mellifera*), coastal goldenbush (*Isocoma menziesii*), seacliff buckwheat (*Eriogonum parvifolium*), coyotebrush (*Baccharis pilularis*), dune ragwort (*Senecio blochmaniae*), purple nightshade (*Solanum umbelliferum* var. *xanti*), sand almond (*Prunus fasciculata* var. *punctata*), peak rush-rose (*Crocanthemum scoparium*) **Herbs:** Deerweed (*Acmispon glaber* var. *glaber*), salt heliotrope (*Heliotropium curassavicum*), California saltbush (*Extriplex californica*), beach evening primrose (*Camissoniopsis cheiranthifolia*), California croton (*Croton californicus*), seaside woolly sunflower (*Eriophyllum staechadifolium*), seaside fiddleneck (*Amsinckia spectabilis*), common sandaster (*Corethrogyne filaginifolia*), clustered field sedge (*Carex praegracilis*), common yarrow (*Achillea millefolium*), Nuttall's milk vetch (*Astragalus nuttallii* var. *nuttallii*), Eastwood's spineflower (*Chorizanthe eastwoodiae*), California spineflower (*Mucronea californica*), coast dudleya (*Dudleya caespitosa*), cardinal catchfly (*Silene laciniata* ssp. *laciniata*), wedge leaf horkelia (*Horkelia cuneata*), giant eriastrum (*Eriastrum densifolium* ssp. *densifolium*) **Dune Swales:** Clustered field sedge (*Carex praegracilis*), slough sedge (*Carex obnupta*), Pacific silverweed (*Potentilla anserina* ssp. *pacifica*), willow dock (*Rumex salicifolius*)	Well-drained sands, with low organic matter and nutrients.	Variable; infrequent flooding.	N/A (Terrestrial)	*Lupinus chamissonis - Ericameria ericoides* Shrubland Alliance, *Eriophyllum staechadifolium - Erigeron glaucus - Eriogonum latifolium* Herbaceous Alliance, *Baccharis pilularis* Shrubland Alliance, *Lotus scoparius - Lupinus albifrons - Eriodictyon* spp. Shrubland Alliance, *Salvia mellifera - (Artemisia californica)* Shrubland Alliance Dune swales: *Carex obnupta - Oenanthe sarmentosa - Scirpus microcarpus* Herbaceous Alliance

View from Black Hill in Morro Bay, overlooking Morro Bay State Park and the Estuary • Photograph by Sean Baumgarten, SFEI.

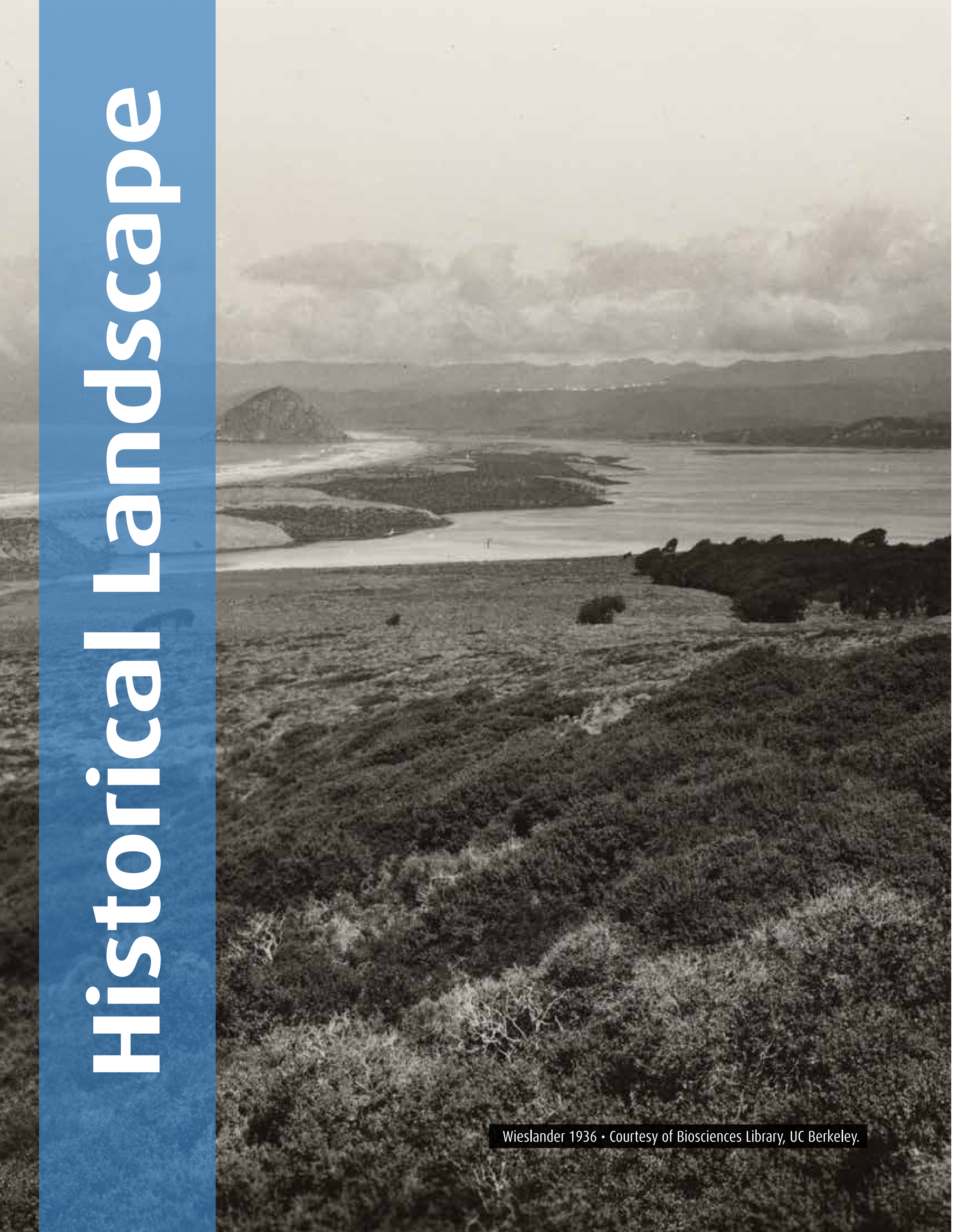
Table 2. Each mapped feature was assigned a certainty level of high, medium, or low for each of three characteristics (interpretation, shape, and location). Interpretation certainty describes the confidence that the habitat type assigned to the feature is accurate and that the feature is representative of the historical period. Size certainty describes the confidence that the feature's spatial extent is accurately depicted. Location certainty describes the confidence that the feature existed at the mapped location. Information on the certainty level is stored in the feature attributes in GIS.

Certainty Level	Interpretation	Shape	Location
High/ "Definite"	Feature **definitely** present before Euro-American modification	Mapped feature expected to be **90%-110%** of actual feature size	Expected maximum horizontal displacement less than 50 m (150 ft)
Medium/ "Probable"	Feature **probably** present before Euro-American modification	Mapped feature expected to be **50%-200%** of actual feature size	Expected maximum horizontal displacement less than 150 m (500 ft)
Low/ "Possible"	Feature **possibly** present before Euro-American modification	Mapped featured expected to be **25%-400%** of actual feature size	Expected maximum horizontal displacement less than 500 m (1,600 ft)

TECHNICAL REVIEW AND STAKEHOLDER ENGAGEMENT

A technical advisory team consisting of four local experts and resource managers provided guidance on project direction, methodology, and reporting (see Acknowledgments on page 62). Four stakeholder meetings were held during the course of the project to present draft findings and solicit comments and feedback from partners, advisors local to the study area, and ytt Northern Chumash and Salinan Tribal members.

Historical Landscape



Wieslander 1936 • Courtesy of Biosciences Library, UC Berkeley.

OVERVIEW

Prior to major Euro-American modification (mid-19th century), the Morro Bay Estuary and surrounding Watershed were characterized by a mosaic of varied habitat types (Fig. 5). In the Bay itself, estuarine and marine habitats experienced tidal influence from the Pacific Ocean, while dunes to the west formed a barrier between the ocean and the Estuary. Palustrine/riparian and terrestrial habitats occupied the long valley floors and paleodunes of present-day Baywood and Los Osos.

Entering the study area from the east, Chorro Creek flowed through prairies blanketing the Chorro Valley floor. Near the present-day Men's Colony and Cuesta College, Chorro Creek supported stretches of riparian forest, and patches of wet meadow and valley freshwater marsh occurred near the creek's confluence with tributaries. At the west end of Chorro Valley, south of where present-day Highway 1 meets South Bay Boulevard, Chorro Creek supported a sizable willow grove, which eventually graded into a large, fanned tidal salt marsh plain as it met the northeastern extent of the Estuary.

In Los Osos Valley to the south, Warden Creek flowed through a complex of wet meadows, willow groves, and riparian vegetation before losing definition just upstream of Warden Lake, a large freshwater marsh. Similar to Chorro Valley, the higher-elevation reaches of the Los Osos Valley were covered by prairies. Los Osos Creek, entering the study area from the south near the present-day Los Osos Oaks State Natural Preserve, flowed through Warden Lake and transitioned into winding tidal channel as it entered the narrow Los Osos tidal salt marsh plain. Both the Chorro and Los Osos marshes gradually gave way to broad expanses of tidal flats, which lined much of the Estuary's interior, as well as thousands of hectares of shallow open water. One confined band of deep water followed the curve of the Bay between present-day Fairbank Point and the Morro Bay State Park Museum of Natural History.

In the northern part of the study area, the lower reach of Morro Creek flowed through an extensive willow grove, atop the now-closed Morro Bay Power Plant, and entered the northernmost extent of the Bay. Historically, the Estuary had two entrances: north and south of Morro Rock, which supported low densities of coastal bluff scrub. Aside from these openings, Morro Bay was protected by a long sandspit occupied by mobile dunes and coastal dune scrub. A tapestry of maritime chaparral, coastal dune scrub, and oak woodland covered vast areas of the paleodunes, south of Morro Bay.

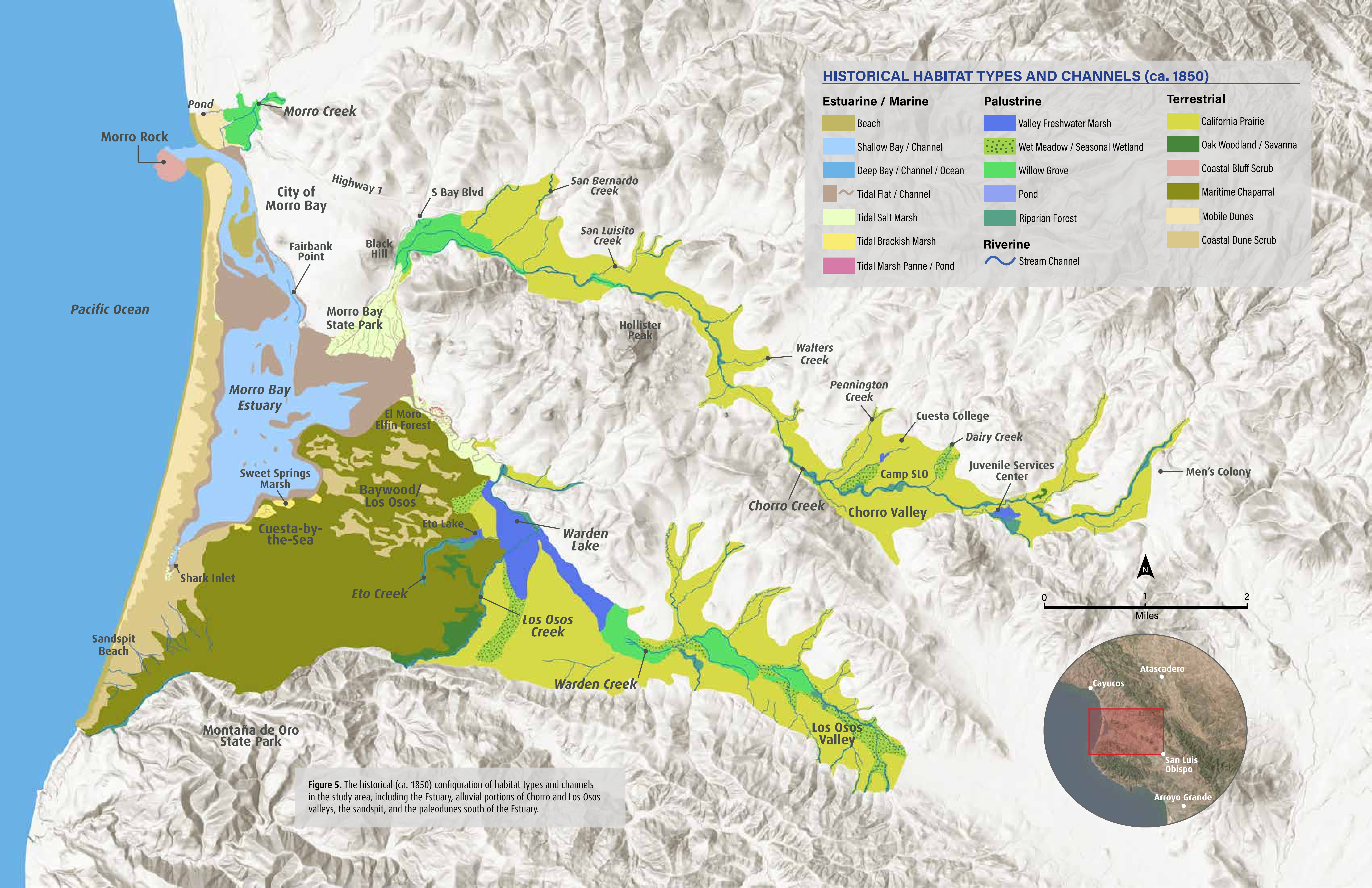


Figure 5. The historical (ca. 1850) configuration of habitat types and channels in the study area, including the Estuary, alluvial portions of Chorro and Los Osos valleys, the sandspit, and the paleodunes south of the Estuary.

Habitat Type	Hectares
Beach	98
Shallow Bay / Channel	526
Deep Bay / Channel	2
Tidal Flat / Channel	372
Tidal Salt Marsh	123
Tidal Brackish Marsh	12
Tidal Marsh Panne / Pond	3
Valley Freshwater Marsh	116
Wet Meadow / Seasonal Wetland	147
Willow Grove	210
Pond	<1
Riparian Forest	129
California Prairie	1650
Oak Woodland / Savanna	48
Coastal Bluff Scrub	18
Maritime Chaparral	1328
Mobile Dunes	173
Coastal Dune Scrub	424
Total	**5,930**

Table 3. Breakdown of area covered by each habitat type in the historical mapping, rounded to the nearest hectare. Tidal flat and shallow bay were the most prevalent habitats in the Estuary historically, while prairies and maritime chaparral covered the majority of the upland areas. Hectare totals are approximate and depend on the granularity of the historical sources used in the mapping.

Top: Chorro Valley shown from Cerro Cabrillo Peak. Photograph by Morro Bay National Estuary Program.
Middle: El Moro Elfin Forest looking northeast. Photograph by Sean Baumgarten, SFEI.
Bottom: Tidal channel within Sweet Springs Marsh. Photograph by Morro Bay National Estuary Program.

> "The recent heavy seas left their mark upon the peninsula which forms the outer boundary of Morro channel. The long narrow arm of sand which has extended from the big rock out to the head of the Pecho was broken at a point about three-eights of a mile from the rock."
>
> San Luis Obispo Morning Tribune 1897 in Tognazzini 1997

MORRO BAY ESTUARY

The Estuary Entrance

A tidal connection to Morro Bay existed both to the north and south of Morro Rock. Passing by in 1769, for instance, Juan Crespí noted a "great rock in the form of a round morro, which, at high tide, is isolated and separated from the coast by a little less than a gunshot" (Crespí and Bolton 1927). Nineteenth century depictions of the mouth of the Estuary vary, but consistently show two distinct entrances (Fig. 6). A full analysis of historical inlet dynamics was beyond the scope of this study, but some preliminary information is summarized below.

Early sources suggest that the width of the channel entrances were variable over time and had an inverse relationship, meaning that when one became deeper and wider, shoaling often occurred in the other (Orme 1990). An 1895 report notes that the southern channel tended to be wider in summer months: "These two channels are subject to considerable variations; when one is at its maximum width and depth the other is at its minimum... The southerly channel opens up to the southward, and is exposed to the southerly winter gales that prevail, and is, therefore, usually better in summer than in winter" (Benyaurd 1895).

Both the northern and southern channels experienced periods of closure—at least in the intertidal zone—though it's unclear how frequently this occurred; none of the historical sources examined indicate that both channels were closed simultaneously (Benyaurd 1895, San Francisco Chronicle 1899, Tognazzini 1997). A note (added at a later date) in the 1884 H-Sheet, for instance, states that, "During the year 1887 the North Channel into Morro Bay was closed and a new channel opened around the south east sides of the Morro [Morro Rock]" (Taussig 1884). Though based on a limited number of observations, these sources suggest that closure may have been less frequent than predicted by Jacobs et al. (2011), who analyzed expected estuary closure dynamics in California estuaries. Considering factors such as watershed size, wave exposure, setting, and estuary formation process, Jacobs et al. predicted that Morro Bay would experience closure above the level of Mean Higher High Water (MHHW) approximately 50% of the time. An earlier analysis by Williams (1984, cited in Haltiner and Thor 1991), considering tidal prism volume and deep water wave power, found that Morro Bay is near the threshold between permanently tidal estuaries and intermittently closing lagoons.

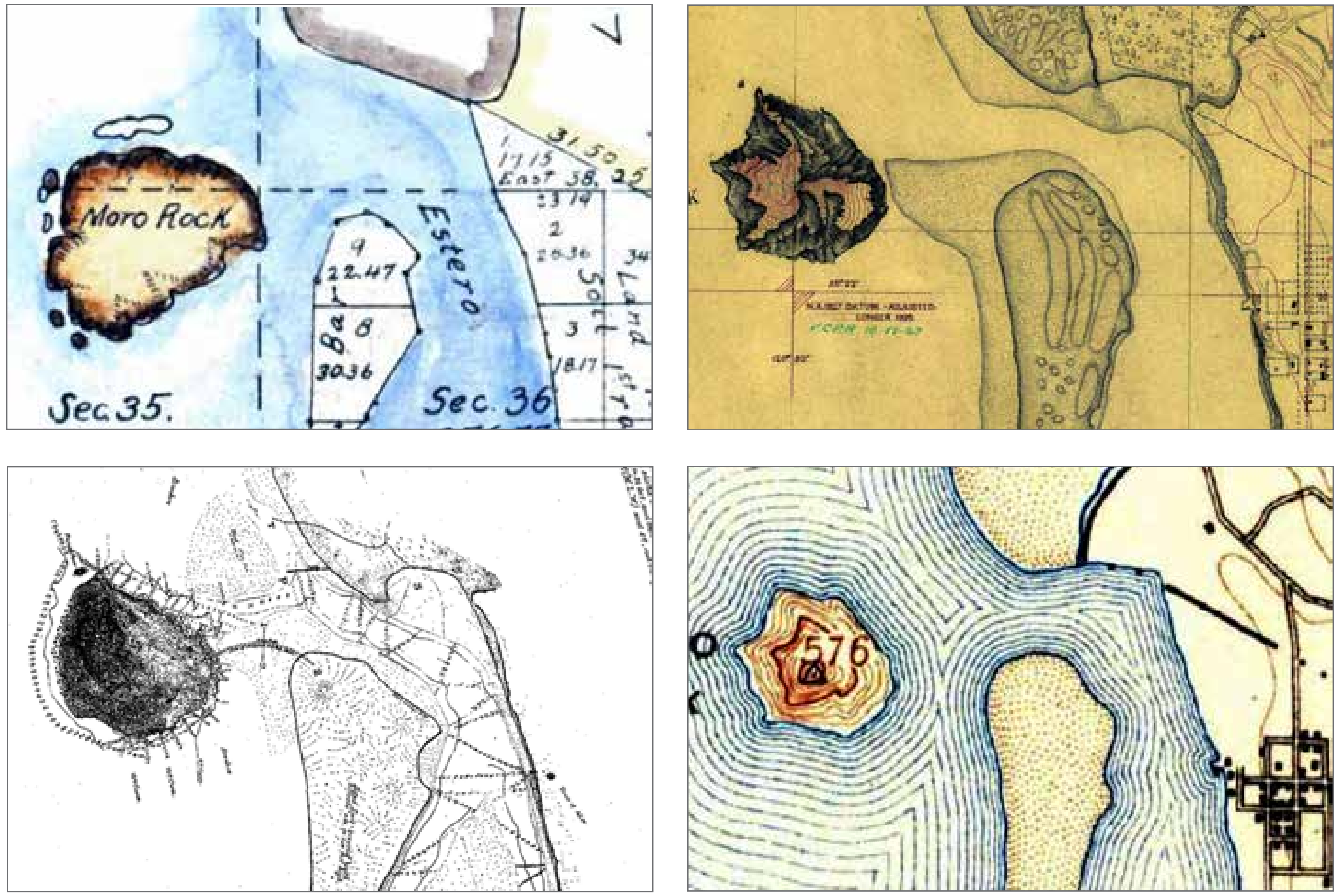


Figure 6. (above) Nineteenth century depictions of the Estuary mouth showing two distinct entrances on either side of Morro Rock. **(Top left:** *U.S. Surveyor General's Office 1870, courtesy of BLM;* **Top right:** *Forney 1883, courtesy of NOAA;* **Bottom left:** *Sears and Bradford 1873, courtesy of the City of Morro Bay;* **Bottom right:** *USGS 1897a, courtesy of USGS).* **(below)** Contemporary image showing the Estuary mouth open only to the south and the constructed breakwater to the north. *(courtesy of Maxar)*

Modern photo showing the Estuary mouth open to the south and the constructed road to the north • Photograph by Lynda Roeller.

Intertidal Flats and Shallow Bay Throughout the Estuary

Tidal flats and shallow bay characterized the vast majority of the Estuary. Tidal flats, defined as muddy or sandy habitats exposed between low and high tides, made up approximately 364 ha (919 ac) of Morro Bay. Patches of tidal flats were found throughout the Bay, but were primarily concentrated along its interior rim and two major expanses: one extending 1,200 m (4,000 ft) east from the sandspit and the other, about 1,600 m (1 mi) wide, just beyond the Chorro and Los Osos tidal salt marshes. Subtidal estuarine areas between the elevation of MLLW and 5.5 m (18 ft) below MLLW were classified as shallow bay and totaled over 526 ha (1,300 ac) of the Estuary. One narrow strip of deep bay—subtidal estuarine areas deeper than 5.5 m (18 ft) below MLLW—occurred west of the present-day Morro Bay Golf Course.

An 1884 U.S. Coast and Geodetic Survey H-Sheet provided the earliest spatially accurate information on the Bay's varying water depths relative to MLLW and was used to map nearly all of the Bay and tidal flat habitats (Taussig 1884; Fig. 7). However, the H-Sheet did not cover the very southern end of the Bay and thus areas of shallow bay and tidal flats here were mapped off the 1881 T-Sheet (Greenwell 1881).

Extensive stands of eelgrass (*Zostera marina*), and potentially other seagrasses, were found on the intertidal flats and shallow open water habitats throughout Morro Bay (Sears and Bradford 1873, Dixon 1918a, Tays 1937). An 1873 depth soundings map specifically labels three large swaths of "mud flats" (classified as tidal channel/flat) as being "covered with grass at low water" (presumed to be eelgrass), while one expanse of sand flat (classified as beach) is called out as "bare at low water" (Sears and Bradford 1873; Fig. 8). Decades later, eelgrass was still found to grow "in great abundance" in the open water habitats at the head of the Bay (Tays 1937), though a report from 1941 blamed "eelgrass depletion" for "the reduction in the numbers" of brant geese (*Branta bernicla*) observed in Morro Bay (Moffitt 1941).

Historical accounts and archeological records document a rich variety of wildlife in the Estuary. Archaeological and archival records support the presence of marine mammals, including California sea lions (*Zalophus californianus*), harbor seals (*Phoca vitulina*), and sea otters (*Enhydra lutris*), on the local coast dating back 5,000-6,000 years (San Luis Obispo Morning Tribune 1898, Sullivan 1995, SLOCAS 2000, Jones et al. 2019). Shellfish, such as California mussels (*Mytilus californianus*), Pismo clams (*Tivela stultorum*), and Olympia oysters (*Ostrea lurida*), were also documented in archaeological records and historical accounts (Kroeber 1925, Tays 1937, Tognazzini 1989 and 1993, SLOCAS 2000, Jones et al. 2019). Topsmelt (*Atherinops affinis*), jacksmelt (*Atherinopsis californiensis*), Pacific herring (*Clupea pallasii*), Pacific staghorn sculpin (*Leptocottus armatus*), prickly sculpin (*Cottus asper*), and northern tidewater goby (*Eucyclogobius newberryi*) were among the most common nearshore fish species to occupy the Bay historically (Scofield 1918, Hubbs 1921a-c, Tognazzini 1995). Large numbers of birds could often be seen on the exposed mudflats and sandbars, which afforded species like American white pelicans (*Pelecanus erythrorhynchos*), double-crested cormorants (*Nannopterum auritum*) and marbled godwits (*Limosa fedoa*) a "safe retreat from all enemies" because they were surrounded by water (Grinnell and Hunt 1929). Wintering brant could also be seen on the tidal flats or shallow waters of the Bay (Grinnell and Hunt 1929, Moffitt 1941, Otto ca. 1946).

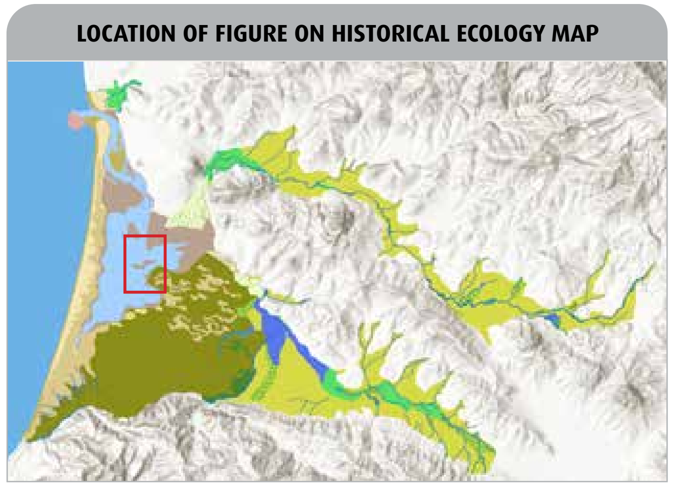
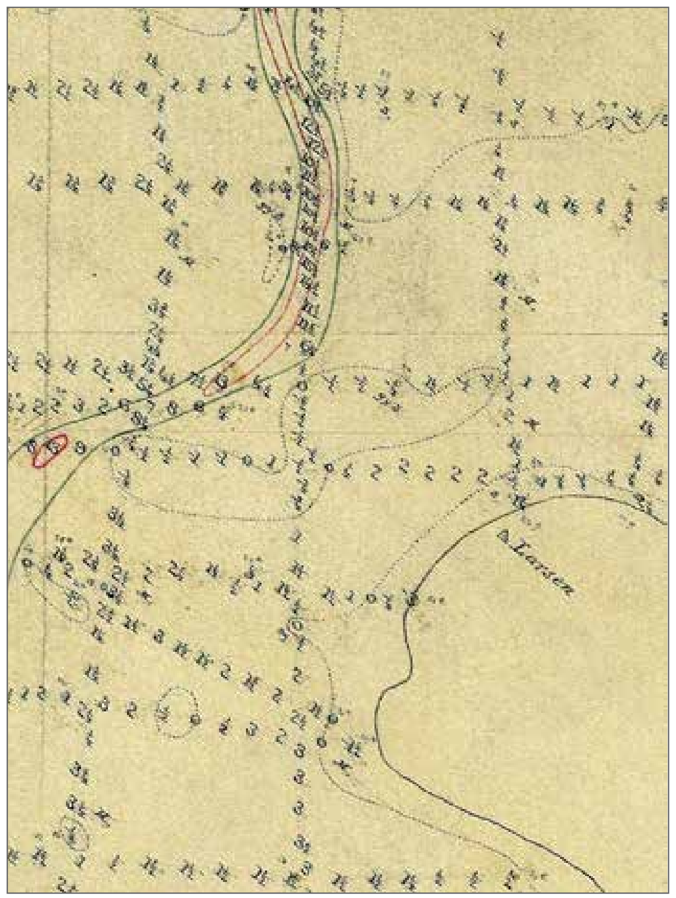
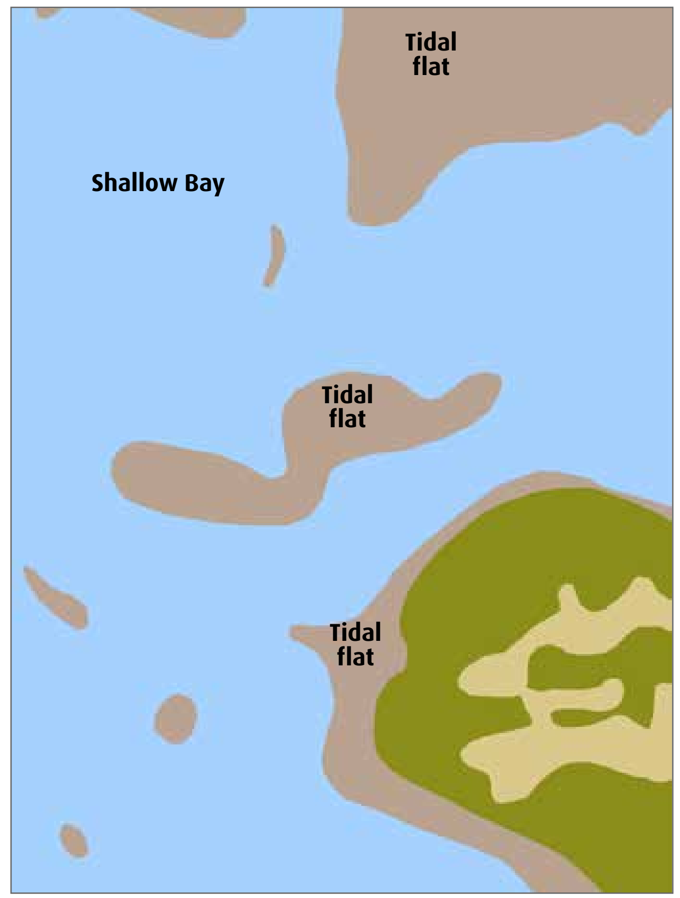


Figure 7. (below, left) 1884 U.S. Coast Survey H-1607a sheet detailing varying depths of the Bay, generally given in feet below Mean Lower Low Water (MLLW). Dotted black lines indicate the MLLW line which was used to differentiate tidal flats from subtidal water. *(Taussig 1884, courtesy of NOAA)* **(below, right)** The same area is depicted on the historical ecology map, showing the resulting tidal flat and shallow bay delineations.





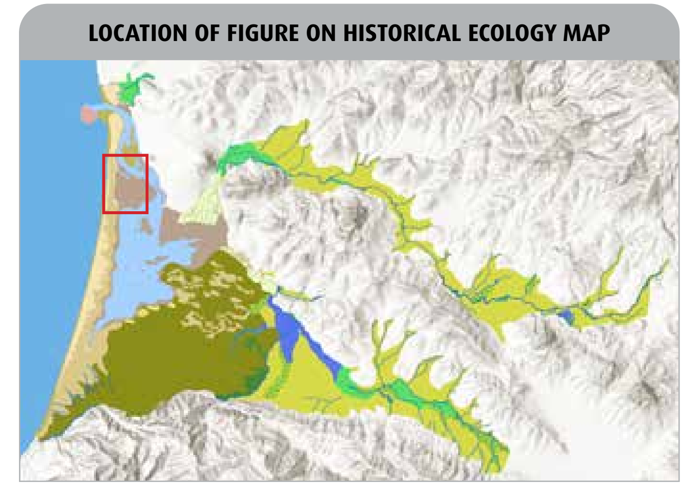
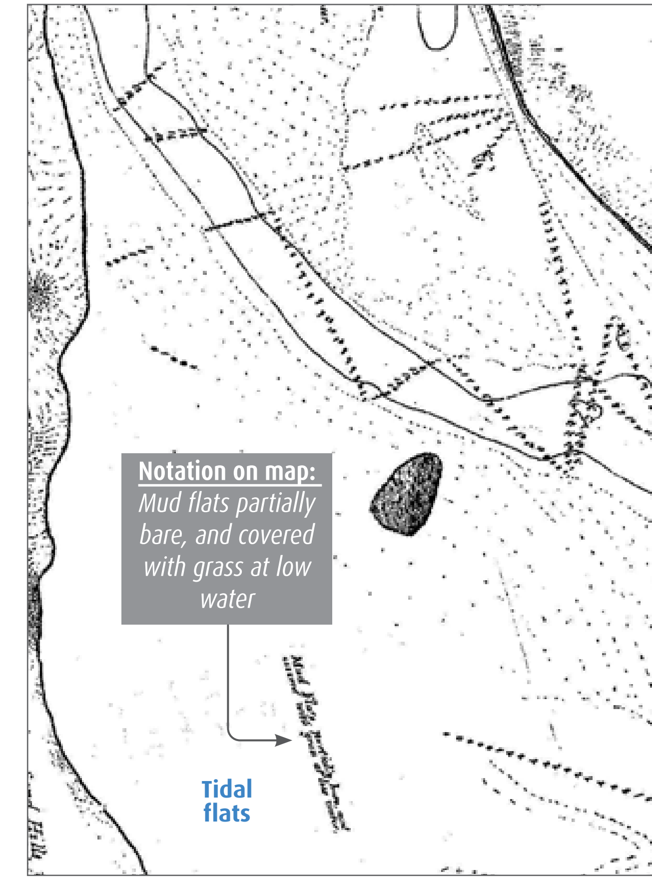


Figure 8. Portion of an 1873 Depth Soundings Map of Morro Bay. The label on the intertidal flats reads: "Mud flats partially bare, and covered with grass at low water," likely referring to eelgrass. *(Sears and Bradford 1873, courtesy of Jeff Ebner)*



Extensive Tidal Salt Marsh Complexes

The Morro Bay Estuary supported approximately 123 ha (304 ac) of tidal salt marsh in the early 1880s. The largest tidal salt marshes were concentrated along the east end of Morro Bay at the mouths of Chorro and Los Osos creeks, which supported 80 and 40 ha (198 and 99 ac), respectively. Additional, smaller patches were present along the southernmost rim of the Bay, nearby present-day Shark Inlet.

The earliest spatially accurate documentation of tidal marsh extent is from 1881 (Fig. 9) and 1883 (Fig. 10) U.S. Coast Survey T-Sheets, which were created after the introduction of widespread livestock grazing in the Watershed during the mission and rancho periods. Analysis of sediment cores from the marshes at the mouths of Chorro and Los Osos creeks indicate that rates of sediment deposition, following Spanish colonization in the late 18th century, increased from approximately 2.16 mm (0.1 in)/year to 7-10 mm (0.3-4 in)/year for Chorro marsh and 0.9 mm (0.04 in)/year to 6 mm (0.2 in)/year for Los Osos marsh (Broadman et al. 2022). This increase in sedimentation, and subsequent colonization of accreting mudflats by salt marsh plants, may have resulted in the expansion of tidal marsh extent in the Estuary by the 1880s (as well as the expansion of intertidal mudflats into formerly subtidal areas; Broadman et al. 2022).

Tidal salt marsh complexes in Morro Bay were characterized by high marsh plains interspersed with marsh pannes and ponds and tidal channels. Tidal salt marsh plains were dominated by species like pickleweed (*Salicornia pacifica*), alkali heath (*Frankenia salina*),

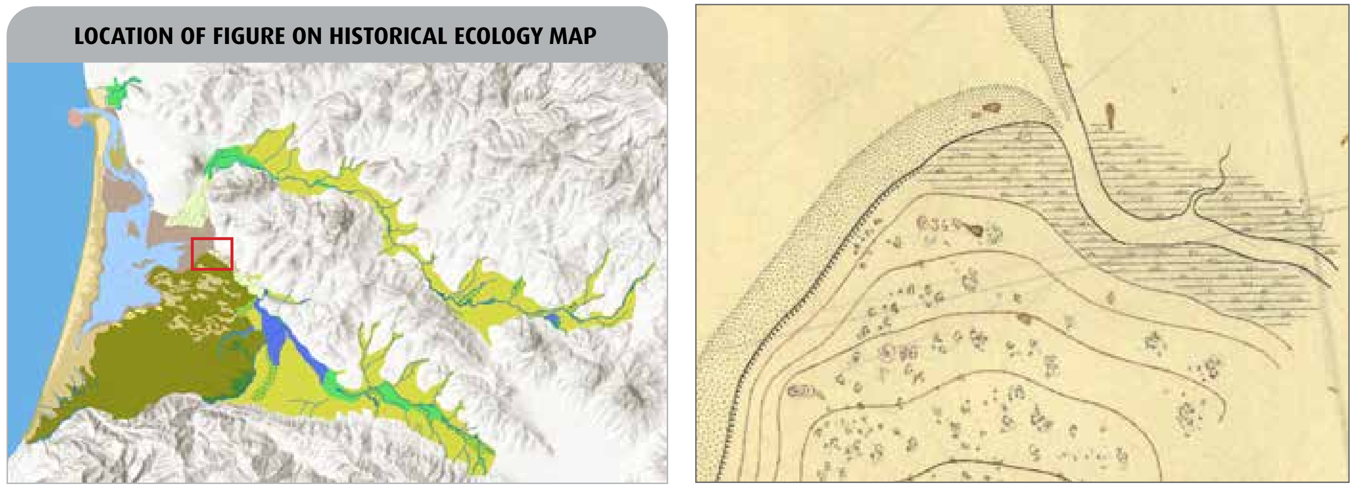


Figure 9. 1881 U.S. Coast Survey T-Sheet (T-1500B) of Point Buchon to Morro Rock depicting tidal salt marsh at the mouth of Los Osos Creek. The Los Osos marsh plain included marsh pannes or ponds and narrower tidal sloughs. *(Greenwell 1881, courtesy of NOAA)*

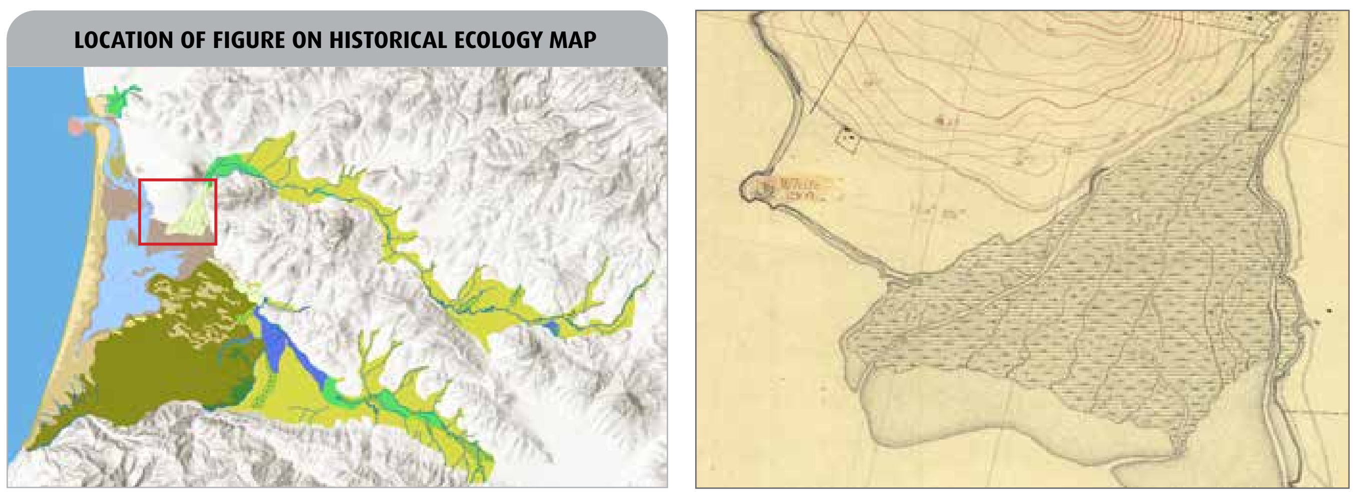


Figure 10. 1883 U.S. Coast Survey T-Sheet (T-1662) of "Moro [sic] Bay to Toro Point" depicting the expansive tidal salt marsh plain at the mouth of Chorro Creek. The map also details the tidal sloughs and marsh pannes or ponds in the plain. *(Forney 1883, courtesy of NOAA)*

and marsh jaumea (*Jaumea carnosa*), and included a variety of other species such as saltgrass (*Distichlis spicata*), California seablite (*Suaeda californica*), California sea lavender (*Limonium californicum*), and seaside arrowgrass (*Triglochin concinna*) (Dixon 1918a, Dixon 1918b, data from the California Consortium of Herbaria; Fig. 11).

While tidal salt marsh was the most extensive tidal marsh type in the Estuary, there is evidence that tidal brackish marsh existed in southern Morro Bay, in and around the area of present-day Sweet Springs Marsh, totaling approximately 12 ha (30 ac). Tidal brackish marsh in these areas was sustained by freshwater inputs from springs in the present-day Baywood Park area (Lippincott 1931). Zones of tidal brackish marsh likely also occurred in the transitional zones at the mouths of Los Osos and Chorro creeks. They were characterized by species such as alkali bulrush (*Bolboschoenus maritimus*), slough sedge (*Carex obnupta*), and salt rush (*Juncus leusuerii*).

Tidal marsh habitats were often seen teeming with innumerable birds of many species, including Bryant's savannah sparrow (*Passerculus sandwichensis nevadensis*), marsh wren (*Cistothorus palustris*) and green-winged teal (*Anas carolinensis*) (Grinnell 1918). On one September morning in 1918, Joseph S. Dixon documented dozens of least sandpipers (*Calidris minutilla*) in a "tidal pond surrounded by a dense growth of Salicornia [pickleweed]" (Dixon 1918a). On another September day, Joseph P. Grinnell described seeing double-crested cormorants (*Nannopterum auritum*), Northern phalaropes (*Phalaropus lobatus*) and great blue herons (*Ardea herodias*) among the "open playas and winding sloughs" of the salt marshes at the head of Morro Bay (Grinnell 1918). Other species documented in tidal marshes include pied-billed grebe (*Podilymbus podiceps),* willet (*Tringa semipalmata*), pectoral sandpiper (*Calidris melanotos*), and Baird's sandpiper (*Calidris bairdii*) *(*Grinnell and Hunt 1929).

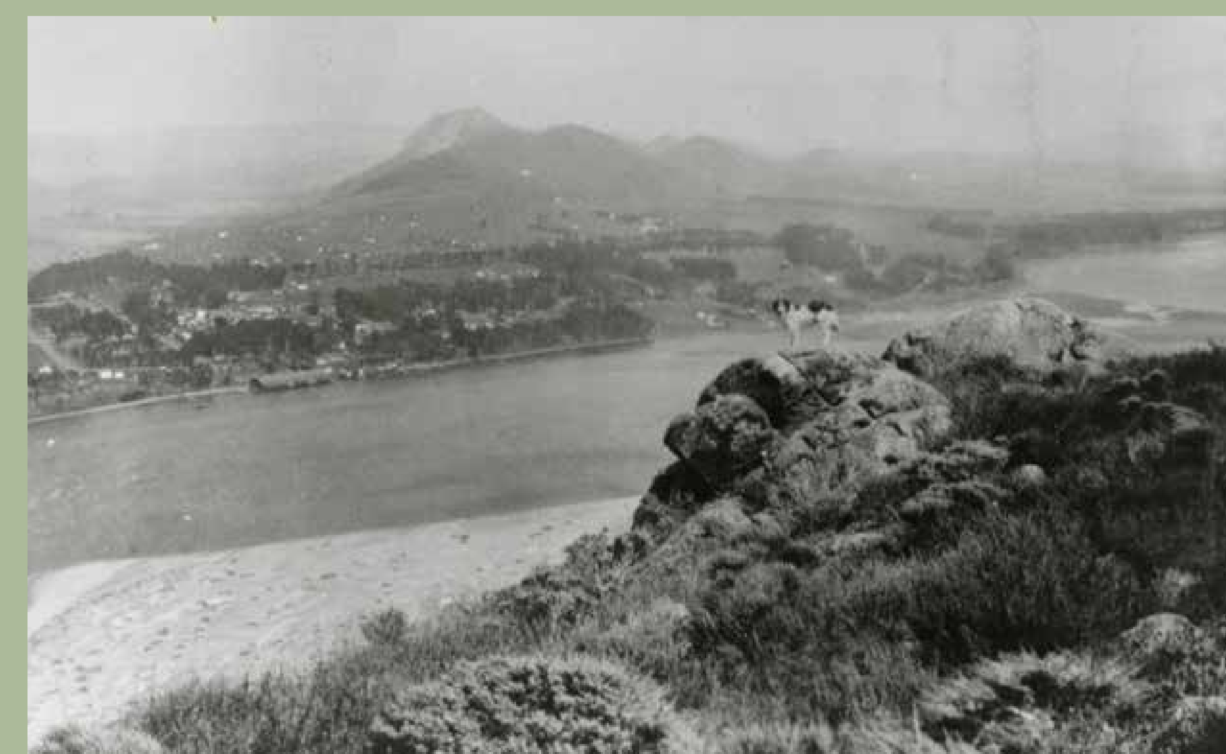
Figure 11. 1918 photograph of a portion of Chorro Marsh in Morro Bay. The caption reads: "Salicornia salt marsh partly covered at high tide." Pickleweed *(Salicornia pacifica)* was one of the most prevalent species making up the tidal salt marsh. *(Dixon 1918b, courtesy of Museum of Invertebrate Zoology, UC Berkeley)*

COASTAL BLUFF SCRUB ON MORRO ROCK

Morro Rock, the nearly 180-m (800-ft) tall and 27 million-year-old volcanic plug at the entrance to Morro Bay—part of the Nine Sisters volcanic belt— historically supported coastal bluff scrub habitat. Early evidence suggests Morro Rock, while not heavily vegetated, hosted a sparse cover of species such as California goldenbush (*Ericameria ericoides*), deerweed *(Acmispon glaber)*, seacliff buckwheat *(Eriogonum parvifolium)* and California sagebrush *(Artemisia californica)* (Cooper 1875, Wieslander 1935). In one 1875 report on the resources of San Luis Obispo County, Morro Rock was described as consisting solely of a "scrubby growth of chemise, in the crevices" (Cooper 1875; note that "chemise" or "chamisal" was sometimes used generally in early accounts to refer to scrub cover rather than to *Adenostoma fasciculatum)*. Morro Rock was a common nesting spot for a variety of bird species, including peregrine falcon *(Falco peregrinus)*, cormorants *(Phalacrocoracidae* spp.), loons *(Gavia* spp.), ravens *(Corvus corax)* and brown pelicans *(Pelecanus occidentalis)* (Willett 1895, Jones et al. 2019).

Morro Rock is a culturally significant place and a key feature in Native American storytelling, referred to as Lisamu by the Obispeño Chumash and as Le'saam or Le'samo' by the Salinan. In 1542, Portuguese explorer Juan Cabrillo named the rock "El Morro," the Spanish word for "crown shaped hill" (Wood 1914).

Since at least the late 19th century, settlers of the area quarried Morro Rock to "provide material for breakwaters" (History of Morro Bay n.d.) and help create a causeway between the rock and the mainland (Bailey 1982). It wasn't until the 1960s that public pressure forced the cessation of quarrying and Morro Rock became a State Historical Landmark (Bailey 1982).



Top right: An elevated view of Morro Rock, surrounded by shallow water and sparsely vegetated with coastal bluff scrub, ca. 1880. (*SoCA Digitization Project ca. 1880, courtesy of the California State Library*)

Bottom right: A photograph of a dog on Morro Rock, with a part of the sandspit, the Estuary, and the growing town of Morro seen in the distance. (*[Dog on Morro Rock] ca. 1900-1950, courtesy of the History Center of San Luis Obispo County*)

Eelgrass in the Estuary • Photograph by Morro Bay National Estuary Program.

Dune habitats on the sandspit and Morro Rock in the background • Photograph by Morro Bay National Estuary Program.

STREAMS AND FRESHWATER WETLANDS

Freshwater Inputs from Chorro and Los Osos Creeks

Chorro and Los Osos creeks were the two largest sources of freshwater input to the Estuary historically. Chorro Creek was characterized by a single-threaded, meandering channel along most of its length, except for a short multi-threaded reach near its mouth. Numerous tributaries, including San Bernardo, San Luisito, Pennington, and Dairy creeks flowed into Chorro Creek, primarily from the hills to the north. Early sources suggest that streamflow in Chorro Creek and tributaries such as San Bernardo and San Luisito creeks was perennial; one estimate from late summer or early fall of 1892 suggests Chorro Creek had flows upwards of 400,000 gallons per day (0.02 m^3/s or 0.62 cfs) (Ward 1892, USGS 1897a, Fig. 12). For instance, as the Portolá Expedition passed through the Chorro Valley area in 1769, Juan Crespí described entering a hollow with a stream and tributaries that had "good little flows of water, nearly all of them flowing very deep down and sunken" (Crespí and Brown 2001). Given that this account is from the end of the dry season, it may provide additional evidence that the Chorro Creek mainstem and some of its

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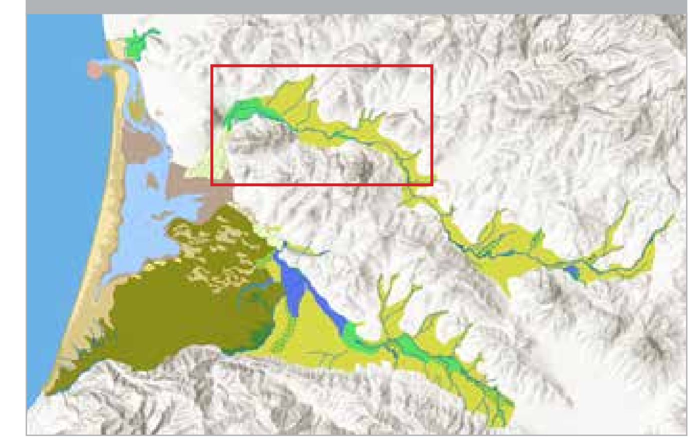

Figure 12. Chorro Creek and some of its tributaries depicted in the 1897 USGS topographic quad of Cayucos. A solid blue line indicates perennial streamflow in that reach, while a dotted blue line represents intermittent streamflow. (*USGS 1897a, courtesy of USGS*)

tributaries supported year-round steamflow. Evidence from the 1928 soil survey suggests groundwater was relatively shallow near the mouth of Chorro Creek, occurring at depths of about 1 m (3 ft) during the rainy season (Carpenter and Storie 1928b).

Los Osos Creek, also characterized by a single-threaded meandering channel historically, exited Clark Valley to the south and flowed north, cutting across Warden Lake in Los Osos Valley before eventually draining into the eastern edge of Morro Bay (Fig. 13). Unlike Chorro Creek, the depiction of Los Osos Creek in the 1897 USGS topographic quad suggests it was predominantly an intermittent stream (USGS 1897a). However, a portion of Los Osos Creek's flows came from freshwater springs along the west side of Los Osos Valley that were reported to have been "dried up by the extensive pumping for irrigation" and drought by the early 20th century, so it is possible that before these water use changes there was year-round streamflow (Lippincott 1931). Eto Creek, a tributary to Los Osos Creek flowing northeast through the paleodunes, also received freshwater input from groundwater springs in the area (Michael Brandman Associates 2008). Warden Creek was the primary channel draining Los Osos Valley, and is shown as intermittent on the 1897 USGS topographic quad. The Warden Creek channel lost definition in a large willow grove southeast of Warden Lake, where its flow met that from Los Osos Creek to the south (Stratton 1868, USGS 1897a).

"The combined streams of San Bernardo, San Luisito and Chorro creeks cut a deep narrow canyon between San Bernardo Valley and the chain of hills east of it. After breaking through this box canyon the three streams disgorge their waves into the eastern extremity of Morro Bay by a wide fan-like, marshy delta."

George Tays, 1937, describing the Choro Valley watershed

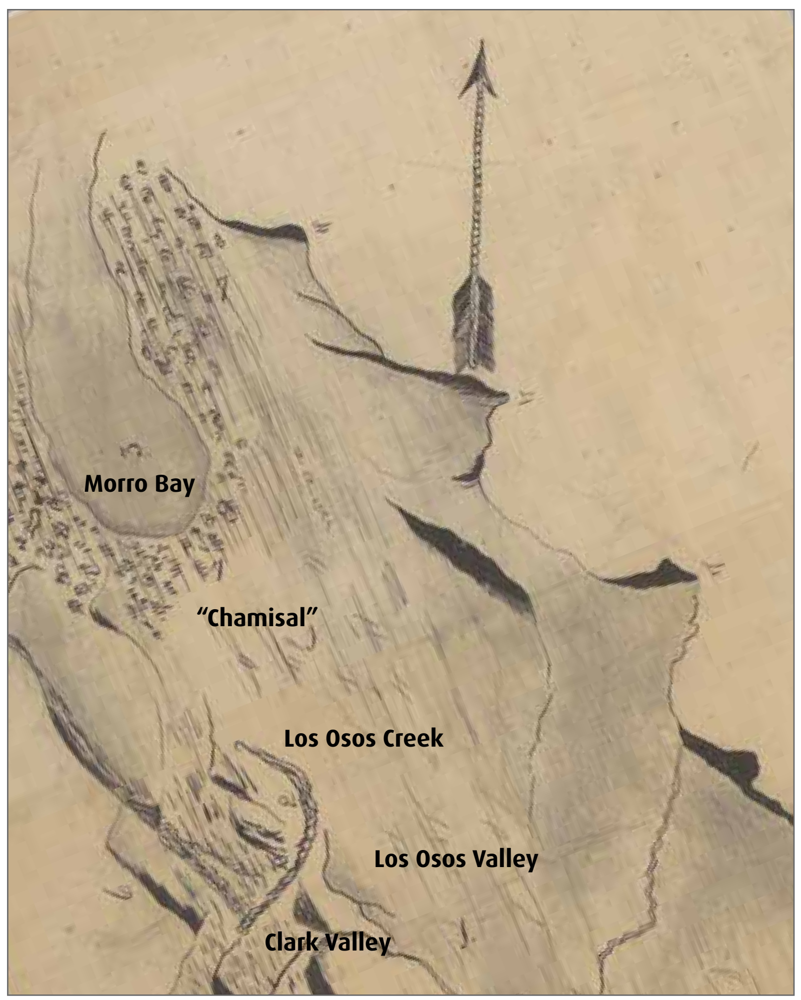

Figure 13. Los Osos Creek depicted flowing from Clark Valley into Los Osos Valley in a ca. 1840 diseño of Rancho Cañada de Los Osos y Pecho y Islay. Clark Valley is referred to as "Cañada de los Alisos" or "Valley of the Sycamores." *(U.S. District Court California, Southern District ca. 1840, courtesy of the Bancroft Library)*

Nineteenth century newspaper accounts and fisheries reports provide evidence for steelhead (*Oncorhynchus mykiss*) in Chorro Creek, Los Osos Creek, and several of their tributaries. An 1894 article in the San Luis Obispo Morning Tribune, for instance, describes San Bernardo Creek and Los Osos Creek as "all overrun with salmon trout," likely referring to steelhead (Tognazzini 1994); steelhead were also documented in San Luisito Creek and Chorro Creek (California Commissioners of Fisheries 1888). Another newspaper account from 1894 describes settlers of the area constructing cobble dams along Los Osos Creek, which prevented "salmon from going up to spawn" (Tognazzini 1994). Pacific staghorn sculpin *(Leptocottus armatus)* could also be found in the "fresh tidewater" of Chorro Creek and Morro Creek (Hubbs 1921b; despite this description, salinity ranges in the tidal portions of these creeks were likely brackish rather than fresh; W. Ferren pers. comm.).

Riparian Forests Along the Major Channels

Riparian forests bordered many of the creeks within the study area. The spatial distribution of riparian forests is not well-documented in mid-19th century sources, and thus the 1937 aerial imagery was used as the primary source in most areas for mapping riparian habitat (Fig. 14; see pages 12-13 for more information on mapping methods). However, because the extent of riparian forest was likely reduced by livestock grazing, agriculture, and other land use changes during the 19th and early 20th centuries, the 129 ha (318 a) of riparian forest included in the mapping likely represents an underestimate. Over half of the mapped riparian forest occurred along Chorro Creek and its tributaries in Chorro Valley, where it reached widths of nearly 305 m (1,000 ft). In Los Osos valley, roughly 59 ha (147 a) of riparian forest was documented along stretches of Los Osos Creek, Warden Creek, Eto Creek, and one tributary.

Riparian forests were largely dominated by coast live oak (*Quercus agrifolia*), willow (*Salix* spp.) and western sycamore (*Platanus racemosa*) (Freeman 1855, Henry 1858, Stratton 1868, Morrison and Haydon 1917, Crespí and

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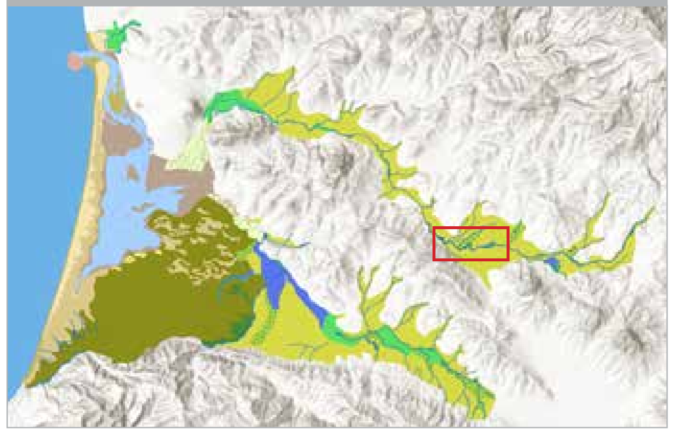


Figure 14. Riparian forest captured along Chorro Creek in the 1937 historical aerial imagery. By the time this aerial imagery was taken it is likely that major sections of the riparian forest had been cleared along Los Osos and Chorro creeks, as well as their tributaries. *(United States Army 1937, courtesy of UCSB)*

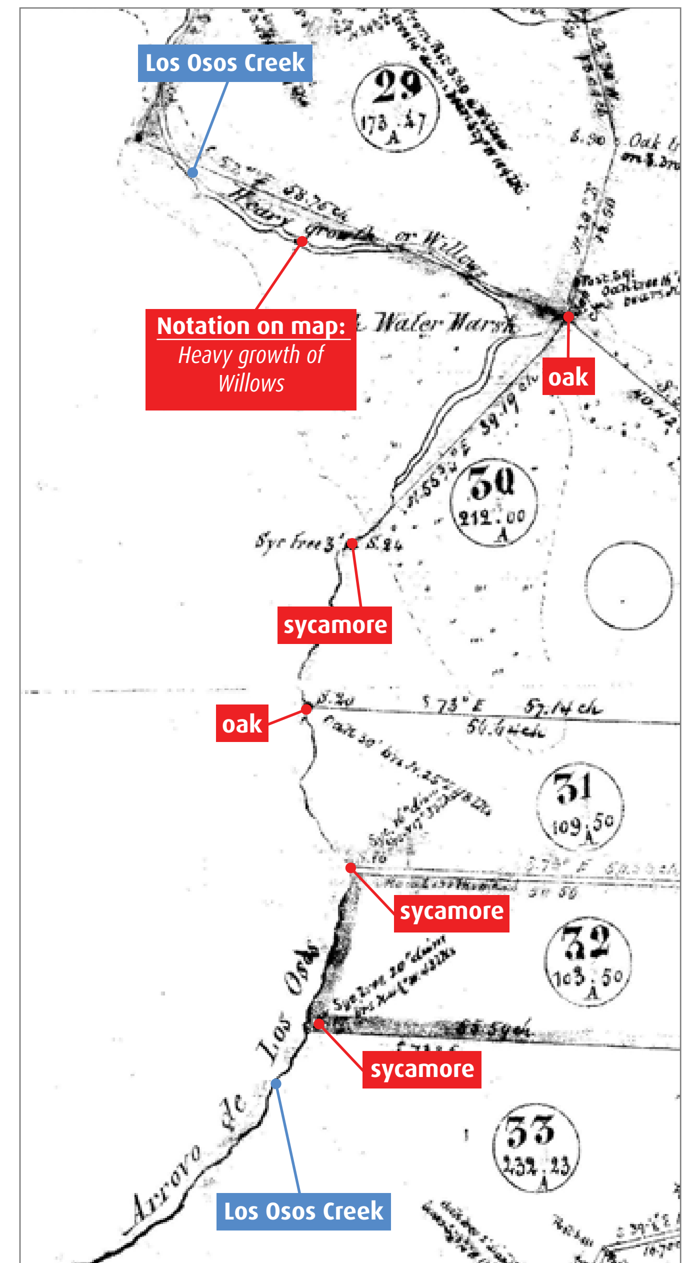
Brown 2001). Missionary Juan Crespí, traveling with the Portolá Expedition in September 1769, described Chorro Creek as having “many sycamores and a good many live oaks” (Crespí and Brown 2001). Nearly 100 years later, in 1855, General Land Office Surveyor James E. Freeman described “sycamores” and “wild oats” (likely referring to non-native *Avena* spp.) along a different stretch of Chorro creek (Freeman 1855). In Los Osos Valley, a subdivision map from 1868 captured the composition of the riparian corridor along Los Osos, labeling oaks, sycamores, and a “Heavy growth of Willows” (Stratton 1868, Fig. 15).

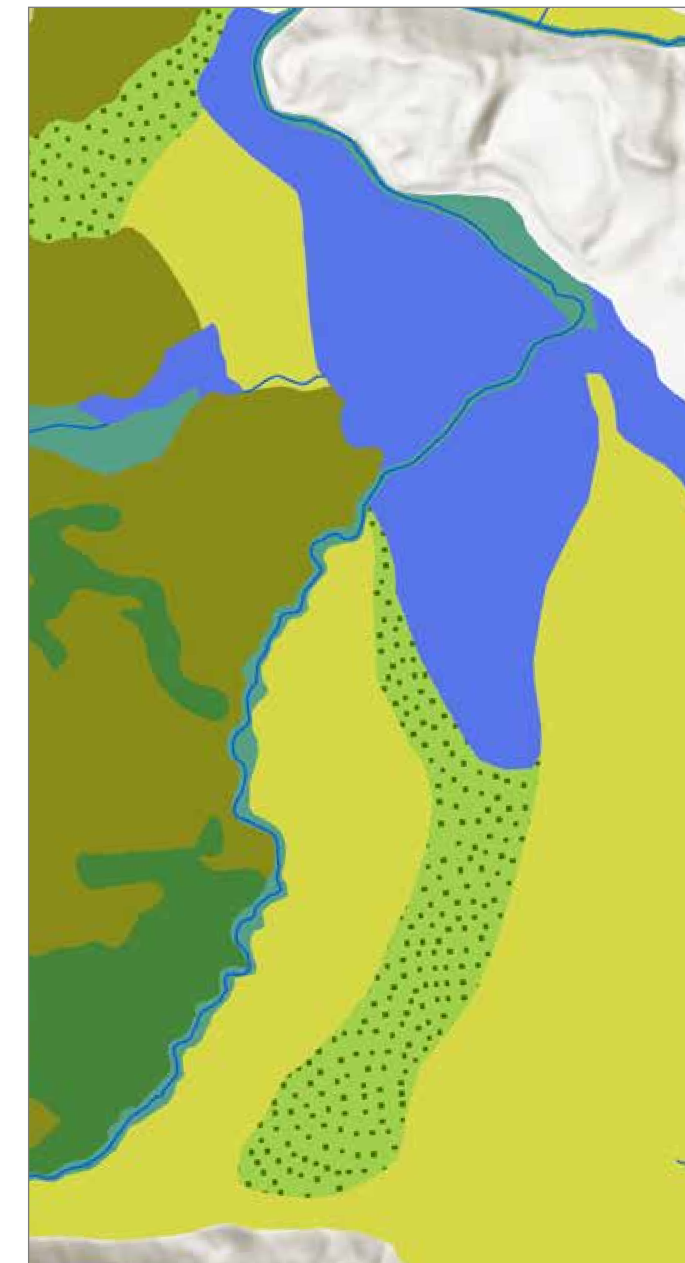
In addition to a canopy generally dominated by coast live oak, Western sycamore, and willows, riparian forests included a variety of plant species such as serpentine willow (*Salix breweri*), California wax myrtle (*Morella californica*), California wild rose (*Rosa californica*), and spreading gooseberry (*Ribes divaricatum* var. *pubiflorum*) (data from the California Consortium of Herbaria).

Numerous species of passerine birds inhabited the riparian forests along the major creeks and tributaries. Among them were willow flycatcher (*Empidonax traillii*), least Bell’s vireo (*Vireo bellii pusillus*), Wilson’s warbler (*Cardellina pusilla*), and Swainson’s thrush (*Catharus ustulatus*) (data from the Global Biodiversity Information Facility).

LOCATION OF FIGURE ON HISTORICAL ECOLOGY MAP

Figure 15. (below, left) An 1868 subdivision map of the ranchos Cañada de los Osos and La Laguna. The map labels points where oaks, sycamores, and willows were documented along Los Osos Creek. *(Stratton 1868, courtesy of San Luis Obispo County)* **(below, right)** The same area is depicted on the historical ecology map, showing riparian forest bordering Los Osos Creek.





Varied Habitats Around Lower Morro Creek

Historically, Lower Morro Creek flowed west into the study area, then turned south and deposited its waters onto the tidal flats bordering the northern rim of Morro Bay just opposite the Estuary entrance. The 1883 T-Sheet, the primary source used to map the channel, depicts Lower Morro Creek traversing a broad grove of willow trees, upwards of 600 m (2,000 ft) wide in some areas (Forney 1883; see also Fig. 21 on page 47). An expanse of mobile dunes bordered the lower section of the creek to the west. Little Morro Creek drained off the hills further south, and joined Morro Creek in the willow thickets for about 240 m (820 ft), before splitting off and draining into the tidal flats of the Bay (Forney 1883, Harris 1880, Fig. 16). Archaeological evidence supports the presence of southwestern pond turtles (*Actinemys pallida*) and southern alligator lizards (*Elgaria multicarinata*) along Morro Creek (SLOCAS 2000).

While the mapped channel appears to represent the dominant configuration of Lower Morro Creek in the mid- to late 19th century, evidence suggests that flows shifted over time as a result of flooding and sand deposition. Longtime resident Marie Walsh McKennon recounted in 1959 how the dunes, built up "during the dry seasons by heavy winds and high tides along the bayshore," would occasionally push the creek north and west, flooding the willow groves and forming a pool of water in the sand just before the shore (McKennon 1959). The 1883 T-sheet and 1897 USGS topographic quad both depict a small pond feature fed by a stream just north of Morro Creek, likely in the location of this alternative flow path (Forney 1883, USGS 1897a).

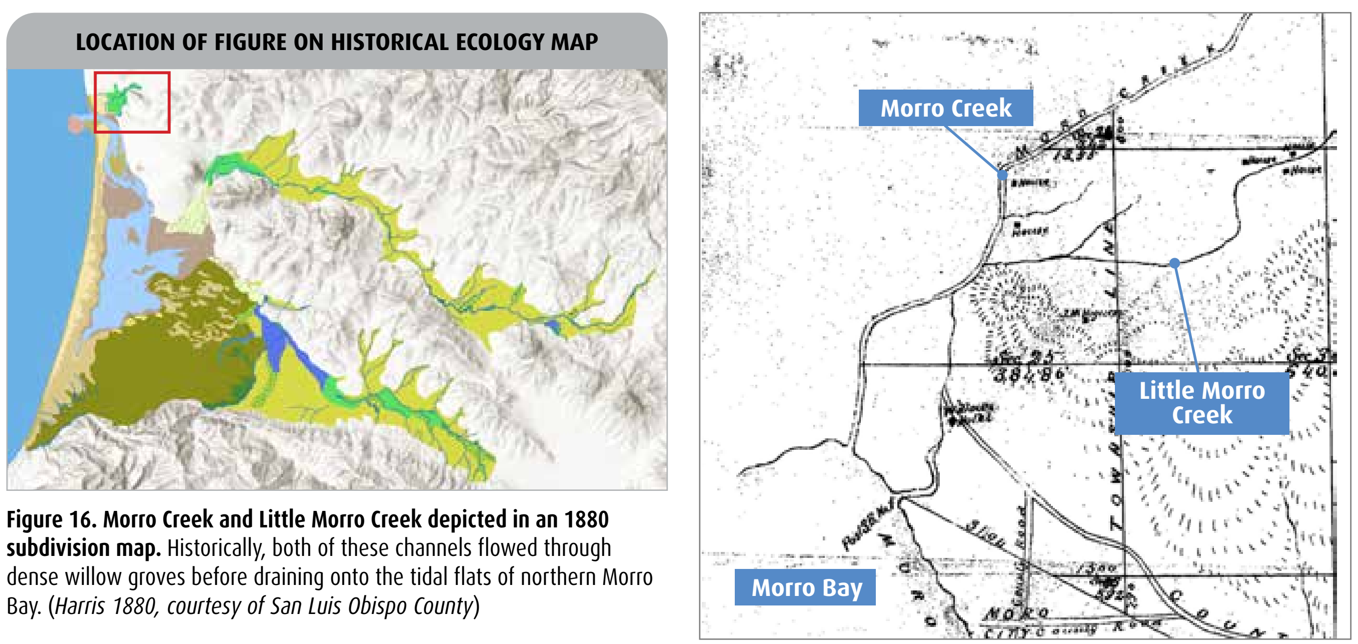


Figure 16. Morro Creek and Little Morro Creek depicted in an 1880 subdivision map. Historically, both of these channels flowed through dense willow groves before draining onto the tidal flats of northern Morro Bay. (*Harris 1880, courtesy of San Luis Obispo County*)

Valley Freshwater Marsh in Warden Lake and Ciénega de Romualdo

Freshwater marshes occupied approximately 116 ha (287 ac) in both Chorro and Los Osos valleys. Tule (*Schoenoplectus* spp.) and other emergent vegetation, such as broadleaf cattail (*Typha latifolia*), sedges (*Carex* spp.), and rushes (*Juncus* spp.), likely dominated the freshwater marshes, alongside shrubs such as California wax myrtle (*Morella californica*) and Western dogwood (*Cornus sericea* ssp. *occidentalis*) (Dixon 1918a, data from the California Consortium of Herbaria, Jones et al. 2019). Northern Chumash living in Morro Bay used tule stems to construct boats to fish in and navigate the Estuary (SLOCAS 2000, Jones et al. 2019).

The largest expanse of valley freshwater marsh in the study area was known as Warden Lake, located in Los Osos Valley near the confluence of Los Osos and Warden creeks. An 1868 subdivision map depicts Los Osos Creek flowing through Warden Lake—labeled "Fresh Water Marsh"—before transitioning into a tidal channel at the start of the tidal salt marsh (Stratton 1868; Fig. 17). The 1897 USGS topographic quad of Cayucos and the 1928 soil survey map both depict Warden Lake as a slightly smaller feature, likely reflecting some reduction in the extent of the wetland by that time (USGS 1897a, Carpenter and Storie 1928a; Fig. 18). Accounts from the Portolá Expedition, which traveled through Los Osos Valley in September of 1769 and again in May of 1770, do not appear to explicitly reference Warden Lake, but do describe "a great many... pools and lakes" in the valley likely east of the study area (around Laguna Lake) (Crespí and Brown 2001). Juan Crespí also noted the "vast numbers of geese" at lakes throughout the floor of Los Osos Valley (Crespí and Brown 2001). Directly to the west of Warden Lake, Eto Creek flowed into a much smaller freshwater marsh called Eto Lake (United States Army 1937, Yates and Wiese 1988, Maughan and Strock 1991).

Geologic structure is likely a key factor explaining the location of Warden Lake and other wetland features in the region. The formation of Los Osos Valley was strongly influenced

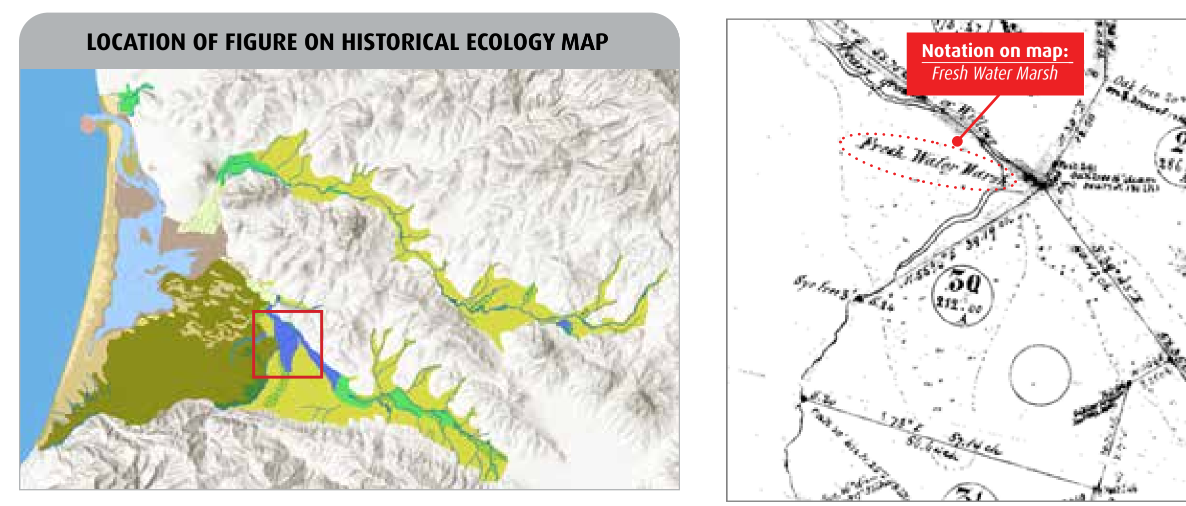
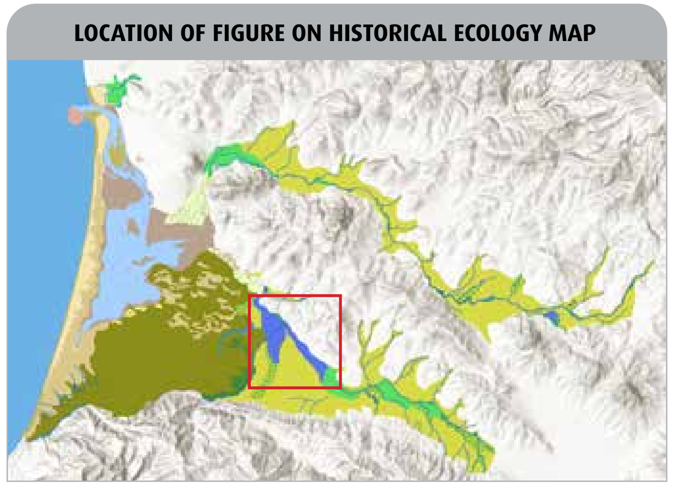


Figure 17. An 1868 subdivision map of the ranchos Cañada de los Osos and La Laguna. The map shows Warden Lake as a "Fresh Water Marsh" in Los Osos Valley. (*Stratton 1868, courtesy of San Luis Obispo County*)



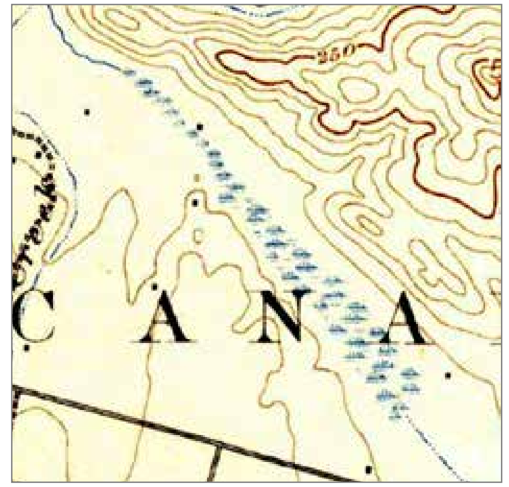
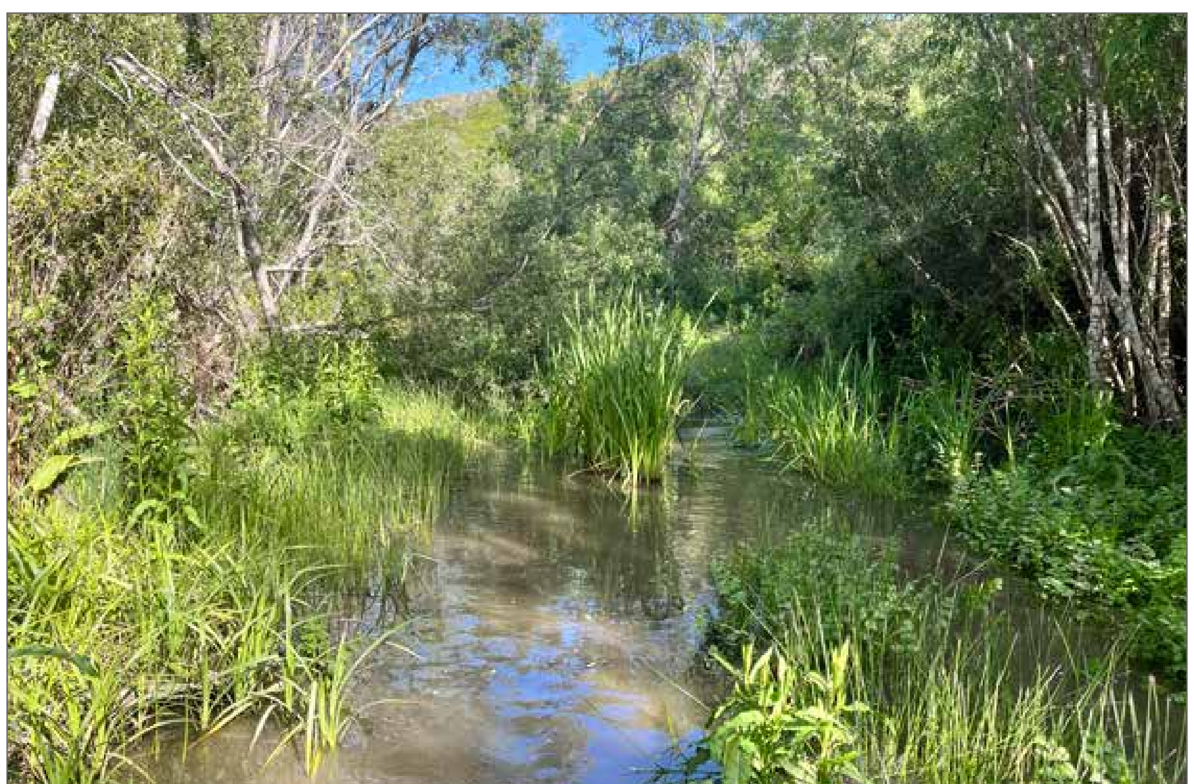


Figure 18. Warden Lake depicted on the 1897 USGS topographic quad of Cayucos. The extent of the marsh as depicted here is reduced relative to its depiction 30 years earlier in the 1868 subdivision map (see Fig. 17). (*USGS 1897a, courtesy of USGS*)

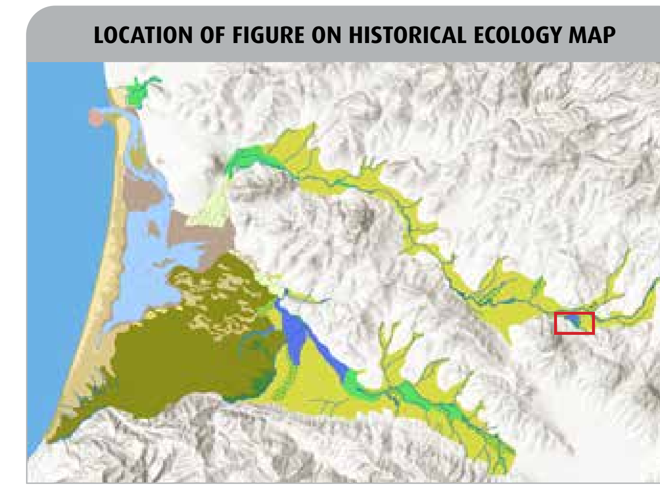
by tectonic movement along the Los Osos Fault on the south side of the valley, leading to subsidence on the western side of the valley and ultimately to the formation of the coastal Los Osos Valley Groundwater Basin during the late Tertiary and Quaternary periods (Yates and Wiese 1988, Cleath-Harris Geologists 2018, Wiegers 2021). Warden Lake formed where surface and groundwater flow accumulated in this topographic depression just inland from the Pleistocene eolian deposits in the Los Osos-Baywood Park area; a bedrock constriction near the northwest corner of Warden Lake likely further contributed to wetland formation upstream (Hall 1979, Cleath-Harris Geologists 2018).

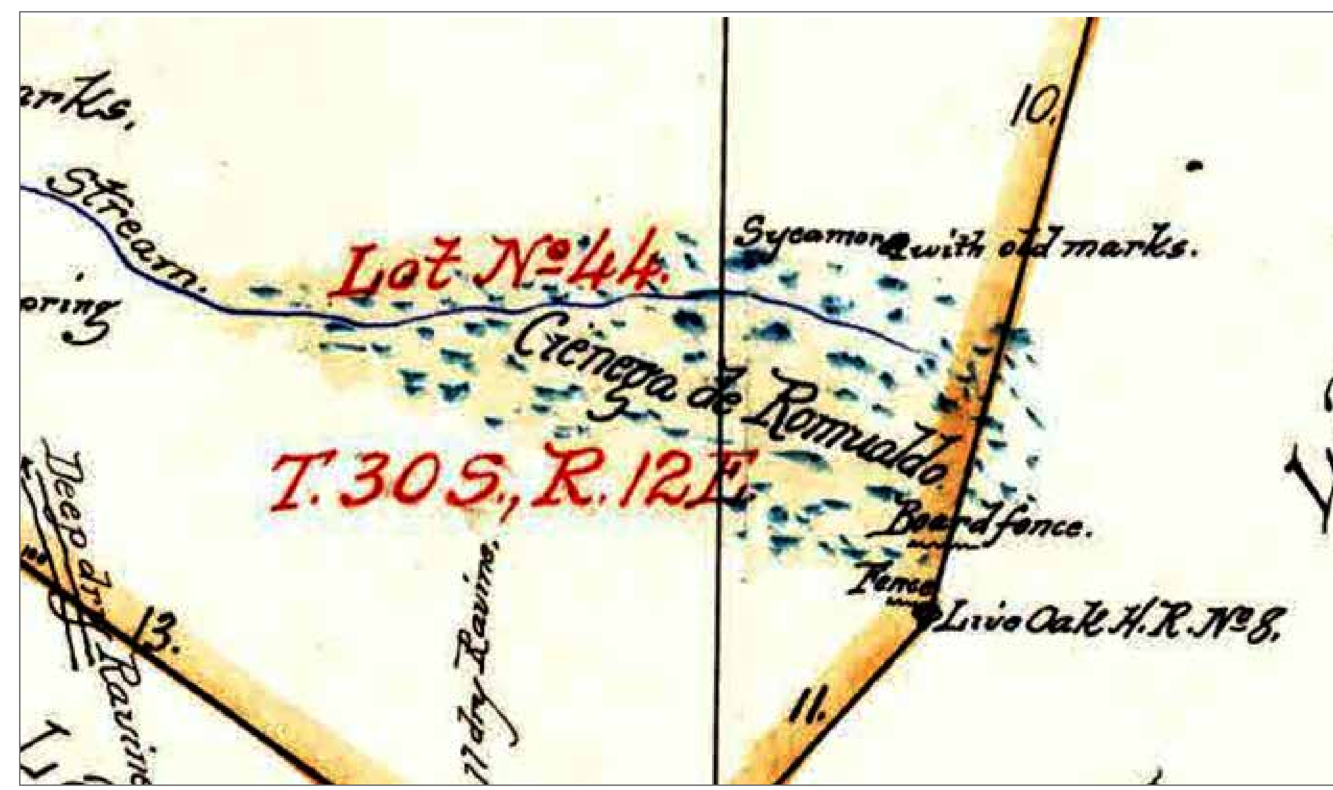


Riparian and freshwater wetland habitats in Los Osos Wetlands Preserve • Photograph by Sean Baumgarten, SFEI.

Another notable freshwater marsh existed historically in Chorro Valley, between Chorro Creek and a tributary slightly to the south. A GLO land grant plat from 1871 shows a stream flowing through an area symbolized with wetland markings and the label "Cienega de Romualdo" ("Romualdo's Swamp") (Drummond 1871; Fig. 19). The footprint of the freshwater marsh is still visible six decades later in the 1937 aerial imagery, which was used to map the boundary of the wetland.

Figure 19. A GLO land grant plat of the Huerta de Romualdo or El Chorro from 1871. A patch of freshwater marsh in Chorro Valley is labeled "Cienega de Romualdo," translating to "Romualdo's Swamp." *(Drummond 1871, courtesy of BLM)*





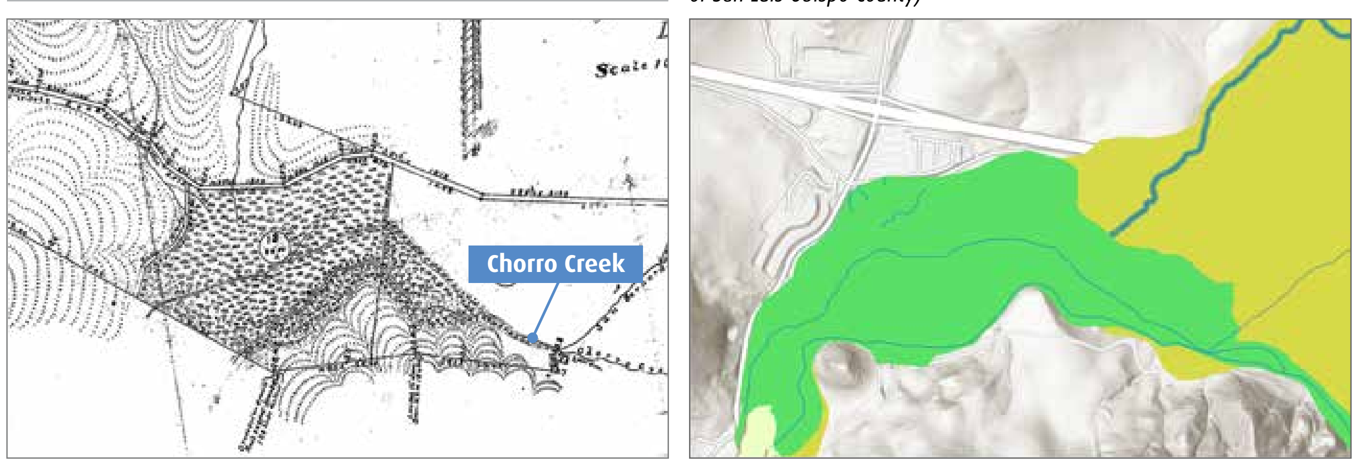
Willow Groves Found Throughout the Valley

Chorro Valley, Los Osos Valley, and Lower Morro Creek supported numerous stretches of willow groves, with one as large as 55 ha (135 ac) (Fig. 20). These willow thickets were dominated by willows (e.g., arroyo willow [*Salix lasiolepis*], Pacific willow [*S. lasiandra*]*), along with associated species such as straggly gooseberry (*Ribes divaricatum*), Pacific wax myrtle (*Myrica californica*), and twinberry honeysuckle (*Lonicera involucrata* var. *ledebourii*) (data from the California Consortium of Herbaria). Often occurring alongside streams located in the lower valleys and grading into riparian forests, this habitat type was temporarily or seasonally flooded and associated with areas of emergent groundwater. Willow groves provided habitat for birds, bats, and small terrestrial mammals, such as moles (*Scapanus* spp.), gophers (*Thomomys* spp.), and brush rabbits (*Sylvilagus bachmani*) (Dixon 1918a, Grinnell 1918).

*Pacific willow (*Salix lasiandra*) is not documented in historical botanical records but was likely present in the region; records of red willow (*S. laevigata*) may represent a mis-identification of this species (D. Keil pers. comm.).

LOCATION OF FIGURE ON HISTORICAL ECOLOGY MAP

Figure 20. An 1884 subdivision map (left) depicting a multi-threaded Chorro Creek flowing through an extensive willow grove at the mouth of Chorro Valley. The grove totals approximately 55 ha (135 ac) and borders prairies to the east and Chorro marsh to the south. *(Harris 1884, courtesy of San Luis Obispo County)*



In Los Osos Valley, several large willow groves occurred along Warden Creek (Stratton 1868, Morro Bay Improvement Co. 1894, Morrison and Haydon 1917). A 1917 retelling of an 1858 account, for instance, describes the “immense willow thickets that grew on the Los Osos” (Morrison and Haydon 1917). A single large willow grove occupied the downstream end of Chorro Valley, just upstream of the tidal salt marsh (Freeman 1855, Harris 1880, Wieslander 1935, United States Army 1937). Another large willow grove bordered Morro Creek just upstream of the Bay (Phillips 1875, Forney 1883, Harris 1880; Fig. 21). For example, Joseph Dixon described “thick clumps,” and Joseph Grinnell “big tracts,” of willows at the mouth of Morro Creek in 1918 (Dixon 1918a, Grinnell 1918).

LOCATION OF FIGURE ON HISTORICAL ECOLOGY MAP

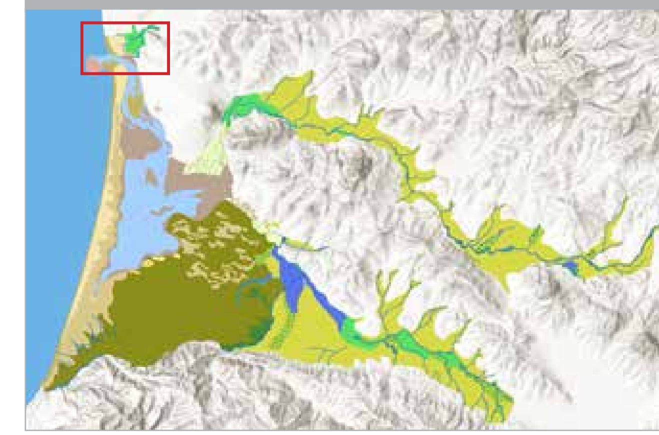


Figure 21. The 1883 U.S. Coast Survey T-1662 sheet depicting willow groves surrounding Morro Creek, just north of the Estuary. Although the tree symbol on this map was used to depict a number of habitat types, textual accounts, GLO Surveys and other maps helped to confirm the presence of willow groves in this area. *(Forney 1883, courtesy of NOAA)*

Wet Meadows Along the Los Osos Valley Floor

Wet meadows were prevalent throughout the floor of Los Osos Valley, covering 126 ha (312 ac). Several patches of wet meadow also occurred in Chorro Valley along tributaries to Chorro Creek. These seasonal wetlands were characterized by poorly drained soils, temporary or seasonal flooding, and a low-stature herbaceous plant community. Most of the documented wet meadow features were mapped from the Dublin clay adobe class in the 1928 soil survey, which had a subsoil layer “mottled with rust brown,” attributed to poor subdrainage (Carpenter and Storie 1928b; Fig. 22). Wet meadows supported a varied herbaceous plant community made up of species such as rushes (e.g., brown-headed rush [*Juncus phaeocephalus*], spreading rush [*Juncus patens*],* salt rush [*Juncus lesueurii*]*), sedges (e.g., pale spikerush [*Eleocharis macrostachya*], *Carex* spp., saltmarsh bulrush [*Bolboschoenus maritimus* ssp. *paludosus*], common threesquare bulrush [*Schoenoplectus pungens* var. *longispicatus*), grasses (e.g., California meadow barley [*Hordeum brachyantherum* subsp. *californicum*], creeping wild rye [*Elymus triticoides*]*), and forbs (e.g., roundleaf leather-root [*Hoita orbicularis*], cows clover [*Trifolium wormskioldii*],* pacific silverweed [*Potentilla anserina* var. *pacifica*], water parsley [*Oenanthe sarmentosa*], lesser water-parsnip *[Berula erecta*]*) (data from the Consortium of California Herbaria, D. Keil pers. comm.).

***Spreading rush (*Juncus patens*), salt rush (*Juncus lesueurii)*, creeping wild rye (*Elymus triticoides)*, cows clover (*Trifolium wormskioldii*), and lesser water-parsnip (*Berula erecta*) are not documented in historical botanical records but were likely present in the region (D. Keil pers. comm.).

LOCATION OF FIGURE ON HISTORICAL ECOLOGY MAP

Figure 22. A portion of a soil map of the study area from 1928, focusing on the Dublin clay adobe class (Dc). The Dublin clay adobe soils are poorly-drained and supported wet meadow/seasonal wetland habitats. The majority of wet meadows were found in Los Osos Valley. *(Carpenter and Storie 1928a, courtesy of the University of Alabama)*

TERRESTRIAL HABITATS

Mobile Dunes and Coastal Dune Scrub on the Sandspit

The Morro Bay sandspit is one of the defining features of the study area, forming a barrier between the Pacific Ocean to the west and the Estuary to the east. Comprised of late-Holocene sand dune deposits, the sandspit extends approximately 6.4 km (4 mi) from present-day Sandspit Beach to just south of Morro Rock. Historically, the sandspit supported two main dune habitat types: mobile dunes and coastal dune scrub. Sparsely vegetated mobile dunes occupied approximately 146 ha (360 ac) on the western side of the sandspit generally facing the Pacific Ocean, while coastal dune scrub occupied approximately 186 ha (460 ac) on the eastern side facing the Estuary. Symbology on the 1881 and 1883 T-Sheets provides the earliest evidence differentiating between the two dune types on the sandspit (Greenwell 1881, Forney 1883), with mobile dunes shown with a speckled pattern and coastal dune scrub with a denser shrub-like pattern. Although captured decades later, this same general distribution of dune habitats on the sandspit is reflected in the 1937 aerial imagery (United States Army 1937; Fig. 23).

LOCATION OF FIGURE ON HISTORICAL ECOLOGY MAP

Figure 23. Mobile dunes and coastal dune scrub on the sandspit, as seen in historical aerial imagery from 1937. Mobile dunes were largely on the Pacific Ocean side of the sandspit, while coastal dune scrub occupied the bay-facing areas. (*United States Army 1937, courtesy of UCSB*)

Mobile dunes and coastal dune scrub on the sandspit supported distinct plant assemblages. Mobile dunes were characterized by sparse cover of early successional or pioneer species, including beach salt bush (*Atriplex leucophylla*), American dunegrass (*Leymus mollis*), and pink sand verbena (*Abronia umbellata*) (data from the Consortium of California Herbaria). Coastal dune scrub was characterized by denser cover of shrubs, grasses, and forbs such as chamisso beach lupine (*Lupinus chamissonis*), California goldenbush, and California saltbush (*Extriplex californica*) (data from the Consortium of California Herbaria). Wetter dune swales were likely present at the low points of coastal dune scrub habitats, with 20th century botanical records identifying characteristic species such as clustered field sedge (*Carex praegracilis*), slough sedge (*Carex obnupta*), Pacific silverweed (*Potentilla anserina* ssp. *pacifica*), and willow dock (*Rumex salicifolius*) on sandy substrates in the study area (data from the Consortium of California Herbaria).

The height of the dunes on the sandspit varied considerably. According to the 1873 depth soundings map, dunes closer to the northern end of the sandspit were characterized by mounds ranging from 0.2-3 m (0.5-10 ft) high. At the widest part of the sandspit, roughly halfway down, dunes were documented as being 9-18 m (30-60 ft) high (Sears and Bradford 1873).

Dunes North of the Estuary

Mobile dunes were also historically found north of the Estuary mouth, partially overlapping with the now-closed Morro Bay Power Plant (Fig. 24). The mobile dunes here bordered beach habitat to the west, dense willow groves to the east, and tidal flats to the south. The 1881 T-sheet provided the most detailed evidence for mobile dunes in this area (Greenwell 1881), and early descriptions recall the proximity of the dunes to Morro Creek (Dixon 1918a).

Figure 24. A panoramic photograph of mobile dunes north of the Estuary, ca. 1925. Mobile dunes were characterized by early successional or pioneer species, including beach salt bush (*Atriplex leucophylla*), American dunegrass (*Elymus mollis*), and pink sand verbena *(Abronia umbellata*). (*Aerograph Co. ca. 1925, courtesy of the Huntington Library*)

Maritime Chaparral and Coastal Dune Scrub on the Paleodunes

Late to mid-Pleistocene eolian sand deposits (paleodunes) supported a dynamic mosaic of maritime chaparral and coastal dune scrub in the areas around modern-day Los Osos and Baywood Park (Orme 1990, Wiegers 2021). This area is bordered by the Bay to the north, a section of the sandspit to the west, a stretch of Los Osos creek and upland habitats to the east, and parts of present-day Montaña de Oro State Park to the south. The paleodunes were characterized almost entirely by Baywood fine sand and Garey fine sand soils in the 1928 soil map and survey, which describes Baywood fine sand soils as "partly brush covered and partly open" in its premodification state (Carpenter and Storie 1928a/b; Fig. 25).

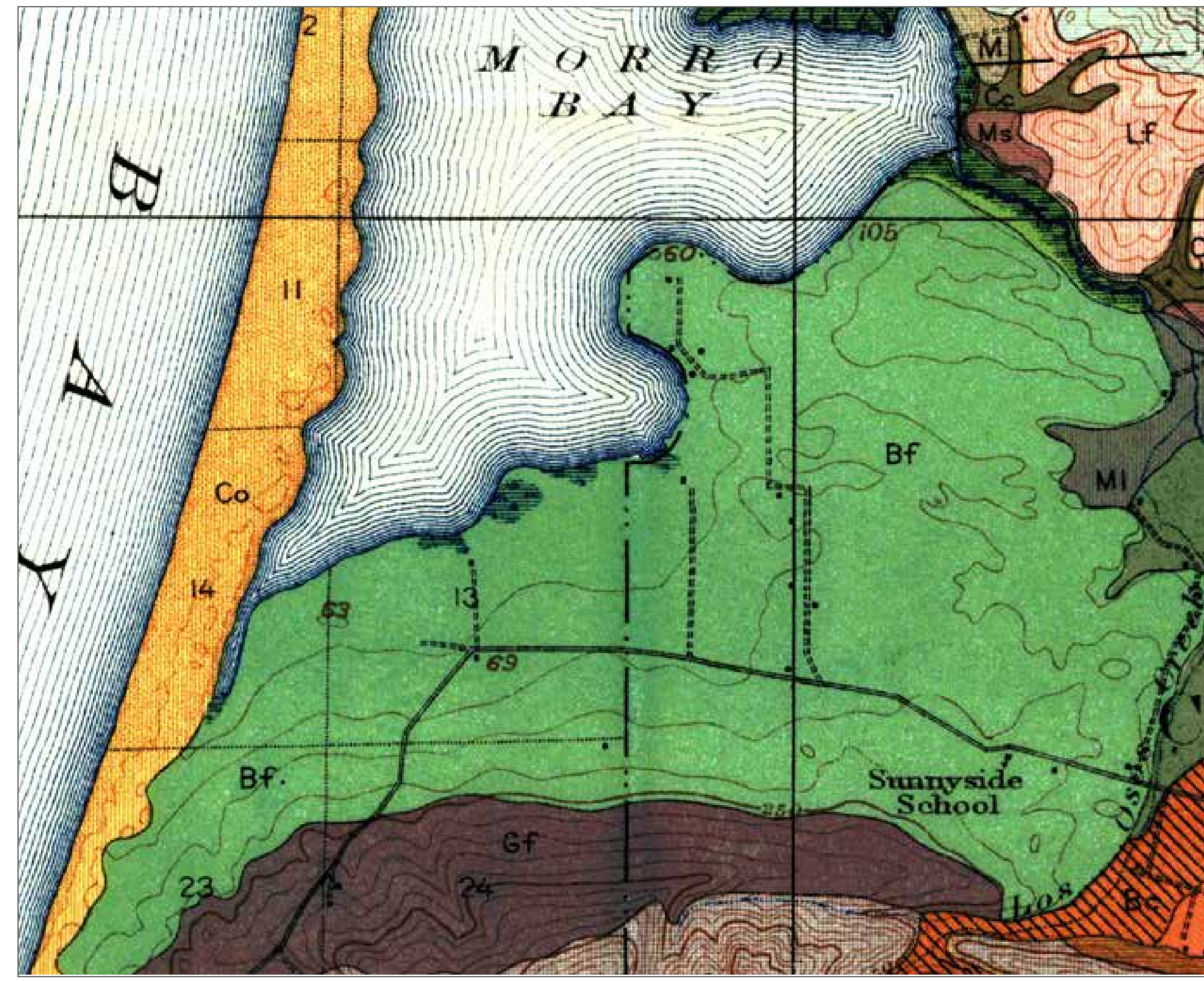


Figure 25. A portion of the 1928 soil map of the study area. Baywood fine sand (Bf) and Garey fine sand soils (Gf) were used to help map maritime chaparral and dune scrub on the paleodunes. The soil survey described Baywood fine sand soils as being "partly brush covered and partly open" in its premodification state. (*Carpenter and Storie 1928a/b, courtesy of the University of Alabama*)

There is strong evidence that maritime chaparral and dune scrub coexisted in much of the paleodunes historically. The area is labeled "chamisal" in a ca. 1840 diseño (sketch map) of Rancho Cañada de Los Osos y Pecho y Islay (USDC ca. 1840). Mid-19th century General Land Office Surveyors consistently described the paleodunes as shrub-dominated, and suggest that maritime chaparral was the dominant vegetation type. In April of 1855, for instance, Surveyor James E. Freeman documented a "dense thicket of chaparral" and "chamisal" while walking through present-day Los Osos (Freeman 1855). Three years later, surveyor Brice M. Henry similarly described sandy hills covered with chamisal and chaparral (Henry 1858). In 1870, surveyor R.R. Harris provided more specificity on species composition, noting live oak (*Quercus agrifolia*), manzanita (*Arctostaphylos* spp.) and sage brush (*Artemisia* spp.) in a number of locations (Harris 1870).

Early 20th century observations also support maritime chaparral as a dominant vegetation type in the paleodunes and provide more clues about its composition. For instance, field biologist and zoologist Joseph Grinnell described the area in 1918 as "sandy country densely clothed… with a chaparral of hosackia, rhamnus, and several kinds of composites," as well as "manzanita, black sage, adensotoma, eriogonum, grindelia, and scrub oak" (Grinnell 1918). His mention of manzanita could be referring to Morro manzanita (*Arctostaphylos morroensis*), a shrub species characteristic of maritime chaparral and endemic to the Los Osos region that grows almost exclusively on Baywood fine sand soils (Jodi McGraw Consulting 2022). Additionally, Grinnell noted this area was habitat for "*Perodipus,*" referring to the Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*), an endangered rodent also endemic to the vicinity of Los Osos that has not been documented since 1986 (Kofron and Villablanca 2016). The Morro Bay kangaroo rat is associated with lower density shrubland (Kofron and Villablanca 2016), and thus its historical occurrence in this area suggests the landscape included a mix of shrubland patches of variable age and density.

Though created after substantial landscape modification, Wieslander Vegetation Type Mapping and photographs from the 1930s offer additional insight into vegetation assemblages in this area (Fig. 26). The mapping identifies nearly thirty shrubland assemblages reflecting dominant species in different areas of the paleodunes, each of which can either be crosswalked to maritime chaparral or coastal dune scrub. While some sections of the mapping depict urban development, cultivation, or eucalyptus (*Eucalyptus* spp.) plantings, others reveal that many parts of the paleodunes supported coastal dune scrub alongside maritime chaparral (Wieslander 1935). The 1937 aerial imagery is generally consistent with the mosaic of habitats documented in the Wieslander mapping, and enabled mapping of these habitat types with greater spatial accuracy. While the specific distribution of maritime chaparral and coastal dune scrub on the paleodunes depicted in the mapping thus reflects a snapshot of early 20th century conditions, these habitats would have experienced continuously evolving stages of succession, likely due in large part to the effects of wildfire and Native American burning practices, as well as other disturbances such as flooding and extreme weather events (Odin and Tyler 2002, Kofron and Villablanca 2016). The northernmost area of maritime chaparral bordering the Estuary overlaps with the present-day El Moro Elfin Forest, which preserves a mature stand of dwarf coast live oaks that have been stunted by and adapted to a combination of harsh environmental conditions: salt spray from the ocean and Bay, poor soil, and frequent winds (Jones et al. 2019, Rojas 2019).

> "The winds sweep up Los Osos Valley very strongly from the ocean. To the south of Morro Bay is a large expanse of ancient dunes now covered with bushes."
>
> H.W. Fairbanks, 1904

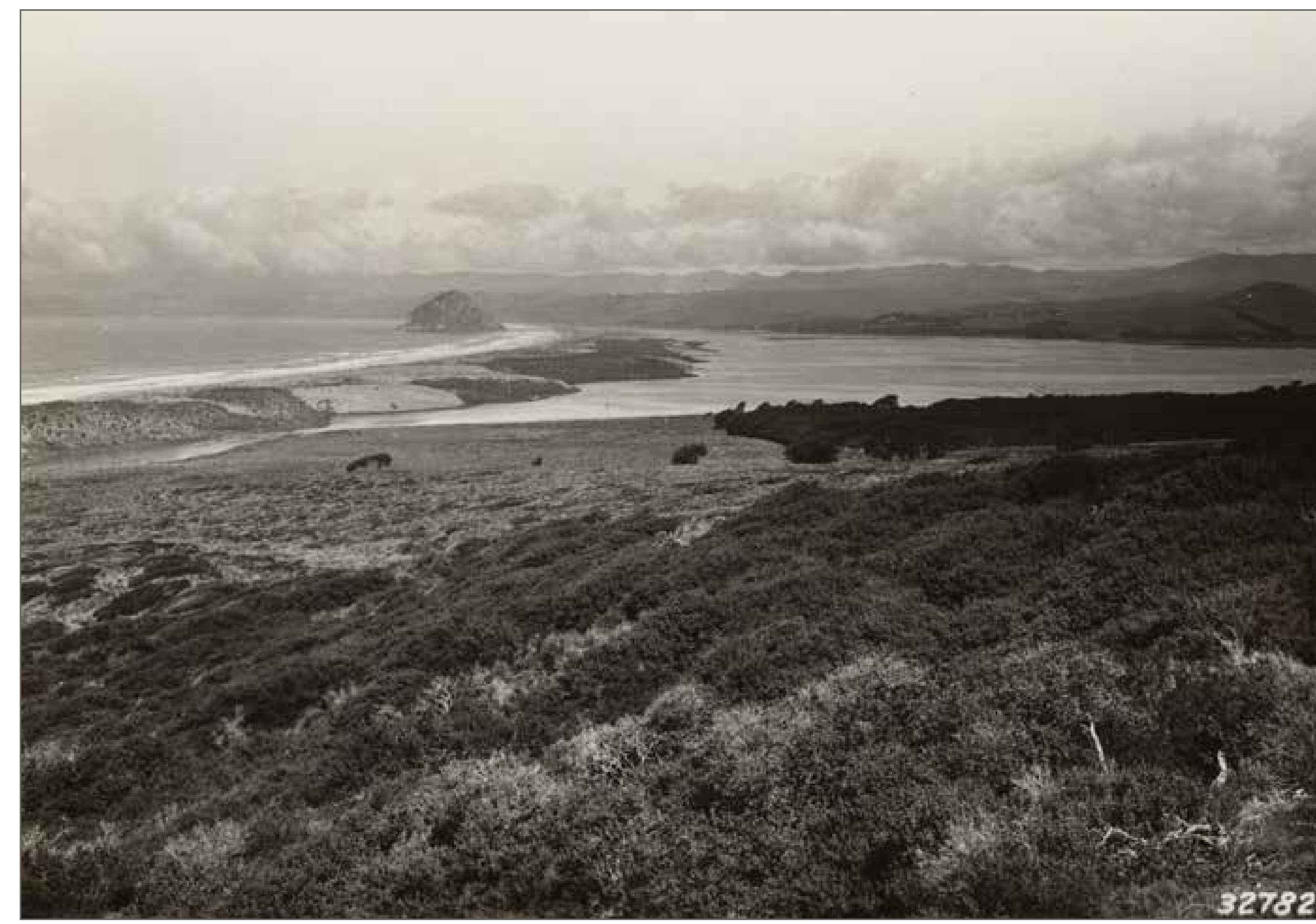


Figure 26. A 1936 photograph looking north toward Morro Bay, with the habitats of the paleodunes in the foreground. The original caption with the photo describes the presence of Morro manzanita (*Arctostaphylos morroensis*), a species characteristic of both maritime chaparral and coastal dune scrub. (*Wieslander 1936, courtesy of Bioscience Library, UC Berkeley*)

Vast Stretches of California Prairie

Prairies were the dominant habitat type in both Chorro and Los Osos valleys, totaling 1650 ha (4,077 ac). Non-native annual grasses and forbs were already widespread along the California coast by the mid-19th century, and documentation of the pre-invasion composition of these habitats is limited (Minninch 2008). While it was long believed that bunchgrasses such as purple needlegrass (*Stipa pulchra*) dominated California's prairies (or "grasslands") historically (Clements 1920, Heady 1977), evidence from early written accounts and phytolith analysis suggests that the historical composition included a diverse mix of annual and perennial grasses and forbs (Hamilton 1997, Minninch 2008, Holstein 2011, Evett and Bartolome 2013). "California prairie" is thus used here in favor of the term "grassland," which may be misleading (Holstein 2011, D. Keil pers. comm.). Historical botanical records suggest these prairies were characterized by a variety of forbs and grasses such as fiddleneck (*Amsinckia* spp.), paintbrush (*Castilleja* spp.), tarweed (*Deinandra* spp.), clover (*Trifolium* spp.), purple needlegrass, and California barley (*Hordeum brachyantherum* ssp. *californicum*) (data from the Consortium of California Herbaria).

> "At once we came onto the shore, and went along it whenever it allowed, but most of the way was over level tablelands with very good soil, very grown over with dry grasses that had been burned off in some spots but not in others, with not a tree to be seen in the whole day's march."
>
> Juan Crespí, 1769, describing prairies north of the study area

The earliest evidence for prairie in the study area come from the Portolá Expedition. In early September of 1769, for instance, Juan Crespí described Chorro Valley as having "a good deal of very grass grown soil" and the floor of Los Osos Valley as having "very tall dry grasses" (Crespí and Brown 2001). Just north and south of the study area, Crespí documented the Chumash practice of intentionally burning prairie, which was used to reduce woody vegetation and enhance the growth of edible species, among other purposes (Crespí and Brown 2001). It is likely that cultural burning practices were used on prairies within the study area.

Extensive prairies throughout Chorro and Los Osos valleys are also documented in 19th and early 20th century sources such as the 1937 aerial photos, 1928 soil survey, and early landscape photos (Pryor n.d., Unknown 1901, Carpenter and Storie 1928b, United States Army 1937). While idealized and potentially not fully representative of historical conditions, 1883 lithographs of ranches in Los Osos Valley and Chorro Valley illustrate expansive prairies covering the low valleys and rolling hills (San Luis Obispo County Historic Lithographs Collection 1883a/b; Fig. 27).

Prairies in the study area supported a profusion of birds and other wildlife. One 1918 account of Los Osos Valley from Joseph Grinnell suggests that the dominant birds were "Meadowlarks, Brewer blackbirds, Linnets [house finch] and Say Phoebes" (Grinnell 1918). On another day in

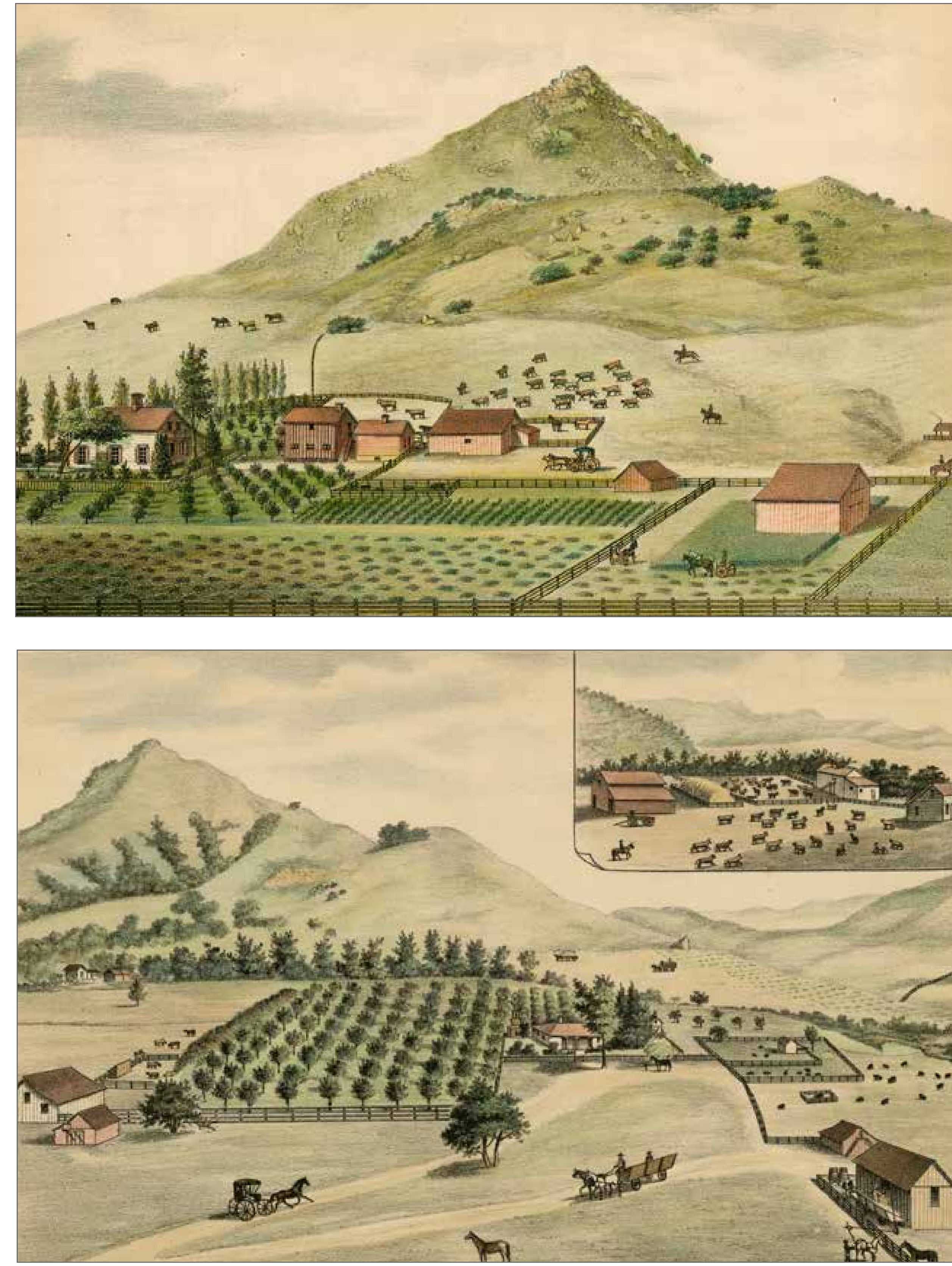


Figure 27. Two 1883 lithographs depicting vast stretches of prairie in both Los Osos Valley (top) and Chorro Valley (bottom). The 1928 soil survey and 1937 historical aerial imagery support the presence of prairies in the study area. (*Thompson and West 1883a/b, courtesy of the Special Collections Department of the Robert E. Kennedy Library, California Polytechnic State University*)

the Valley, Grinnell noted that savannah sparrows (*Passerculus sandwichensis*) had appeared "commonly in weedy and grassy places" in days prior (Grinnell 1918). The name "Los Osos Valley," meaning "Valley of the Bears," comes from the Portolá Expedition of 1769 when Miguel Costansó and his soldiers recalled seeing "troops of bears which kept the ground plowed up and full of holes which they make searching for roots which constitute their food" (Crespí and Brown 2001). Constansó continuously reported sightings of great numbers of bears over the course of his stay in Los Osos Valley (Crespí and Brown 2001).

Oaks Across the Landscape

While a number of early sources collected for this study (e.g., San Luis Obispo Tribune 1872, San Luis Obispo County Historic Lithographs Collection 1883a) document the presence of oak woodlands on hillslopes surrounding the study area (areas not included in the mapping), the archival sources examined do not provide evidence for extensive oak savanna or woodland on the valley floors. Only one small patch of oak woodland/savanna was mapped in Chorro Valley based on evidence in the historical aerial imagery, which overwhelmingly depicts both valleys as being prairie-dominated (United States Army 1937). In addition to coast live oak, other species characteristic of oak woodland/savanna included canyon gooseberry (*Ribes menziesii*), California buckthorn (*Frangula californica*), and California blackberry (*Rubus ursinus*) (data from the Consortium of California Herbaria).

Several other patches of oak woodland/savanna were mapped on the eastern edges of the paleodunes (Wieslander 1935, United States Army 1937), where they likely integrated with maritime chaparral vegetation. The Northern Chumash harvested acorns from oak woodlands in the region, and archaeological evidence suggests shell middens and other cultural sites were extensive along the rim of paleodunes (Jones et al. 2019, John F. Rickenbach Consulting 2020).

Evidence from sediment cores in the Estuary suggests that the watersheds around Morro Bay were generally more forested prior to land clearing for livestock grazing during the mission and rancho periods. For instance, an analysis by Broadman et al. (2022) found changes in the composition of the pollen record following Spanish colonization that are consistent with land clearing and conversion from a more wooded landscape to a landscape more dominated by grassland and pastures (Broadman et al. 2022). It is possible that Los Osos and Chorro valleys historically supported scattered oaks that were removed by early settlers. However, in light of early Spanish accounts attesting to the presence of "very grass grown soil" in the valleys and to Norhern Chumash management of the prairies through fire (see page 54), it seems likely that prairies were a dominant vegetation type in the valleys, and that the loss of woodland habitat and conversion to pasture may have been more prevalent on the surrounding hillslopes.

Photo from Cerro Alto peak looking north to lower Chorro Creek floodplain • Photograph by Morro Bay National Estuary Program.

Chorro Valley (left) and Cabrillo Peak (right), one of the Nine Sisters volcanic outcrops in the area • Photograph by Sean Baumgarten, SFEI.

Conclusion

Aerial view looking southwest across tidal sloughs in Chorro Marsh • Courtesy of Jeff Ebner, CA State Parks.

SUMMARY OF FINDINGS

This report provides an in-depth look at the Morro Bay Estuary and valleys of the surrounding Watershed as they existed under Indigenous stewardship prior to major Euro-American modification of the landscape. The Bay was characterized by expanses of tidally-influenced shallow open water, mudflats, and marsh plains, while mobile dunes and coastal dune scrub on the sandspit served as a protective buffer against the Pacific Ocean. Chorro and Los Osos creeks flowed through the adjacent valleys, where riparian forests, freshwater marshes, willow groves, and wet meadows bordered broad prairies. Paleodunes south of the Estuary were characterized by a mosaic of maritime chaparral, dune scrub, and to a lesser extent, oak woodlands.

In many ways, Morro Bay and its Watershed are a different environment today than they were in the mid-19th century. Sensitive habitats, patterns of sediment deposition, tidal influence, and hydrology have all been impacted by ranching, urban and agricultural development, other land use modifications, and the loss of Native American land management practices. However, despite these changes, the Estuary and surrounding Watershed still support large swaths of undeveloped habitat and provide substantial value for both people and nature.

MANAGEMENT AND RESTORATION OPPORTUNITIES

The historical ecology mapping and information developed through this study provides a critical foundation for setting actionable restoration targets and goals within the Estuary and greater Morro Bay Watershed. This historical lens is not intended to help recreate historical conditions on the contemporary landscape, but instead to help identify restoration opportunities and inform prioritization of restoration areas that align with both ecological potential and current land uses. Historical baselines provide a reference for evaluating suitability and trade-offs among restoration alternatives, helping planners distinguish between interventions that work with natural processes and those that may require ongoing maintenance. Working in collaboration with Native communities, historical ecological knowledge can support efforts to re-establish Tribal guardianship and Traditional management practices.

Analysis of the historical landscape suggests a range of restoration targets across different parts of the study area, and supports recent or ongoing restoration efforts in sites like the Los Osos Creek Wetland Preserve and Chorro Creek Ecological Reserve. Historical floodplain wetlands along Chorro Creek, Los Osos Creek, and key tributaries offer opportunities to reestablish hydrologic connectivity and improve the capture of sediment. Riparian corridors, especially where existing vegetation or geomorphic features persist, may support recovery of sensitive native plant communities, provide critical wildlife habitat, and enhance water quality. Reestablishing dune and maritime chaparral systems can support endangered species such as Morro manzanita and enhance habitat hetereogeneity. Restoration of historical eelgrass beds can support estuarine food webs and help reverse substantial losses of this habitat in recent years.

While historical ecology can reveal important insights about ecological potential, planning for management and restoration must also account for accelerating future environmental impacts. Sea level rise is expected to reshape the Estuary by driving landward migration of tidal habitats, increasing salinity intrusion, drowning portions of the historical salt marsh along the Los Osos and Chorro Creek deltas, threatening high marsh biodiversity, and displacing palustrine and riparian habitats. These shifts will compound with existing stressors—such as sedimentation, reduced tidal prism, and habitat fragmentation—to further alter estuarine, marine, palustrine, riparian, and terrestrial ecosystems. Findings from the historical ecology research must therefore be considered in the context of predicted future changes when evaluating opportunities and constraints. For instance, low elevation, undeveloped private and public lands could be targeted for acquisition and preservation to allow for landward migration of estuarine habitats.


View northwest from El Moro Elfin Forest • Photograph by Morro Bay National Estuary Program.

FUTURE RESEARCH DIRECTIONS

There are a number of potential future research directions that could help to build upon these findings and address some of the outstanding questions and uncertainties highlighted in this report. Topics warranting more comprehensive analyses include the composition and structure of vegetation communities, the influence of physical processes and controls (e.g., geology, flooding, streamflow patterns, surface-groundwater interactions) on habitat distribution, wildlife support, and land and water use changes. Future research directions may include broadening the study area to the full Morro Bay Watershed, which would require collecting additional historical data.

Another promising future research direction would be to integrate additional archaeological, zooarchaeological, and paleobotanical datasets to complement the archival sources used in this study. Although the current analysis focuses on the period just before major Euro-American modification, these data can help clarify longer-term ecological trajectories that influence conditions documented in the historical record. For example, pollen and sediment analyses can reveal how variable vegetation patterns and hydrologic conditions were over longer time spans, while zooarchaeological data can provide information about the presence of species that may be underrepresented or missing in archival sources. Working in collaboration with tribes, historical ecology can be further integrated with archaeological data and other sources of information to deepen understanding of Native peoples' influence on and management of the landscape.

Beyond further historical research, the historical ecology mapping and associated data presented here provide the basis for a quantitative spatial analysis of landscape change over time. Assessment of landscape change can reveal which habitats in the Watershed have been disproportionately lost or altered, where remnant habitats remain, and how altered landscape patterns have impacted support for key ecological functions. The historical ecology and landscape change assessments can be integrated with existing planning documents—such as the Comprehensive Conservation and Management Plan (MBNEP 2022) and MBNEP Habitat Protection and Restoration Strategy (Fields et al. 2024)—to anchor management and restoration in an understanding of historical landscape functioning and change over time, and build consensus around a shared vision for ecological resilience in the Watershed.

Acknowledgments

This project was funded by a federal grant from the U.S. Environmental Protection Agency to the Morro Bay National Estuary Program. We would like to thank Carolyn Geraghty, Ann Kitajima, Melodie Grubbs, and Jenn Fields at the Morro Bay National Estuary Program for their guidance, support, and feedback throughout the course of the project.

The report benefited greatly from the input of our advisory team (see page 21). Technical advisors Eric Stein, Jeff Haltiner, Wayne Ferren, and David Keil provided insightful comments on project synthesis and reporting. We are grateful to project partners Emily Bales, Hayley Barnes, Tim Baxter, Ethan Bell, Don Chartrand, John Chestnut, Katie Drexhage, Jeff Ebner, Meredith Hardy, Phil Kaijanowski, Chad Jackson, Hallie Richard, John Sayers, and Aleks Wydzga for their contributions to the project. We would also like to thank Becca Lucas Thomas, Haylee Bautista, and Kelsey Shaffer of ytt Northern Chumash Tribe of San Luis Obispo County and Region, as well as Karen R. White, Karen Fontanetta, and Penny Pierce-Hurt of the Xolon Salinan Tribe, for sharing their insights, including guidance on building collaborative relationships with respect for Traditional Ecological Knowledge, and for their thoughtful review of this report.

We are indebted to the staff and volunteers at the local, regional, county and state archives that we visited or consulted over the course of the project. In particular, we would like to thank Betsy Bertrando of the San Luis Obispo County Archaeological Society; Brittany Waltemate of the University of Alabama; Brittany Webb of the History Center of San Luis Obispo; Craig Nelson of the San Luis Obispo County Public Works Department; Glenn Silloway of the Morro Bay Historical Society; Laura Sorvetti and Maryam Momeni of the Kennedy Library at California Polytechnic University, San Luis Obispo; Michelle Koo of the Museum of Vertebrate Zoology at the University of California, Berkeley; and Seth Romera of the San Luis Obispo Public Library.

Numerous SFEI staff contributed to research and report development, including Laura Feinstein, Melissa Foley, Kendall Harris, Alison Whipple, and Aviva Rossi. Natalie Ward, an intern from Stanford University, contributed greatly to data collection and compilation efforts.

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Picture yourself at the mouth of Morro Bay in 1769. In every direction, the Bay presents a busy tableau of life, with thriving ecosystems under Indigenous stewardship. Sea otters hunt and play in the surf. Sharks, rays, and a myriad of fish dart beneath the surface of the water, weaving through dense stands of eelgrass. In the distance, a family of grizzly bears ambles across the sand dunes, hunting for prey and digging for edible bulbs. Songbirds flit through a dense willow grove bordering the salt marsh, looking for a sheltered place to build a nest. As the tide flows out, you hear the calls of thousands of shorebirds arriving to forage on the expanses of mudflats emerging throughout the Bay. Each species responds to daily and seasonal variations in the environment, and in turn contributes to the complex and interconnected ecosystems of this rich Estuary.