Catching Carbon: A Blue Carbon Assessment of San Diego Wetlands for Equitable Climate Action Planning

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List of Acronyms

BIPOC	Black, Indigenous, and people of color
C	carbon
CAP	Climate Action Plan
CH_4	methane
CO_2	carbon dioxide
GHG	greenhouse gas
ha	hectare
I-5	Interstate 5
JEDI	justice, equity, diversity, and inclusion
KFMR	Kendall-Frost Marsh Reserve
Mg	megagrams (equivalent to a metric ton)
MgC	megagrams of carbon (equivalent to a metric ton of carbon)
mm	millimeter
N_2O	nitrous oxide
NOAA	National Oceanic and Atmospheric Administration
NWP	National Wildlife Preserve
PCH	Pacific Coast Highway
RDF	Regional Decarbonization Framework
SLR	sea level rise
SOM	soil organic matter
UC	University of California
USD	U.S. dollars

List of Definitions

Aerobic	having or requiring the presence of oxygen
Anaerobic	having or requiring the absence of oxygen
Blue Carbon	carbon captured and stored in coastal and marine ecosystems, particularly forested ecosystems including mangrove forests, tidal and salt marshes, and seagrass meadows
Brackish	slightly to moderately saline water; between freshwater and seawater
Climate Equity	just distribution of the benefits of climate action and equal access to opportunities by addressing the historical inequities suffered by people of color
Estuarine	of or relating to an estuary, which is a partially enclosed, coastal water body where freshwater from rivers and streams meet and mix with saltwater from the ocean
Environmental Justice	fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies; the right to a safe, healthy, productive, and sustainable environment for all
Mudflat	unvegetated channels and ponds that are either permanently flooded or intermittently inundated by tidal fluctuations; formed when silt and mud are brought in by water inflow; includes both subtidal and intertidal areas
Peatlands	a wetland where dead plant material accumulate due to waterlogged conditions forming peat soils or decomposed organic material
Salt Marsh	a coastal wetland that are flooded and drained by tides and therefore dominated by salt-tolerant vegetation and slow rates of decomposition
Social Equity	fair and just distribution of societal benefits and burdens
Tidal Prism	volume of water exchanged between a lagoon or estuary and the open sea
Wetland	an ecosystem characterized by hydric soils, hydrophytic vegetation, and wetland hydrology: areas that are either covered by water or saturated with water intermittently including small lakes, floodplains, marshes, mudflats, swamps, estuaries, and lagoons.

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Abstract

At present, wetlands cover only 5.5% of land in the contiguous United States.[1] In California, only 10% of the historical wetland extent remains. [2] Despite covering a small portion of land, wetlands provide an enormous amount of ecosystem services including food production, shelter, flood storage, shoreline erosion protection, and opportunities for recreation, education, and research. One ecosystem service of utmost importance is carbon (C) sequestration. Wetlands are one of many "blue carbon" ecosystems – ecosystems that naturally absorb and store atmospheric carbon within their soils. Studies have demonstrated that blue carbon ecosystems can capture and store as much as, or even more C per unit area than, global terrestrial forests.[1,2] In 2021, the latest Intergovernmental Panel on Climate Change report demonstrated that climate change is widespread, rapid, intensifying, and unprecedented at present.[5] The "climate crisis" is characterized by a variety of environmental impacts including sea level rise, loss of species, and more intense weather events. These impacts disproportionately affect low-income and Black, Indigenous, and people of color (BIPOC) communities around the world. In response, countries, organizations, and other stakeholders are ramping up efforts to address the climate crisis and the County of San Diego is one of them. San Diego County is currently updating their 2018 Climate Action Plan (CAP) to better meet the State of California's greenhouse gas reductions and climate adaptation goals. Currently, the CAP focuses primarily on reducing future emissions through the implementation of energy-efficient and decarbonization technologies. However, there are two missing pieces to the CAP – utilizing natural climate solutions, like blue carbon ecosystems, and achieving climate equity. This report synthesizes years of wetland and blue carbon research, outlines the wetlands around San Diego County, and identifies climate equity priorities. It sheds light on how wetland restoration can act as a placed-based strategy for local climate mitigation, climate equity, and inclusive and just conservation.

Overview

Scattered around San Diego County, California are some of the most productive yet endangered places on Earth – coastal wetlands.[6] Positioned where land and sea meet, coastal wetlands are saturated with fresh or saltwater, for all or part of the year, and are characterized by vegetation that can tolerate wet soils and low oxygen levels. As the endpoints of watersheds, coastal wetlands connect upstream freshwater to downstream brackish waters and open sea, creating an ever-changing and ever-mixing environment. Coastal wetlands include small lakes, floodplains, marshes, mudflats, swamps, estuaries, and lagoons. These fragile and unique places supply water for drinking, habitats for endangered species, barriers for flooding, storage for carbon, and playgrounds for all. Despite occupying a small portion of land around the world, only 5.5% of the contiguous U.S., coastal wetlands provide extensive and significant ecosystem services.[1] This report focuses solely on one service: the ability to sequester carbon from the atmosphere, referred to as "blue carbon."

Coastal wetlands are considered blue carbon ecosystems, coastal and marine ecosystems that have the natural ability of carbon capture and storage. Blue carbon is a novel yet rapidly increasing subject of research because of its natural role in mitigating carbon dioxide (CO_2), the primary greenhouse gas (GHG) contributing to climate change. Peatlands and vegetated coastal wetlands are among the most carbon rich sinks, areas that store more C than they release, on the planet.[3] They are estimated to sequester approximately as much C as, or in some studies even more C per unit area than, global terrestrial forests.[3,4] Freshwater wetlands are similarly capable of C sequestration, however, they can also be sources of carbon dioxide and methane – which has "a 100-year global warming potential more than 28 times that of carbon dioxide." [4] As such, this report focuses on coastal saline and brackish wetlands, which support higher salinity conditions, influenced by tidal flow, that reduce the likelihood of methane emissions.[7,8,9] According to the Environmental Protection Agency's 2021 U.S. GHG inventory, coastal wetlands in the lower 48 states sequestered 4.8 million metric tons of C equivalent and held about 2.9 billion metric tons in their soils as of 2019.[10] In comparison, the U.S. emitted 5,981 million metric tons of C equivalent in 2020.[10] To meet the ambitious climate goals set out around the world, from the Paris Climate Agreement to the U.S. 30x30 Initiative, climate action plans must actively remove C from the atmosphere and keep it stored for long periods of time. The opportunity to restore wetlands to better sequester and store atmospheric C supports these goals.

Under thoughtful conservation and management, coastal wetlands (referred to interchangeably in this document as blue carbon ecosystems) are essential players in climate mitigation. When these ecosystems are disturbed, degraded, or lost, they can release three major heat trapping GHGs: carbon dioxide, methane (CH_4), and nitrous oxide (N_2O). As such, wetlands are potential liabilities for coastal states, capable of transforming from carbon sinks to carbon sources. Wetlands have roles in both climate regulation and mitigation. Naturally, wetlands regulate the climate by modulating atmospheric concentrations of GHGs through sequestration and storage. They also play a part in mitigation by buffering storm damage, protecting water quality through filtration, supplying water through their connected streams, and strengthening shoreline resilience to sea level rise (SLR). The exact value of wetlands, and the extensive ecosystem services they provide, is a widely researched topic. Current estimates of their economic value range from millions to trillions of U.S. dollars (USD). One estimate concluded that the conservation of 3,800 hectares (ha) alone of wetlands along the Charles River in Massachusetts reduces flood damage by an estimated $17 million USD each year.[11] This amount of wetlands is comparable to the approximately 3,627 ha of coastal wetlands in San Diego County.[12] For all of their ecosystem services, the Millennium Ecosystem Assessment valued wetlands as $15 trillion USD in 1997, and another estimate valued it at $10,000 USD per ha in 2011.[13,14] Wetlands are economically and ecologically important for people and nature, yet, they are increasingly at risk.

Across the globe, wetlands are declining rapidly. Estimates of global coastal wetland loss, primarily due to the land conversion for agriculture and aquaculture, range from 25 to 50%.[15,16,17] In 1988, the U.S. adopted the "No Net Loss" policy as a response to the extensive fill of wetlands by development.[18] The No Net Loss policy established a compensatory mitigation process for the destruction or degradation of wetlands, meaning any lost wetland functions must be compensated for through the restoration of existing wetlands or creation of new wetlands. Despite this policy in place, wetland loss persists in the U.S., with an average of 50% of total loss.[20,21] In California, wetlands have declined at an even higher rate, with total loss ranging from 70 to 90%.[2,12,22] Given these rates, it is critical to protect and conserve the wetlands that remain.

San Diego County (County) is home to many coastal wetlands. One estimate reports that approximately 57% (11,000 ha) of all historical estuarine habitats within the Southern California Bight, the area from Point Conception to the U.S./Mexico Border, are housed within the County.[23] Furthermore, the City of San Diego alone contains approximately 3,625 ha of coastal wetlands, which makes up 2.5% of the total coastal wetland area of California and 4% (84,174 ha) of the total land area of San Diego.[12] San Diego County follows similar trends of wetland loss as the State. Estimates place total estuarine loss in the County at 31%.[23] In the most recent inventory of San Diego County's wetlands (1989), it was estimated that by the 1900s population growth and urban development had modified or impacted all 16 of San Diego County's wetland ecosystems in some way.[6,20]

Beyond land conversion, coastal wetlands are also highly vulnerable to climate change-induced SLR, facing risk of end-of-century submergence and extensive habitat loss.[24] Under high SLR projections, California's wetlands are estimated to lose 59 to 99% of marsh habitat depending on the capability of sites to migrate and grow upland.[24] Wetland loss in the face of growing climate concerns threatens communities near and far. Research has shown that peak warming occurs within approximately one decade after a pulse of CO_2 is added to the atmosphere.[25] Therefore, the benefits of mitigating climate and avoiding added CO_2 emissions from wetland loss will be experienced by the people who acted to avoid them in their lifetime. Further data on the status and history of coastal wetlands in the County are relatively sparse and outdated. The need for an up-to-date wetland inventory and strategies for maximizing the blue carbon potential in San Diego County is vital for addressing climate change. This report summarizes strategies for healthy wetland restoration and identifies recommendations for integrating natural climate solutions into the County of San Diego's CAP.

Background

In 2020 the County of San Diego's Board of Supervisors delayed the approval of the 2018 Climate Action Plan (CAP), a comprehensive and coordinated approach to achieve the State of California's 2030 greenhouse gas emission targets and make progress towards the 2050 GHG reduction goal.[26] In response to the Board Action, the County of San Diego is updating the CAP to address noncompliance issues with the California Environmental Quality Act and more aggressively tackle GHG reductions and climate adaptation. The CAP Update was officially set into motion in 2021 with a series of public scoping meetings. At present, the County is collecting and analyzing GHG emission data, preparing potential CAP measures, and holding public workshops to gain feedback. Alongside the CAP Update, the County announced the Regional Decarbonization Framework (RDF), a partnership with the University of California San Diego School of Global Policy and Strategy, the University of San Diego Energy Policy Initiatives, and Inclusive Economics. The RDF will coordinate with public and private sectors in the County to reduce emissions to zero by 2035.

The CAP Update is scheduled to be brought to the Board of Supervisors for approval in Spring of 2024 and the final RDF in 2022. At present, the CAP focuses on decarbonizing buildings, land use, facilities, vehicles and public transit, and development activities.[26] A vital missing piece is the use of natural climate solutions, specifically blue carbon. Within the 2018 CAP, Strategy T-4, "Invest in Local Projects to Offset Carbon Emissions" states the need to invest in local GHG reduction projects and identified "Coastal Wetland Creation" as one of the considerations to do so.[26] In response, this report provides wetlands data, identifies restoration strategies, and provides recommendations to support the County's GHG goals.

"Blue Carbon" Wetlands

Wetlands exhibit three main characteristics: hydric soils, hydrophytic vegetation, and wetland hydrology. Hydric soils are soils that are frequently saturated with water, causing low oxygen levels. Hydrophytic vegetation are plants that require saturated soils or a high-water table to survive and, therefore, can thrive with low oxygen levels. Wetland hydrology refers to the presence and frequency of water, above and belowground, that drives a wetland's existence. Coastal wetlands tend to have a strong tidal flow above ground and high-water table (saturation of water underground). The sequestration potential of a coastal wetland is similarly influenced by the conditions above: the function of water, deposition of sediment, and presence of healthy vegetation. First and foremost, C cannot be sequestered if biomass is not being produced and subsequently buried. Therefore, living vegetation is essential for the C cycle within coastal wetlands. When wetland organisms respire or decompose, the microbial communities convert plant tissues into CO_2, which is added to the atmosphere, and recycle nutrients for plant growth. This is referred to as "microbial decomposition." Conversely, plants also remove atmospheric CO_2 via photosynthesis to create carbohydrates, some of which are incorporated into their tissues.[27] As plants die and decay, some of their tissues are added to the soil as soil organic matter (SOM), which can store C long-term under the right environmental conditions.

Coastal wetlands are highly effective natural climate solutions because of their ability to "exhibit high sediment accretion rates and slow decomposition rates."[21] Sediment accretion is the accumulation of sediment, which are loose organic materials delivered by water or erosional transport. Within coastal wetlands, sequestered C is primarily stored within soil communities rather than plant communities.[3] Since wetlands continuously accrete and bury organic-rich sediment, their soils have an advantage in accumulating C rapidly over long periods of time. As such, saltwater and freshwater flow are important delivery systems within coastal wetlands for the accretion of sediment. In addition, high sediment accretion rates enable wetlands to grow vertically and "keep up" with SLR. Conversely, wetlands that exhibit low accretion rates are in danger of submergence from SLR. As such, blue carbon ecosystems can be more efficient than terrestrial ecosystems in the sequestration of C due to the lack of a high sediment accretion rate.

Carbon storage is also dependent on conditions that limit or slow decomposition because microbial decomposition releases CO_2 to the atmosphere. The following are the primary factors that influence decomposition: temperatures, oxygen availability, and water availability.[3] First, decomposition is estimated to double every 10 degrees Celsius increase.[28,29] Therefore, lower soil temperatures limit decomposition and support more C storage. Second, oxygen availability is influenced by moisture and aeration. Water-logged soils or high-water levels prevent large amounts of oxygen from reaching wetland soils, creating an anaerobic environment that prevents decomposition. Correspondingly, well aerated soils support the flow and supply of oxygen that increases microbial activity and decomposition.[30] Studies have demonstrated that CO_2 emissions are lower under flooded conditions which create anaerobic (low or lack of oxygen) conditions.[28]

The combination of cooler temperatures, well-saturated soils, and low oxygen availability generally create anaerobic conditions that inhibit microbial growth and the decomposition of organic matter. As a result of slow decomposition rates, most organic matter in wetlands remains undecomposed and later buried, resulting in C sequestration and long-term storage.[21] Accordingly, longer-lived wetlands tend to have larger stores of C.

What Do Wetlands Need? Restoration and Creation

Wetland restoration and creation are key strategies to support climate mitigation and adaptation efforts. Wetland restoration involves returning a wetland from a "disturbed or altered state," caused by anthropogenic activities, to a pristine condition which is characterized as productive and minimally disturbed.[31] Restoration strategies can address four types of remediation focuses: hydrological (re-establishing the natural processes of water presence and transport), sedimentary (re-establishing the natural processes of sediment transport, erosion, and deposition), chemical (restoring the quality of water and sediment through pollutant removal and management), and biological (re-establishing communities of microorganisms, vegetation, and fauna).[31] Wetland creation involves the process of turning wetland-free lands into wetlands. Wetland creation strategies are strongly dependent on the local environment. Techniques include establishing hydrology, soil, and vegetation that can withstand local conditions while manipulating topography, hydrology, soils, and other similar parameters to the type of wetland selected. Both restoration and creation strategies are centered on the three basic elements that constitute wetlands – water, soil, and biota. This report focuses on restoration.

Integral to optimal carbon sequestration and storage is a healthy and productive ecosystem. Projects that include enhancement activities to maintain a wetland will enable the natural functions of a wetland to sequester and store C. Furthermore, natural and long-lived wetlands have sequestered C as long as they have existed. Therefore, they have also sequestered C for longer periods than newly constructed wetlands and hold more C. For example, a 25-year-old salt marsh constructed in North Carolina demonstrated lower soil organic C and total nitrogen reservoirs than a 2,000-year-old natural marsh.[22] As such, natural, older wetlands are higher liabilities, capable of releasing vast C stores if disturbed, degraded, or lost.

The Wetlands of San Diego County

This report identifies 11 main estuarine ecosystems which house the wetlands within San Diego County. These blue carbon ecosystems are Agua Hedionda Lagoon, Batiquitos Lagoon, Buena Vista Lagoon, Los Peñasquitos Lagoon, Mission Bay, San Diego Bay, San Dieguito Lagoon, San Elijo Lagoon, San Luis Rey River, Santa Margarita River Estuary, and Tijuana Estuary. Of them, six are located in North San Diego County. These 11 estuarine ecosystems (referred interchangeably as the wetlands of San Diego County) are the focus of this report and are analyzed as potential sites for wetland restoration and investment. This section contains a summary of the major challenges facing the County's wetlands and highlights from 2020-2021 blue carbon data. Lastly, a full inventory of the County's wetlands was created and can be found in Appendix 1. The inventory informs the basis of this section and includes information on each wetland's characteristics, history, owners, managers, partners, and ongoing concerns.

Highlights

At present, San Diego County has lost approximately 31% of its historical estuarine habitat.[23] Much of the composition of these remaining habitats have changed drastically. The predominant change observed has been the replacement of intertidal and vegetated wetlands by subtidal waters.[23] Along the Southern California Coast, approximately 8,368 ha or 43% of historical estuarine habitats have been converted to non-estuarine features (i.e., developed, agricultural, or open space land uses) from 1850 to 2005.[23] Within the County specifically, all 11 estuarine ecosystems have undergone alterations in some form to non-estuarine features – most of which is extensive. Historically, San Diego's wetlands exhibited strong connections to the ocean via tidal flow and upland streams and rivers via freshwater flow. The transition zones between lowland and upland habitats support a wetland's ability to migrate landward in the face of SLR. However, it has been observed that zonation exhibited between low, middle, and upper marshes found typically in fully tidal systems appears to have been absent at most North County lagoons.[32] North County lagoons were also historically characterized as supporting freshwater and brackish wetlands extending inland, often for many miles, and dominated by habitat types relatively high in the tidal frame (e.g. salt marsh and seasonally flooded salt flat).[32] Salt flats were also found in nearly every system, often composing over half of the total historic estuarine area.[32] The wetlands around the entire County have exhibited similar characteristics and trends.

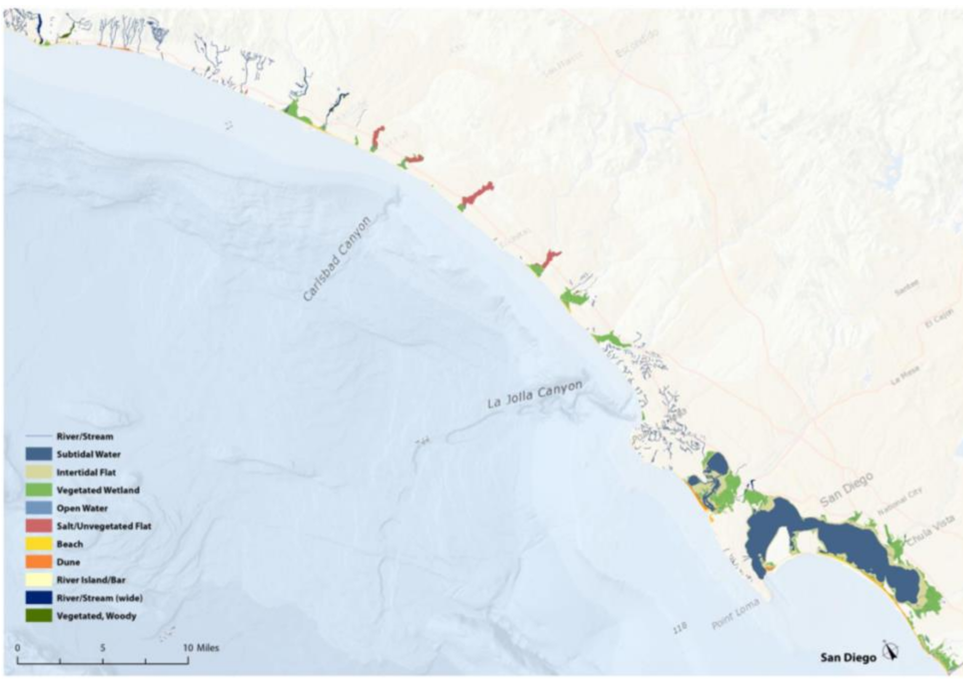

Figure 5a-e. Distribution of historical estuarine wetlands, streams, and other features along the Southern California Coast. ***(Map background provided by ESRI, DeLorme, GEBCO, and NOAA NGDC).***

Map courtesy of the Southern California Coastal Water Research Project, San Francisco Estuary Institute, and California State University, Northridge Center for Geographical Studies.[23]

The wetlands of San Diego County have experienced substantial change from their historic form. Predominantly, these blue carbon ecosystems have deteriorated from land use changes including development for agricultural, economic, and military activities. As a result, the primary concerns facing almost all 11 estuarine ecosystems are sedimentation, sewage contamination, disruption to wetland hydrology, and overall wetland loss.

In the late 18th century, the introduction of cattle grazing by European colonists as well as the expansion of agricultural practices, caused significant sedimentation issues around San Diego County. Sedimentation carries, deposits, and traps sediments. As a result of human activities, sedimentation can increase rapidly or unnaturally, changing the landscape and flow of water and nutrients. Excess sediment can block freshwater and/or tidal flow. Sedimentation that affects freshwater flow will alter the salinity gradient that supports brackish habitats and species.[9] Disruptions to tidal flow can reduce a wetland's tidal prism, also changing habitat and species composition due to freshwater dominance.[9] Additionally, sedimentation can drown existing habitats. This can be seen in Kendall-Frost Marsh Reserve within Mission Bay where sedimentation, stemming from decades of urbanization and agricultural practices, created large, new sand bars and mudflats.[33] The Tijuana Estuary also continues to suffer from sedimentation and has lost at least 80% of its tidal prism since 1852.[6] In the early 20th century, the Tijuana River flooded seven times, causing sediment to fill and alter 80 ha of the estuary. Then, in the 1960s, apartment buildings were developed on dunes, beaches, and filled marshlands along the Estuary. Dunes protect wetlands by capturing beach-blown sand. As the dunes disappeared, sand moved into the northern marsh area and entrance channel of the Tijuana River. The river mouth eventually closed, and the community responded by initiating a series of dredging projects to maintain the channel and restore dunes.[34]

The rapid urbanization, beginning in the late 19th century by European incursion, caused major disruptions to and loss of the historical estuarine habitat. Specifically, the construction of highways, railroads, and dams dissected many estuarine habitats into smaller sections, often isolating wetlands and changing watershed drainage function. One example of this issue is demonstrated at Batiquitos Lagoon. From 1881 to 1965, Batiquitos Lagoon experienced several large changes including the construction of the California Southern Railroad Line, Pacific Coast Highway (PCH), and Interstate-5 (I-5).[32] Each of these structures were developed on fill dumped in the lagoon, which blocked the necessary ebb and flow of tides, nutrients, and sediments. Then, in 1952, the construction of the San Marcos Dam cut off large volumes of freshwater into the lagoon.[32] By 1976, the Lagoon became shallow, predominantly freshwater, and rarely open to the ocean. Finally, in 1994, the Batiquitos Lagoon Enhancement Project commenced to restore the Lagoon to the tidal system it once was. Today, routine dredging maintains tidal flow.

Buena Vista Lagoon similarly experienced a transition from a tidal system to a fully freshwater system due to the construction of a wooden weir and beach berm. The California Southern Railroad Line, PCH, and I-5 also separated the lagoon into four connected basins.[32] These structures impounded freshwater, increased water depth, and stopped all tidal influence. Today, Buena Vista Lagoon still experiences sedimentation issues and a lack of tidal flow as do many other wetland habitats around the County. In fact, the Tijuana Estuary is one of the only estuaries not dissected by highways and railroads.[34] It is also one of the few that has natural, daily tidal flushing, making it among the most biologically productive. Development activities within a wetland interrupts sediment and freshwater supply, eliminates tidal flow, and disrupts the upstream and downstream connections that are essential to wetland health.

By 1945, the City of San Diego began implementing strategies to attract tourism, leading to major development activities followed by a population boom.[20] Following this initiative, many wetlands was developed for military, port, transportation, parks, and other economic activities.

The construction of these projects critically changed the ecology of the County's estuarine habitats, from altered wetland hydrology to increased human disturbance. The impacts of these developments can be seen in all the County's estuarine ecosystems including Mission Bay and San Diego Bay. In 1944, Mission Bay became the subject of the Chamber of Commerce's plan to create a tourist and recreational center to drive economic growth. Construction began shortly after, resulting in 25 million cubic yards of sand and silt dredged to convert wetland habitat into what is now Mission Bay Park. Today, Mission Bay Park is a 4,600-acre aquatic playground, consisting of various recreational islands, beaches, and waterways. Approximately, only 5% of the 4,000 acres of historic wetland habitat in Mission Bay remains.[35] Once a mosaic of lagoons, estuaries, tidal marshes, and saltwater systems, Mission Bay's only remnants of natural wetland habitats are Kendall-Frost Marsh Reserve, Northern Wildlife Preserve, and Famosa Slough.

San Diego Bay is another product of extensive development. The earliest maps of the Bay showed mudflats, marshes, shallow bays, and large freshwater input. Around 1850, the Bay's marshy river delta was filled and developed into the City of San Diego.[6] Construction continued into the 1900s including the dredging and filling of tidelands and widening of beaches to create port facilities and piers for military and domestic use.[6] This development destroyed most of San Diego Bay's wetlands. Today, approximately 90% of the Bay's original salt marshes and 50% of its original mudflats have been filled or dredged.[36]

Lastly, water quality impairment remains a big issue for the County's wetlands. Urbanization, agriculture, and poor sewage management are the main contributors to degraded water quality. In the mid to late 1900s, sewage effluent and other pollutants were widely discharged into estuarine habitats. Though some restoration projects and programs have targeted water quality issues, sewage contamination continues to be a large problem, especially for the Tijuana Estuary. Due to poor land use practices, inadequate sewer systems, and runoff, sewage flows reduced salinity in the estuary which was historically dominated by seawater.[34] As a result, fishes and invertebrates within the tidal channel and creeks showed declines and wetland habitat transformed from salt marshes to brackish marshes.[34] The high-density populations and unstable slopes around the Estuary in Mexico and the U.S. also exacerbate water quality issues. Sewage effluents were discharged in many other wetlands as well including the San Dieguito Lagoon, which received 200,000 to 300,000 gallons from 1940 to 1974.[32]

San Diego County's wetlands have undergone extensive changes since the late 19th century. Generally, a wetland that is healthy and productive will naturally sequester and store carbon. The larger a wetland ecosystem, the more it can sequester and store C. Restoring historical habitats provides an opportunity to re-establish carbon stocks that the County has lost with development. In addition, wetland restoration must consider future local conditions (i.e., the impacts of sea level rise, warming temperatures, weather patterns, etc.) to ensure the longevity of a wetland. Restoration must also prioritize habitats that can withstand present and projected local conditions to withstand the impacts of climate change. The Inventory provides a full history of the County's wetlands to understand historic estuarine extent and guide future restoration strategies and can be found in Appendix 1.

Let's Talk Carbon

Carbon Data: Sequestration, Storage, and Accretion

Estuary	Total Intertidal Habitat Area (ha)	Data Source	Habitat Type	Latitude	Longitude	Sample Data	C Stock (Mg/ha)	Seq Rate (Mg C/ha*yr)	Accretion Rate (mm/yr)	SLR Rate (mm/year)
Research in Preparation[i]										
		Costa (in prep.)	Salt marsh	32.83000	-117.23652	2020-21	229.108	8.102 (+/- 4.177)	4.468 (+/- 2.478)	
Mission Bay	16.19	Costa (in prep.)	Mudflat	32.79300	-117.22700	2020	151.527	0.349 (+/- 0.194)		
San Dieguito Lagoon	121.41	Costa (in prep.)	Salt marsh	32.97462	-117.25253	2020	60.029	1.800 (+/- 0.013)	14.057 (+/- 0.276)	
Famosa Slough	14.97	Costa (in prep.)	Salt marsh	32.75085	-117.22862	2021				2.2
Samples from Peer-Reviewed Literature[i]										
Tijuana Estuary	1011.72	Weis et al. (2001)	Salt marsh	32.56948	-117.13034	1998	239.174[ii]	5.123 (+/- 1.357)	9.517 (+/- 3.608)	
		Ward et al. (2021)	Seagrass bed	32.78952	-117.22600	2021[iii]	180.609[iv]			
Mission Bay	16.19	Ward et al. (2021)	Mudflat	32.78918	-117.22600	2021[iii]	259.727[iv]			2.2

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[i] *Missing values under "Research in Preparation" represent data that is not yet available. Missing values under the "Samples from Peer-Reviewed Literature" section represent data that is not available.*
[ii] *These C stocks were measured down to a depth of 44 cm, not until the button of the sediment column.*
[iii] *When sampling dates are not reported, the date of publication of data is given.*
[iv] *These C stocks were measured down to a depth of 20 cm, not until the button of the sediment column*

Estimate of CO_2 Removal in San Diego's Coastal Wetlands

Carbon samples analyzed for this report were obtained from ongoing research from Dr. Matthew Costa at Scripps Institution of Oceanography and peer reviewed, published data from Weis et al. (2001) and Ward et al. (2021).[37,38,39] Dr. Costa obtained carbon data (i.e., carbon stock, sequestration rate, and accretion rate) via sediment samples, cored until refusal, from the following wetland sites from 2020 to 2022: Mission Bay, San Dieguito Lagoon, and Famosa Slough.[e] Weis et al. (2001) and Ward et al. (2021) obtained carbon data from Tijuana Estuary and Mission Bay, respectively. Using these data, an average estimate of total carbon stock, average sequestration rate, and accretion balance were calculated.

Using data from Costa (in prep.), Weis et al. (2001), and Ward et al. (2021), carbon stock in megagrams per hectare (MgC/ha) for Mission Bay, San Dieguito Lagoon, and Tijuana Estuary were calculated. Using these values, the wetlands within San Diego County are estimated to store on average 186.696 MgC/ha. This amount of C is equal to the amount of CO_2 emissions from powering 133 homes by electricity for one year or the amount of C sequestered by 327.795 ha of U.S. forests in one year.[f] At present, the wetlands within Mission Bay, San Dieguito Lagoon, and Tijuana Estuary represent a small size of their historic extent. In fact, San Diego County, overall, has lost 31% of its historic estuarine area due to development and urbanization over the last 200 years.[23] Based on a report from Stein et al. (2014), San Diego County currently has 873 ha of contemporary estuarine vegetated wetlands.[23] Using this amount and the average carbon stock (186.696 MgC/ha), the total amount of C within the County's estuarine vegetated wetlands is estimated to be 162,985.608 MgC. This amount of C is equal to the CO_2 emissions from powering 116,280 homes by electricity for one year. In comparison, San Diego County historically contained more than three times as many ha of historical estuarine vegetated wetlands (2,844 ha) as it does now. It can be assumed that significant amounts of CO_2 were added to the atmosphere due to this loss of wetlands overtime. Furthermore, the continued degradation or loss of the remaining wetlands in the county will result in substantial additional carbon emissions that the climate cannot afford. Cumulatively, the wetlands around the County contribute a large amount of C storage as exhibited in only three different estuarine ecosystems out of 11 estuarine ecosystems identified in the County of San Diego. Thus, the wetlands sites of Mission Bay, San Dieguito Lagoon, and Tijuana Estuary comprise a small fraction of the total area in each estuary, leaving opportunity for restoration to support a larger contribution to climate mitigation.

The following are calculated average sequestration rates for Mission Bay, San Dieguito Lagoon, and Tijuana Estuary. Sequestration values are based on research from Dr. Costa and Weis et al. only. All sequestration rates are calculated with a 95% confidence interval. Within Mission Bay, the sequestration rate of its salt marshes is calculated at an average of 8.102 (+/- 4.177) MgC/ha each year. In comparison, the sequestration rate of Mission Bay's mudflats is calculated at an average of 0.349 (+/- 0.194) MgC/ha each year. The salt marshes of San Dieguito Lagoon sequester an average of 1.8-00 (+/- 0.013) MgC/ha each year. Lastly, at the

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[e] *The carbon data cited as "Costa (in prep.) in this report are supplied by Dr. Costa. These data are the average values from cores analyzed so far as part of a larger project to sample the estuaries in San Diego County for their blue carbon content. Future publication of the full dataset may differ from these reported values due to the inclusion of more data.*

Tijuana Estuary, the salt marshes were estimated to sequester 5.123 (+/- 1.357) MgC/ha each year.[38] Based on these values, salt marshes at Mission Bay exhibit higher sequestration rates than mudflats. The salt marshes of San Dieguito Lagoon and Tijuana Estuary also exhibit significantly higher rates of sequestration than the mudflats within Mission Bay. Using these four values of sequestration rates, the average sequestration rate for the coastal wetlands within San Diego County is 3.844 MgC per one ha each year. The average variation within this estimate is +/- 1.435 Mg/C ha each year. In comparison, it would take 6.758 ha of U.S. forests to sequester the same amount of C in one year.[f] Based on these values, San Diego's coastal wetlands demonstrate a more effective process for sequestering C than terrestrial forests. Continued research and sampling on the wetlands within San Diego County, specifically across different habitat types, can inform the restoration of wetlands into specific habitats that can maximize C sequestration. Dr. Costa's ongoing research can also inform climate action planning on the role of various wetland habitats in carbon sequestration potential and where to prioritize investment.

Lastly, accretion rate is analyzed in order to understand vulnerability to sea-level rise. To understand the accretion balance for the County's wetlands, the local SLR rate is subtracted from each wetland's accretion rate. Accretion balance demonstrates insufficient or sufficient levels of accretion within a wetland to keep up with rates of SLR. A positive value for accretion balance demonstrates a sufficient level of accretion to keep up with SLR. A negative value for accretion balance demonstrates an insufficient level of accretion, meaning it is vulnerable to submergence by SLR. For San Diego, the relative sea level trend is 2.2 mm/year of SLR with a 95% confidence interval of +/- 0.17 mm/year.[40] The following are calculated accretion balances for Mission Bay, San Dieguito Lagoon, and Tijuana Estuary. Accretion values are based on research from Dr. Costa and Weis et al only. All accretion rates are calculated with a 95% confidence interval. Assuming a relative SLR for San Diego of 2.2 mm/year (+/- 0.17), the accretion balance for Mission Bay's salt marshes was calculated at 2.268 (+/- 2.478). Assuming the same SLR rate, the accretion balance for San Dieguito Lagoon's salt marshes was calculated at 11.857 (+/- 0.276) mm/year. Lastly, at the Tijuana Estuary, the accretion balance is calculated at 7.317 (+/- 3.608). Based on this data, all sites exhibit an accretion rate that will keep up with current rates of SLR. Mission Bay demonstrated the lowest accretion balance of the three sites, potentially indicating a need to explore restoration strategies that support vertical growth. San Dieguito Lagoon demonstrated the highest value for accretion rate (though this is based on one sampling site in the northwest part of the Lagoon). With that said, assuming that these data are representative, this estuary is most likely able to keep up with SLR. Using similar methodologies and continued research, future restoration efforts can use projected accretion balance to determine what strategies best support wetland health, especially in regard to sea-level rise. Data on San Diego's wetlands are still sparse. Long-term monitoring and research can better quantify the contribution of coastal wetlands to climate mitigation and inform management and restoration strategies.

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[f] *These values were calculated using the [EPA's Greenhouse Gas Equivalencies] Calculator which converts emissions or energy into abstract measurements.*

Conservation Communities – Past, Present, Future

Beyond long-term carbon research and monitoring, climate solutions must be centered on equity and justice. San Diego is already experiencing the impacts of climate change – from rising sea levels to warming temperatures to increased drought. While these impacts affect all communities, they do not affect them in the same way. Centuries of unjust and inequitable systems have caused low-income and BIPOC communities to bear the brunt of climate change around the world.[41] This remains true in San Diego. The City of San Diego's Climate Equity Index identified "communities of concerns" as census tracts with very low, low, and moderate access to opportunity. When communities of concern were compared with race and ethnicity data, it was found that below-average access to opportunity disproportionately impacts communities with high percentages of people of color.[42] As climate change persists, the historic injustices that remain today are exacerbated, making it crucial for climate adaptation to be centered on social equity and community building. The County of San Diego does not address climate equity and environmental justice in their CAP despite successful climate action being fundamentally dependent on justice, equity, diversity, and inclusion (JEDI). Similarly, the Regional Decarbonization Framework lacks a prioritization of social equity, focusing primarily on creating a just transition of jobs in low-carbon sectors. However, one of the goals of the CAP Update is to "emphasize environmental justice and equity."[43] To rectify these inequities and adequately update the CAP, the County needs to embed equity into its mission and values, prioritizing JEDI amongst all their efforts especially for sustainability and climate action. This section discusses the importance of climate equity and the framework to begin progress towards achieving it.

Case Study #1: Parks for Everyone – 10 Years in Review

In 2020, the San Diego Foundation released a review of the past 10 years of progress since its 2010 Parks for Everyone Report. The report demonstrates a strong example of integrating social equity into the outdoors by first illuminating disparities that exist in San Diego[44] First, the report found that many local communities lack access to parks and green space. Second, communities that have historically suffered from inequities in usable outdoor space are "those with higher concentrations of lower income households, as well as communities with greater racial and ethnic diversity." [44] It is apparent that barriers to a welcoming and inclusive outdoors remain for low-income and BIPOC communities.

To address the obstacles that persists, the Foundation identified types of access to prioritize and equity barriers to address. It describes two types of access: physical and functional access. Physical access refers to the location and physical attributes of a designated location that influence access. This includes infrastructure, street condition, natural and built environment, and placement. Functional access refers to aspects that are not place-based that influence access to a designation location. These factors could include cost, permitting, capacity, property ownership, political will, neighborhood safety, climate change impacts, and more. The equity barriers are identified as safety (e.g., poor trail conditions and multilingual maps), walkability (e.g., street access and knowledge of terrain), transportation (e.g., cost and timing), cultural inclusion (park signage, events, and information in multiple languages), and fees, permits and expenses. The San Diego Foundation centers programs, goals, and grants around areas that address the limitations to access and equity barriers. The full report can be found at this link.[44]

An inequitable distribution of power and resources alongside institutionalized racism and biases have made low-income and BIPOC communities especially vulnerable to the impacts of climate change. First, sea level is estimated to rise from 1 to 1.4 meters by 2100 along the California Coast, under medium to medium-high GHG emission scenarios.[12] Communities at heightened risk to these projections included low-income households and communities of color.[12] Similarly, the impacts of natural disasters are disproportional, affecting low-income communities and communities of colors more than others. For example, the ability to remain safe or evacuate during natural disasters are driven by "income, possession of a vehicle, race, and proximity to environmental hazards that compound health risk, such as toxic waste facilities."[12] As such, low-income communities, particularly, have been unable to find safety during disasters due to financial constraints and limited access to buy supplies or find transportation. Regarding outdoor access, the benefits of natural spaces are also inequitable. For instance, it is reported that San Diego residents from low-income neighborhoods (median income below $51,026) in Escondido, El Cajon, Oceanside, and South San Diego have less than 3 acres of parkland per 1000 residents compared to The City of San Diego in which residents enjoy 28 acres of parkland per 1000 residents.[44]

The need for social equity to be operationalized and prioritized within climate action plans, sustainability initiatives, and conservation programs is important now more than ever. The case studies within this section look at successful first steps to introducing social equity into conservation, protection, and outdoor access in California.

Case Study #2: Los Angeles - OurCounty

In 2019, Los Angeles County (LA County) launched the OurCounty Initiative, a regional sustainability plan centered on social justice.[45] The plan defines four types of equity that guide the County's sustainability efforts: procedural, distribution, structural, and transgenerational equity.[45] Procedural equity refers to prioritizing inclusivity, accessibility, "authentic engagement," and representation within LA County's sustainability programs and policies. Distributional equity is the result of fair distribution of benefits and burdens across communities while prioritizing benefits to communities with the highest burden. Structural equity is defined as the institutionalization of accountability and inclusive decision-making. Decision-making is informed by recognizing the historical, cultural, and institutional barriers to marginalized communities and effectively communicated to those groups. Lastly, transgenerational equity is achieved by considering generational impacts to fair opportunity and works to eliminate those burdens.

Furthermore, the County established 12 goals centered around resilient and healthy nature and communities. The four pillars of equity create a framework to guide each goal to produce equitable, measurable impacts.

This initiative is led by the County Chief Sustainability Office with an interdisciplinary team of consultants and stakeholder engagement. One key success of the plan was the distribution of participation stipends for community-based organizations and advocacy/environmental policy organizations. These funds compensated community organizations and their staff, who might not have been able to participate otherwise, for their participation and feedback. This framework is an example of leading sustainability with social equity. The final Plan can be found at this link.

Defining equity and access are the first steps to achieving environmental justice. Full acknowledgement and education on the barriers that remain today enables strategies and planning that can help achieve climate equity and JEDI in conservation. In conjunction, defining communities and stakeholders, particularly communities historically excluded by decision-making and climate action, is integral to developing goals, visions, and values that are genuinely needed by these communities.

Climate action should be driven by and supported by the communities of San Diego County, past and present. The County's wetlands, and the communities amongst them, lie on the traditional territory of the Kumeyaay, Payómkawichum (called Luiseño by the Spaniards), Cupeño and Cahuilla, who lived along the San Diego coast for many millennia. San Diego's First People were the Kumeyaay, named Diegueño by the Spaniards. The Kumeyaay lived extensively over the coastline of modern-day Southern California for more than 10,000 years. Historically, the Kumeyaay ranged from Ensenada, Mexico to beyond Batiquitos Lagoon. Around the area of Agua Hedionda Lagoon, and overlapping with Batiquitos Lagoon, lived the Payómkawichum, meaning the People of the West. These two tribes occupied most of San Diego County. The Acjachemen people, known as the Juaneño, also overlapped with a smaller portion of modern-day North San Diego County.[46]

The historic Kumeyaay population size is estimated to range from 10,000 to 20,000.[32] Records indicate many Kumeyaay villages lied along the San Diego Coast, along the valleys and near the lagoons.[32] The Kumeyaay depended on and stewarded the productive waters around the shoreline for sustenance, connections, culture, and their way of life. The arrival of Spanish missionaries in the late 18th century began the secularization of the missions, forced displacement of the Kumeyaay that remains today, and genocide of indigenous peoples that also occurred throughout the Americas. From 1769 onward, nearly all Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] At present, Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47] The Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in East County, however, of that total acreage, more than 15,000 acres are unusable to the Kumeyaay due to the removal of El Capitan Reservoir from their ownership.[47]

The Payómkawichum also inhabited the Southern California Coast for many millennia. Before the Spanish invaded the land, Payómkawichum territory extended from around Agua Hedionda Lagoon north to Riverside County.[32] Estimates of their population were lower than the Kumeyaay, ranging from 5,000 to 10,000, however they occupied a smaller area. As such, their population densities were significantly higher. Like the Kumeyaay, many Payómkawichum settlements were founded along the coast and near lagoons and depended on marine resources. European invasion displaced the Payómkawichum from their ancestral lands. Today, the Payómkawichum are made up of seven bands – Pechanga, Pauma, Pala, Rincon, San Luis Rey, La Jolla, and Soboba – many living within tribal reservations inland from the coast.[48]

Historically, the Acjachemen mainly inhabited lands within modern-day Orange, Los Angeles and Riverside Counties. The settlement of the Spanish also marked the beginnings of ancestral lands taken from the Juaneño. Today, the Juaneño Band of Mission Indians, Acjachemen

Nation, is a State-recognized Native American Indian Tribe.[46] The lack of federal recognition remains a barrier to the Juaneño, preventing access and protection of their ancestral lands as well as tribal sovereignty.

Today, the communities of San Diego are entirely different in people and nature. As of July 2021, San Diego County is estimated at 3,286,069 San Diegans, of which the largest ethnic group is White followed by Hispanic.[49] Amongst today's communities, there are significant disparities in income and access to opportunity around racial and ethnic groups. The Equinox Project reported that the median household income among Native American, Latinx, and Black San Diegans in 2018 was lower compared to the countywide median income while it was higher for Asian and White San Diegans.[50] Disparities can also be exemplified in other parameters such as housing needs. All local governments in California are required to establish housing plans that meet the housing needs of the community including addressing land use, transportation, conservation, noise, safety, open space, and housing.[51] It is reported that San Diego County is close to meeting the housing needs for high income households (92%) while only meeting 12% for very low, low, and moderate income households.[52]

As climate change persists, it is critical that all San Diegans have a strong quality of life, access to healthy, natural spaces, and say in climate decisions. All San Diegans must also include communities that are often overlooked and excluded but impacted the most: low-income and BIPOC communities. The recognition, education, and prioritization of the past and present is integral to successful climate action planning in the future. Healthy wetlands not only support a more resilient climate but improve quality of life, strengthens connections between people and nature, and creates more supported communities. Moving forward, climate action planning must empower underserved communities, address historical inequities, and make steps towards collective action to steward important, natural spaces.

Outreach and Engagement

In an effort to outline the goals, existing efforts, and perspectives of the communities of San Diego County, this report conducted informal meetings with community organizations, blue carbon experts, and other stakeholders around the County. The discussions with the following stakeholders informed the *Recommendation* section of this report. These discussions focused primarily on strategies to maximize the blue carbon potential of wetlands and elevate social equity in wetland restoration and climate action. These discussions illuminated the need to center conservation around people and their well-being in order to achieve long-term, equitable, climate justice and celebrate cultural connections to nature.

- Jonathan Appelbaum, Restoration Crew Manager - San Diego CanyonLands
- Joel Barkan, Research Manager – Ocean Discovery Institute
- Marc Chavez, Program Director/Founder – Native Like Water
- Jeff Crooks, Ph.D., Researcher Coordinator – Tijuana River National Estuarine Research Reserve
- Christiana DeBenedict, MBA, Director of Environmental Initiatives – The San Diego Foundation

- Elise Hanson, Management Fellow – County of San Diego
- Jules Jackson, Ocean Conservation & Education Coordinator – WILDCOAST; Executive Director – Coastal Defenders
- Hilary Stevens, Coastal Resilience Manager – Restore America's Estuaries
- Tito Marchant, Ecology Director – Nature Collective
- Andrew Meyer, Director of Conservation, San Diego Audubon Society // ReWild Mission Bay
- Hannah Morrisette, Ph.D., Blue Carbon Postdoctoral Researcher – Smithsonian Environmental Research Center
- Heather Rossetti, Manager, Thrive Outside San Diego – The San Diego Foundation
- Lisa Stratton, Ph.D. – University of California Santa Barbara's Cheadle Center for Biodiversity and Ecological Restoration
- Valerie Vartanian, Natural Resources Land and Wetland Program Manager – Naval Base Ventura County

Recommendations for Restoration: People and Nature

San Diego County's coastal wetlands function as important natural carbon sinks. These blue carbon ecosystems play a key role in the health of our community and its natural spaces. Degradation and loss of coastal wetlands result in the release of carbon that has been sequestered, accumulated, and stored for centuries. As shown in the *Let's Talk Carbon* section, a small salt marsh of Mission Bay held an average of 229.107869 MgC per ha. Today, only 40 acres of wetlands remain in Mission Bay, representing only 1% of its historical extent.[35] The capacity of C storage of the original 4,000 acres of Mission Bay would be enormous, playing a much bigger role in climate mitigation. Restoration of modern-day habitats to carbon-rich wetlands reminiscent of historic habitats, in both quantity and quality, would provide a significant contribution to the County's overall climate adaptation and mitigation strategy.

Five overarching recommendations are identified to support climate mitigation specific-wetland restoration strategies for the County. These recommendations aim to foster climate equity, support healthy wetland ecosystems, and contribute to supporting the County's climate mitigation goals.

(1) Prioritize Historically Excluded Communities, Enhance Engagement, Celebrate Cultural Connections

One of the biggest improvements to climate planning will be creating processes that more equitably distribute the benefits and burdens of climate solutions. Alongside these efforts, prioritization of communities that are hit first and worst by climate change is imperative to protecting the County's citizens. This can be done through the following strategies:

- Define equity, climate equity, and environmental justice. These values must be central to existing power structures to address historic discriminatory decisions, institutionalized racism, class bias, and disinvestment. Social equity should be woven into the fabric of the County's climate action planning and paired with measurable impacts delineated for each of the CAP's strategies.

    - Decolonize climate action and policy. Develop a new framework and way of thinking that centers around Indigenous peoples, their rights, their traditions, and their cultures.

- Identify and define communities of concern – communities that have been historically excluded, marginalized, and disproportionately affected by decision-making and policy. This information should guide climate solutions strategies and the placement of wetland restoration efforts.
- Establish inclusive partnerships that are representative of past and present communities. Indigenous communities have been stewards and inhabitants of these spaces for multiple millennia. Yet, they are continually excluded from fair access and use of natural spaces, including San Diego County's coastal wetlands. These communities should be supported, empowered, represented, and celebrated in climate planning, conservation, and wetland restoration.
    - Establish indigenous co-leadership and co-management of restoration. Indigenous peoples and local communities play a central role in stewardship and enjoyment of natural spaces. Long-term conservation and restoration should reinforce the roles, capacity, rights, and traditional ecological knowledge of indigenous communities.
    - Identify and eliminate the barriers to access and use of coastal wetlands by supporting cultural education programs, increased access to coastal spaces, and traditional tribal connections to nature.
    - Create working groups to inform climate equity strategies that are comprised of a diversity of stakeholders including low-income and BIPOC communities
- Prioritize and allocate more funding to low-income and BIPOC communities and areas of high risk from climate change.
- Prioritize restoration activities in communities with the highest needs and historically have not received green spaces.
- Create two-way streets for collaboration, engagement, and follow-through.
    - Empower community leaders and let them lead in their own communities.
    - Listen instead of telling. Offer support and identify needs of excluded communities ahead of asking for public participation (e.g., allocate participation stipends to community organizations for public workshops, identify community desire for projects, and understand community priorities).
    - Prioritize trust-building with historically ignored communities.
    - Foster authentic relationships, have honest conversations, and follow through with engagement, recreation, education, and other relationship-building efforts (e.g., learn about indigenous history from indigenous peoples, create long-standing programs, and lead events within communities and alongside community leaders).
- Create an inclusive process for engagement
    - Understand the barriers to community engagement and public participation (e.g., lack of access to computers, unavailability to make in-person workshops, and lack of awareness of the CAP).

- Offer multiple ways to receive public feedback on the CAP (online, in-person, workshops within the community, or through social media).
- Ensure representation of all communities within the CAP Update.

(2) Maintaining Ecological Connectivity

Within estuarine ecosystems, everything is interconnected and should remain connected in the future. Improving ecological connections, within and between habitat types, can foster healthier wetlands and carbon sequestration. This can be done through the following strategies:

- Create and restore buffer zones or similar habitats adjacent to wetlands. Connected habitats facilitate wildlife movement and distribution, support biodiversity, and provide a natural ebb and flow between habitats such as the potential for lateral export of carbon burial (the carbon from one blue carbon habitat may be entrapped and buried in a neighboring habitat). Buffer areas are also important spaces to preserve as they could be areas of future restoration.
- Conserve transition zones between adjacent lands and wetlands. Transition zones are areas between habitats that are characterized by gradients of topography, salinity, and soil moistures. These areas support species movement, especially to escape flood events, and landward wetland migration in the face of SLR.
    - Reconnected wetlands improve connection and nourishment of freshwater and sediment which support wetland functions and health.
    - Conservation of different habitat types can bleed benefits into other habits (e.g., subtidal habitats, like oyster reefs and eelgrass beds, increase bottom friction and attenuate wind waves, buffer erosion, and protect upland habitats that sequester C).
- Create conditions that foster natural recruitment to improve ecosystem resiliency. Natural recruitment enables ecosystems to design itself over time (i.e., vegetate itself) instead of leading to habitat loss or artificial planting to achieve specific outcomes,
    - Planting of native species or species that will naturally thrive in the area can support natural recruitment.
    - Supporting the presence of regular tidal and freshwater flow supports seed dispersal, seed recruitment, and wetland productivity.

(3) Restoring the Pillars of Wetlands: Hydrological and Sedimentary Connection

Wetlands have the ability to move and grow. Re-establishing and nurturing their natural formative processes, including nourishment by freshwater and sediment inputs from watersheds, supports wetlands existence and therefore C storage. Additionally, coastal wetlands can sequester and store C with little to no methane emissions. As previously mentioned, higher saline conditions and low-oxygenated soils support anaerobic conditions which slows decomposition and the release of CO_2. When organic matter in wetlands remains undecomposed, their C-rich soils can be buried and stored over long periods of time. Therefore, coastal wetlands need an adequate freshwater supply and tidal flow to maintain salinity levels that inhibit methane emissions and support sediment supply. Improvements to water and sediment connections should be focused on the following strategies:

- Ensure adequate freshwater supply from upstream by removing human disturbance where possible and maintaining or realigning stream courses to restore natural sediment delivery processes.
- Identify isolated wetlands, such as those cut off by levees or roads, that can be reconnected hydrologically to restore natural hydrologic exchange.
- Restore tidal flow and maintain tidal channels to support anaerobic conditions, facilitate salinity gradients, and promote bioturbation for microorganisms which inhibit methanogenesis and support productivity in the soils.
- Prioritize restoration in areas with high sediment loads from local rivers and streams in order to ensure wetlands can keep up with SLR and prevent the release of CO_2.
- Consider other strategies for inorganic sediment supply such as transplanting wetland soils from successful wetlands to restoration sites to create more successful establishments and to support vertical accretion of wetlands.

(4) Remember the Past, Plan for the Future: Historic Habitats and Sea Level Rise

Natural, long-lived wetlands have larger C storages. Historic habitats are a representation of the types of wetlands that can thrive within the landscape and environment. As climate change persists, however, local conditions are changing and wetlands must be able to manage rising seas, increasing temperatures, and other impacts. Therefore, wetland restoration should balance restoring historical habitats and being able to survive changing conditions. The following overarching strategies should be considered to achieve this:

- Incorporate remnants of historically prevalent habitat types into restoration design and preserve the remaining historic habitats to keep C stored where it is.
    - Coastal wetlands are naturally formed next to tidal forces, freshwater inputs, sediment transport and biota. Maintain these inputs in future restoration to continue wetland productivity.
- Restore various habitat types and transition zones within an ecosystem to increase biocomplexity and resiliency.
- Prioritize restoration in wetlands that have the capacity to migrate or grow vertically to keep up with SLR. These ideal wetlands have high initial elevations, high sediment supply, or adjacent natural space to move (uninhibited by urban development).
- Explore inorganic sedimentation strategies to create elevation for wetlands to keep up with SLR – build lands, shaping topography, re-using dredge spoils, etc.
- Horizontal migration will be difficult for coastal wetlands in San Diego due to highly urbanized environments restricting wetland space. Instead, prioritize vertical accretion, avoid any more damage to wetlands, protect traditional wetland ecosystem services, and protect climate resiliency functions.
- Protect other natural spaces, especially coastal lands, to allow wetlands to move inland.
- Plant communities that reflect historical plant communities and can withstand salinity gradients and flooding, such as the flood tolerant species California cordgrass (*Spartina foliosa*) which could also support a site's short-term resilience to SLR.[24]

- Eliminate invasive species which threaten the resilience and existence of a wetland.

(5) Long-term Research, Monitoring, and Prioritization

Blue carbon research is still relatively new. Scientists are still investigating what drives variation in carbon stocks, strategies for maximizing C sequestration, and differences in wetland habitat types. Investments in long-term research and data-gathering help decision-makers understand how to respond to it. Additionally, local conditions, communities, and ecosystems change and adapt, especially in the face of climate change. It is critical to monitor these changes to best adapt to a changing climate. Lastly, the prioritization of restoration efforts is critical as climate change impacts rapidly affect nature and people. The following overarching strategies should be considered to achieve this:

- Invest in and prioritize long-term research and monitoring as products of effective climate mitigation and successful wetland restoration.
- Understand sediment dynamics as tidal wetlands can build elevation by sediment accumulation and organic matter production, however, human activity can disturb these dynamics. Development on top of wetlands can increase land subsistence and soil compaction which increases vulnerability to SLR.
    - Prioritize research on accretion rates to better understand impacts from projected SLR.
- Understand the role of vegetation in sequestering C and invest in research that compares C sequestration capabilities amongst vegetation types.
- Identify "Value Indicators" for restoration which provide reasonings for restoration. Value indicators can be used to help determine the prioritization and selection of restoration sites. The following are Value Indicators identified by this project as important priorities for restoration:
    - Potential for blue carbon research
    - High acreage
    - Potential to improved carbon management, sequestration, and storage
    - Adjacent to historically excluded, displaced, underrepresented, BIPOC, and/or low-income communities
    - Potential to support indigenous communities, enhance engagement, and restore and celebrate cultural connections
    - Desire from historically excluded, displaced, underrepresented, BIPOC, and/or low-income communities
    - Protection to communities from SLR and other climate change impacts
    - Strong political will
    - Strong existing research/data
    - Extremely degraded (e.g., low sequestration rates, dominance by invasive species, closed to tidal influence, etc.)
    - Potential for upland migration
    - Restoration plans/efforts already underway

The five recommendations above have been applied to an example wetland below: Kendall-Frost Marsh Reserve/Northern Wildlife Preserve.

Kendall-Frost Marsh Reserve: Equitable Restoration in Action

Today, Kendall-Frost Marsh Reserve and the Northern Wildlife Preserve (KFMR/NWP) protect the last 40 acres of the approximately 2,000 acres of emergent wetlands found in Mission Bay in the early 20th century. KFMR/NWP remains tidal, with high tides capable of covering the entire marsh, depending upon the tide and weather.[33] The habitat follows a classic vertical zonation from high marsh to submerged shoreline. Amidst this gradient includes eelgrass beds, mudflats, marsh, and upland habitat. These habitats are gradually undergoing restoration to introduce native species and remove non-natives. Mission Bay is an important resting ground for migrating birds, winter ground for waterbirds, and home for many endangered species. The marsh's tidal creeks and smaller channels provide habitat and refuge for a variety of fish.[33]

(1) Prioritize Historically Excluded Communities, Enhance Engagement, Celebrate Cultural Connections

KFMR lies on the traditional territory of the Kumeyaay. Restoration activities at the Marsh should prioritize restoring cultural connections, supporting existing Kumeyaay stewardship activities and reconnections to water, celebrating the culture of the Kumeyaay and the significance of their relationship between people and nature; creating educational programs, and informational materials that tell the story of the Kumeyaay from the Kumeyaay. These strategies can be started by allocating funding to ensure the Kumeyaay have access to KFMR, space to recreate and learn, and tools to support wetland restoration.

The CAP Update should identify priorities and needs from low-income and BIPOC communities to understand how KFMR can be restored to meet all needs. Public workshops, informational meetings, and public comment meetings should be held *within* low-income and BIPOC communities as well as at the County level. Feedback on the CAP should be facilitated through means of communications that communities use. For example, the County can provide multiple avenues to provide comments on the Update such as options online, in-person, via mail, text, or on social media. Following the Los Angeles OurCounty Initiative (Case Study #2) guide, the County of San Diego can provide participation stipends. Community organizations and their staff can use the stipend to compensate for their time and participation in providing feedback to the CAP or holding public workshops. Similarly, stipends can support community members who attend in-person meetings to cover costs of transportation or time.

Lastly, climate adaptation plans should identify all communities impacted by climate change, next to the coast or not, and center climate solutions around them. Communities that are most at-risk should be prioritized. The County can carry these actions out by allocating funds to support displacement by SLR, providing transportation to escape natural disasters, disseminating natural disaster and climate change information in multiple languages, and explicit, measurable indicators of success that outline how each community will benefit from the CAP Update. Following Mission Bay's placement within Census Tract 76 for San Diego, the Census' 2019 American Community Survey estimated that the total population is 3,978.[53,54] Of the population, 55.3.% are male and 44.7% are female. The population is predominantly white, followed in order by Asian, Hispanic or Latinx, Native Hawaiian and other Pacific Islander, Other, and Black or African American. Restoration activities should be informed by and catered to all San Diegans identified.

(2) Maintaining Ecological Connectivity

KFMR contains isolated wetland habitats due to the residential and urban development surrounding it. This site offers a good opportunity to reconnect historical marsh habitat to support wildlife movement, seed dispersal, natural recruitment, and sediment and water flow that supports healthy wetland functions. Adjacent to KFMR is Campland and De Anza Special Study Area. The County should focus restoration efforts on creating similar wetland habitats around KFMR that can support overall estuarine function and the ebbs and flows between these natural spaces.

Since KFMR spans only 40 acres, there is an opportunity to expand its marsh habitat. Adjacent to KFMR, the County can create additional salt marshes to produce a larger wetland area that could increase overall C storage. Alternatively, protecting natural spaces next to KFMR and prohibiting any land use change can increase the resiliency of KFMR. These natural spaces act as buffer zones, allowing the wetland to migrate landward in the face of SLR. Overall, KFMR can benefit from increased natural space and various wetland habitat types surrounding the site.

(3) Restoring the Pillars of Wetlands: Hydrological and Sedimentary Connection

At present, KFMR receives an adequate amount of saltwater as it is open to tidal flow. However, KFMR faces issues with water quality, freshwater input, and sediment supply. Urban storm runoff, boat fuel, and other human activities have degraded water quality over the years especially since the rise of Mission Bay Park. Additionally, one of KFMR's main tributary, Rose Creek, was redirected from its historic route which originally entered through what is now Campland.[33, 35] This redirection cut off the main source of freshwater, nutrients, and sediment to Mission Bay's Wetlands and now impacts water and sediment quality.[35]

Restoration efforts should investigate restoring freshwater flow. Realigning Rose Creek could support stronger freshwater flow to KFMR which could support salinity gradients, flush out pollutants, and deposit sediment to support accretion and wetland services. Additionally, accretion rates and sediment supply should be examined to understand the impact of future SLR to the habitat. Inorganic sedimentation could be one possible strategy to support the vertical growth of the marsh. Overall, the County should focus restoration efforts on sediment and freshwater nourishment in KFMR.

(4) Remember the Past, Plan for the Future: Historic Habitats and Sea Level Rise

KFMR is minimally disturbed from human activities, at present, which should be maintained. However, the rest of Mission Bay is directly influenced by recreational and economic activities. Restoration strategies should focus on restoring plant communities that reflect historical, native plants in order to return habitats to its historic extent. Restoration can also explore opportunities to restore other historical habitat types that might support the existing habitat's fight against SLR at KFMR.

KFMR has been colonized by several invasive species, including the Pacific oyster, Asian mussel, River mangrove, and the Algerian sea lavender.[35] Invasive species pose a threat to native communities, outcompeting them for natural resources. Native marsh communities are especially vulnerable to invasive species. Invasive species can be targeted for removal efforts to bolster marsh resiliency, especially since climate change can compound the impacts to native communities.

In order to plan for SLR, restoration strategies should investigate natural spaces that allow KFMR "room to grow." This is a challenge for KFMR since it is surrounded by urban development. Therefore, SLR strategies may focus more on opportunities to increase the elevation of KFMR.

(5) Long-term Research, Monitoring, and Prioritization

KFMR is an important research site for UC and a study site for San Diego Audubon's ReWild Mission Bay proposed project. Ongoing research is working to obtain blue carbon data, accretion rates, and understanding the habitat. Long-term monitoring and research should remain a priority for KFMR as it protects some of the last wetland habitats in Mission Bay and offers opportunities to highlight indigenous cultural connections as well. Other potential research topics could investigate the role of vegetation in sequestering C, the sediment dynamics that have evolved from urbanization, and the contribution of KFMR to climate mitigation.

The following value indicators have been selected for KFMR/NWP.

- Strong existing research/data
- Restoration plans/efforts already underway
- Potential to support indigenous communities, enhance engagement, and restore and celebrate cultural connections
- Strong political will
- Potential for blue carbon research
- Potential to improved carbon management, sequestration, and storage
- Protection to communities from SLR and other climate change impacts

Value indicators can act as the first step in prioritizing where to begin restoration efforts that are beneficial to the entire community affected by it.

Next Steps

A "code red for humanity" was issued in response to the Intergovernmental Panel on Climate Change Working Group 2021 report due to the widespread, rapid, intensifying, and unprecedented changes in the climate at present.[5] Global warming has led to a "climate crisis" characterized by environmental and community impacts felt around the world – sea level rise, loss of species, more frequent hurricanes, more intense droughts, community displacement, climate inequity, and more. As the County of San Diego designs new strategies for climate mitigation and adaptation, it is important that blue carbon ecosystems are prioritized in their plans. Above all, future activities should avoid any further impacts to the wetlands that remain. While coastal wetlands offer important services towards climate mitigation, they are also liabilities. Any loss of or disruption to wetlands adds CO_2 to the atmosphere that the climate cannot afford. Furthermore, the update to the County's CAP provides an opportunity to address climate change in a novel way – one that leads with justice, diversity, equity, and inclusion. The prioritization of collaboration, representation, and leadership from all San Diegans can build a better future for people and nature. This analysis describes San Diego County's blue carbon baseline inventory, the communities affected by climate change, and strategies to optimize coastal wetlands in the County's Updated Climate Action Plan. This document is a preliminary report, based on growing and ongoing research, restoration plans, and available

data. Building upon this report to include increasingly available data on blue carbon and climate change impacts, specifically SLR, will help the County better capitalize on opportunities to mitigate CO_2 emissions and achieve climate equity.
Next steps to build on this report and works towards equitable climate action include:

- Identify, engage, support, and collaborate with a diverse group of partners to inform all aspects of the CAP. Alongside the stakeholders identified in this report, suggestions for partnership building include (but are not limited to):
    - Agua Hedionda Lagoon Foundation
    - Bands of the Luiseño Tribe
    - Batiquitos Lagoon Foundation
    - Buena Vista Audubon Society
    - Buena Vista Lagoon Foundation
    - Climate Science Alliance
    - Environmental Health Coalition
    - Friends of Famosa Slough
    - Friends of Mission Bay Marshes
    - Friends of the San Diego Wildlife Refuges
    - Hispanic Access Foundation
    - Juaneño Band of Mission Indians, Acjachemen Nation
    - Kumeyaay Community College
    - Kumeyaay Diegueno Land Conservancy
    - Living Coast Discovery Center
    - Los Peñasquitos Lagoon Foundation
    - Mid-City Community Advocacy Network
    - Ocean Connectors
    - Rise San Diego
    - San Dieguito River Valley Conservancy
    - Southwest Wetlands Interpretive Association
    - The Nature Collective
    - University of California San Diego's Intertribal Resource Center
- Continue research and education of JEDI. Prioritize co-management with blue carbon scientists, climate equity and environmental justice experts, and community organizations.
- Identify present-day population dynamics and community demographics around wetland areas. Use this information to build onto the Inventory of San Diego County's wetlands which can then guide equitable distribution of benefits and burdens from wetland restoration activities.
- Assess existing funding resources available to support blue carbon strategies and climate equity goals.
- Indigenize education, meaning incorporate Indigenous knowledge, values, languages, histories, and cultures into school curriculums and public education, to better acknowledge indigenous communities in San Diego County and inform the new CAP.
- Research the financial mechanisms needed for blue carbon investment. Aggregate data and financial incentives to understand the role of blue carbon in financial markets.
- Expand this report to address other natural climate solutions (i.e., eelgrass beds, mangroves, and kelp forests).
- Continue the development of value indicators and a priority list of restoration projects that balance ecological needs, climate preparedness, and climate equity.
    - Identify other value indicators of restoration (e.g., habitats for endangered/vulnerable populations, opportunity to enhance recreation by historically excluded, displaced, low-income, and BIPOC communities, and refuge and nursery habitat for fauna and flora).

The list above is not a complete list of actions needed to achieve climate equity and support the County's GHG reduction goals, but it is the initial steps to begin an initiative for the County that supports people and nature. Restored coastal wetlands are a valuable tool in fighting climate change. Restoration can enhance the County's natural wetlands, bolster climate resiliency, and create natural space that can be enjoyed and stewarded by all. This report aims to help integrate blue carbon into climate strategies in an effort that is representative and inclusive of the communities involved, can be scalable throughout coastal California, and contribute to the Nation's 30x30 goals.

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Appendix 1: Inventory of the San Diego County's Wetlands

Agua Hedionda Lagoon	
Characteristics	Agua Hedionda is characterized as a lagoon that is dominated by open water tidal/saltwater wetlands. [32] The Lagoon's habitats include marshlands, upland plant communities (including coastal sage scrub, mixed chaparral, grasslands and forests), intertidal mudflats, and subtidal zone.[55] It is composed of three connected lagoons: an outer, middle, and inner lagoon. Its main tributary is the Agua Hedionda Creek, and the watershed serves the Cities of Carlsbad, Vista, and Oceanside.
Size	The lagoon is made up of three sections. In its entirety, it is 400 acres. The outer lagoon, middle, and inter lagoons are 66 acres, 27 acres, and 295 acres respectively.[32] A portion of the Lagoon is designated as the Agua Hedionda Lagoon Ecological Reserve, which is 186 acres.
Location	San Diego County, City of Carlsbad
Owner	The Lagoon is owned by combined powers including Cabrillo Power 1 LLC, cities of Carlsbad and Vista, County of San Diego and other municipalities in the Agua Hedionda watershed group.[56] The Agua Hedionda Ecological Reserve is owned by the California Department of Fish and Wildlife.
Land Managers	Encina Power Station and its owner NGR Energy and San Diego Gas and Electric (SDG&E) manage a portion of the Lagoon. The Agua Hedionda Ecological Reserve is managed by the California Department of Fish and Wildlife.
Non-Profit Partners	Agua Hedionda Lagoon Foundation

Past Inhabitants	Predominantly, the Payómkawichum lived in this area.[32] The Payómkawichum inhabited the region for many centuries before the Spanish occupied the land. Payómkawichum territory extended from Agua Hedionda Lagoon north to Riverside County. Estimates of their population range from 5,000 to 10,000. The Payómkawichum occupied a smaller area than the Kumeyaay, thus, their population densities were higher despite higher estimates of the Kumeyaay population.[32] Some portions of the estuary overlap with the Kumeyaay Nation. The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[32] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[32] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon indigenous peoples, including the Kumeyaay and Payómkawichum, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point and onward, nearly all the indigenous lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Payómkawichum remain displaced from their ancestral lands, many living within tribal reservations. The Payómkawichum are made up of seven bands: Pechanga, Pauma, Pala, Rincon, San Luis Rey, La Jolla, and Soboba.[48] The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	Historically, Agua Hedionda Lagoon was a tidal estuary with more salt marsh than present today. Maps from 1887 depict marsh covering the entire western half of the lagoon. It comprised 51% seasonally flooded salt flats, 42% salt marsh, and 7% open water/mudflats.[32] 1790s: European invasion begins[32] 1881: Construction of the California Southern Railroad Line, intersecting with the Lagoon 1912: Construction of PCH, intersecting with the Lagoon 1954: Construction of the Encina Powerplant over a partially filled wetland on the south shore of the lagoon, dredging over 4 million cubic yards of material; construction of jetties along the mouth of the Lagoon to prevent closures 1960s: Construction of a mussels and oysters aquaculture operation on the western basin, remains today as the Carlsbad Aquafarm 1990: Agua Hedionda Lagoon Foundation established[32]

	The eastern basin was leased by the City of Carlsbad and operated as a water recreation area for boats. This remains now as a watersport's facility, the Carlsbad Lagoon Recreation Area.[6]
Restoration History	2002: The invasive tropical algae, Caulerpa taxifolia, was found in 2000 in the Lagoon. The goal was to achieve full eradication of the species. No new species were found in 2002 and onward. The project continued long-term monitoring and surveying through 2006.[57] 2016: The Nature Collective began a comprehensive habitat restoration project on 65 acres of coastal wetlands focused on enhancing indigenous plant cover at sites including Agua Hedionda Lagoon, Batiquitos Lagoon, and Ponto Beach. As a result, indigenous plants are growing at all restoration sites.[58]
Current Status	Today, Agua Hedionda lagoon is 75% open water, and the rest is a combination of marsh and mudflat. It has multiple uses, mainly focused on recreation and economic activities. The Lagoon is home to the SDG&E Encina Power Plant, the Carlsbad Aquafarm, the Hubbs/SeaWorld White Sea Bass hatchery, the Carlsbad Desalination Plant, and recreational boating.[32] Three major roadways cross the Lagoon: Highway 101, the railroad, and Interstate 5, and divide it into three connected basins.[32] Until the late 1900s, SDG&E owned most of the Lagoon. To prevent the clogging of the Encina Power Plant's intake pipes, SDG&E dredged the sand from the western basin. Over 4 million cubic yards of material was dredged. At present, maintenance dredging continues to support all the uses on the lagoon.[32]
Ongoing Issues	As a result of dredging, bridge construction, and other development, the habitat of the Agua Hedionda bears little resemblance to its historical habitat. The Lagoon once was dominated by salt flats and salt marshes. Today, it is 75% open water and marsh remains only in the eastern basin on a thin band. The watershed is largely in agricultural use or undergoing development, which has and continues to lead to degraded land, erosion, and large sediment inflows. Water quality is a concern because of the multiple uses of the lagoon. Sewage spills, boat fuel, and other human disturbance impair the water.[32] Due to the extensive development on the lagoon, including for residential purposes, dredging and jetties currently keep the mouth of the Lagoon permanently to the ocean to maintain its tidal flow.[32] After the 1954 dredging project to support the construction of the Encina Power Plant, the delta of Agua Hedionda Creek extended 50 feet into the open waters of the lagoon, significantly changing the landscape and likely the sediment and freshwater flows. Maintenance dredging is now required to remove a flood-tide shoal in the Outer Basin to maintain the tidal exchange and provide seawater to support the operation of the Carlsbad Desalination Plant.[55] Furthermore, the Encina Power Plant takes water away from the lagoon for cooling purposes which reduces the volume of water available to flush the lagoon. This results in sand accumulation within the outer basin and routine dredging to maintain tidal circulation. Poseidon Water will be taking over dredging operations and payment to maintain the project to support tidal flow and replenish sand on the Carlsbad beaches.[55]

Batiquitos Lagoon

Characteristics	Batiquitos Lagoon is characterized as a lagoon that is dominated by salt flats. Its habitats include open water, subtidal, and intertidal zones, mudflats, southern coastal salt marsh, coastal brackish marsh, transitional zones, and southern arroyo willow riparian forests. Its primary freshwater tributaries are the San Marcos and Encinitas Creeks.[59] Its watershed encompasses approximately 50 square miles or 32,000 acres and includes the cities of Carlsbad, San Marcos, and Encinitas.
Size	The Lagoon is 610 acres.[59]
Location	North San Diego County, between southern Carlsbad and Encinitas
Owner	California Department of Fish and Wildlife
Land Managers	California Department of Fish and Wildlife
Non-Profit Partners	Batiquitos Lagoon Foundation
Past Inhabitants	The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[59] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[59] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon the Kumeyaay, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47] Around the shoreline, nearly 200 different pre-historic sites have been recorded by the California Paleo-Indians and the Kumeyaay.[59]
Current Inhabitants	The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]

Development History	Historically, research characterizes Batiquitos Lagoon as a fully tidal system until the 1800s.[32] It consisted of 80 acres of salt marsh, 480 acres of salt flats, and 10 acres of open water/mudflat. Salt flats dominated the area, making up 80% of the entire estuarine ecosystem.[32] 1849: European invasion 1881: Construction of the California Southern Railroad Line, and consequent bridge, over the Lagoon mouth 1912: Construction of the Pacific Coast Highway (PCH) adjacent to the Lagoon, creating blockages of tides, nutrients, and sediment over the Lagoon mouth 1920s: Agricultural land uses dominated the region 1934: Portion of lagoon filled for construction of Santa Fe Railroad 1952: Construction of San Marcos Dam, cutting volume of freshwater to the Lagoon 1965: Construction of I-5 over the lagoon, exacerbates blockages 1976: Lagoon rarely becomes tidal 1983: Batiquitos Lagoon Foundation established 1984: City of Carlsbad annexed the Lagoon, Port of Los Angeles planning for expansion, kickstarts the Batiquitos Lagoon Enhancement Project to mitigate for lost coastal habitat 1989: Lagoon had not been open to tidal flow for many years[32]
Restoration History	1996: The Batiquitos Lagoon Enhancement Project began in 1994 to renew historic tidal flushing to the Lagoon and slow the filling of the Lagoon with silt because it was expected to fill up within 50 years.[32] The Lagoon also experienced biodiversity loss with only five fish species remaining. The Lagoon was dredged to an average depth of 6-7 feet. The sand was deposited on adjacent beaches and fortified with large rocks to prevent decomposition. Post-project completion, the fish population significantly increased, and it became a breeding and nursery ground for a variety of species.[60] The project fully finished in 1997 with funding by the Port of Los Angeles. 2016: The Nature Collective began a comprehensive habitat restoration project on 65 acres of coastal wetlands focused on enhancing indigenous plant cover at sites including Agua Hedionda Lagoon, Batiquitos Lagoon, and Ponto Beach.[58] As a result, indigenous plants are growing at all restoration sites.[58]

	2019: The Lagoon was dredged again to increase tidal flow. Approximately 114,512 cubic yards of sand was piped from the central basin to South Ponto State Beach.[59]
Current Status	Today, as a result of the 1996 Enhancement Project, Batiquitos Lagoon is a continuously tidal, largely open water estuary. The estuarine portions of the Lagoon comprise 49% open water/mudflat, 48% salt marsh, and 3% salt flat. [32] A portion of the Lagoon is designated as the Batiquitos Lagoon State Marine Conservation Area (SMCA), owned and managed by the California Department of Fish and Wildlife.[60] The SMCA is a no-take zone therefore it prohibits take of all living marine resources, boating, swimming, wading, and diving. Today, 544 acres of the Lagoon is designated as the Batiquitos Lagoon Ecological Reserve, which is owned and managed by the California Department of Fish and Wildlife.[61]
Ongoing Issues	The Lagoon has undergone substantial changes from its historic compositions. The once 80% salt flat-dominated lagoon now comprises only 3% of salt flats.[32] Instead, open water and mudflats dominate the Lagoon. As a result, species composition as well as sediment and water supply have also changed. The construction of the railroad, major highways, and dams greatly altered flow channels, leading to decreased freshwater and inputs to the Lagoon and sedimentation issues. Maintenance dredging is needed for the Lagoon due to sedimentation from reduced tidal flushing.[32]

Buena Vista Lagoon

Characteristics	It is characterized as a coastal, freshwater/brackish lagoon.[62] Its main tributary stream is Buena Vista Creek, a perennial stream originating in the San Marcos Mountain. Its watershed serves the Cities of Oceanside, Carlsbad, and Vista.[32]
Size	The Lagoon is 200 acres.[32]
Location	San Diego County, within the cities of Oceanside and Carlsbad
Owner	California Department of Fish and Wildlife
Land Managers	California Department Fish and Wildlife
Non-Profit Partners	Buena Vista Audubon Society; Buena Vista Lagoon Foundation

Past Inhabitants	Both the Payómkawichum and Kumeyaay inhabited the area around Buena Vista Lagoon. The Payómkawichum inhabited the region for many centuries before the Spanish invaded the land.[32] Payómkawichum territory extended from Agua Hedionda Lagoon north to Riverside County. Estimates of their population range from 5,000 to 10,000. The Payómkawichum occupied a smaller area than the Kumeyaay, thus, their population densities were higher despite higher estimates of the Kumeyaay population.[32] Some portions of the estuary overlap with the Kumeyaay Nation. The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[32] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[32] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon indigenous peoples, including the Kumeyaay and Payómkawichum, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the indigenous lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Payómkawichum remain displaced from their ancestral lands, many living within tribal reservations. The Payómkawichum are made up of seven bands: Pechanga, Pauma, Pala, Rincon, San Luis Rey, La Jolla, and Soboba.[48] The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	Historically, the Lagoon was a 310-acre tidal system with a small tidal prism.[32] It was dominated by salt flats, comprising 75% of the total area, and unvegetated patches of marshes. Freshwater was supplied in the summer by artesian springs, which created brackish and shallow water habitats, mudflats, and marsh. 1790s: European invasion begins 1881: Portion of lagoon filled for construction of the California southern Railroad Line 1912: Portion of lagoon filled for construction of the original Pacific Coast Highway (PCH) which is not Hill Street 1928: Sewage effluent begins flowing into Buena Vista Creek from Vista Sanitation District's treatment pond

	1940: A weir (low dam) was placed at the mouth of the Lagoon and a beach berm was covered with housing development, changing the basic function of the lagoon 1965: Road fills for Interstate 5. The above fills (railroad, PCH, and I-5) separated the lagoon into four connected basins. 1968: Designated as California's Department of Fish and Game's first Ecological Reserve 1970: 100-acre marsh at the eastern end of the Lagoon was filled for the construction of a shopping center 1981: Buena Vista Lagoon Foundation established[32]
Restoration History	1983: California State Coastal Conservancy worked with local cities to lower peak flows to reduce erosion in the creek and sedimentation.[6] 1985: A watershed erosion control plan was constructed to establish strict erosion control and retrofitting the upper watershed to restore its hydrologic balance.[6] 2020: The San Diego Association of Governments (SANDAG) approved a restoration project (previously known as the Buena Vista Enhancement Project) to keep a portion of the lagoon (a small basin owned by the homeowners) intact as a freshwater system, with ocean saltwater bypassing this portion. The weir is to be removed and the lagoon dredged and engineered to allow tidal flushing of ocean water.[63] 2020: The Buena Vista Creek Restoration Project engineered a design for stream bank stabilization and riparian vegetation restoration.[64]
Current Status	Buena Vista Lagoon is the only freshwater lagoon in Southern California as it is protected by a weir at its mouth and a beach berm.[65] Designated as the Buena Vista Lagoon Ecological reserve by the Fish and Game Commission to preserve, protect, and maintain the coastal wetland habitat. This is California's first ecological reserve.[6]
Ongoing Issues	Today, the Lagoon predominantly suffers from extreme sedimentation due to urbanization.[32] Increased peak storms have caused erosion of Buena Vista Creek, contributing to sediment flow. Due to filling and disturbance, the Eastern Basin transformed into a sediment catchment basin. Additionally, sedimentation is contributing to expansion of cattails and bulrush into open water portions of the Lagoon.[32] The construction of the wooden weir at the Lagoon's mouth transformed the habitat from salt-flat-dominant to freshwater/brackish marsh. Discussions have persisted for years over whether to return the habitat to its historic composition and open it to tidal influence.[32]

Los Peñasquitos Lagoon	
Characteristics	It is characterized as a bar-built estuary with a salt marsh lagoon.[6] The Lagoon also includes the Los Peñasquitos Marsh Natural Preserve and Lagoon, and wetlands intersect with Torrey Pines State Natural Reserve.[6] Its habitats include mudflats, salt marshes, salt flats, riparian habitats, coastal sage scrub habitats, salt grass.[6] Its main tributaries are Carroll, Los Peñasquitos, and Carmel Valley creeks, which provide its freshwater supply.[32] Its watershed serves the County of San Diego and the Cities of San Diego and Poway.[32]
Size	The lagoon is 574 acres.[66]
Location	San Diego County, northwestern side of the City of San Diego, forming the natural border with city of Del Mar
Owner	California State Parks (predominantly), California Coastal Conservancy, City of San Diego
Land Managers	California State Parks (manages it as part of Torrey Pine State Reserve)
Non-Profit Partners	Los Peñasquitos Lagoon Foundation (LPLF)
Past Inhabitants	The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[32] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[32] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon the Kumeyaay, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	Historically, the Lagoon was a tidal estuary that covered 380 acres and supported salt marshes, salt flats, and open water/mudflats.[32] However, the predominant feature was pickleweed salt marsh plains that made up 72% of the area.[32] The central lagoon was substantially covered with salt flats. Through time, it evolved to a lagoon that was closed to tidal action for long periods of time. An important feature of the Lagoon was the Los Peñasquitos Creek Riparian Corridor as it comprised riparian sycamores and live oak. Today, the lower corridor is dominated by dense stands of willow. Some sycamore and oaks remain on higher ground.

	1790s: European invasion 1881: Construction of the California Southern Railroad, which passed through the eastern part of the Lagoon. 1925: Construction of the Santa Fe Railroad, passed through the center of the lagoon, impeding tidal flow 1915: Construction of the PCH 1930s: PCH Expansion including the construction of a bridge over the Lagoon's mouth which clogged sand and debris, impacting water flow. 1937: Construction of Highway 1 which crossed and constricted the mouth of the Lagoon 1962: Discharge of sewage effluent into the lagoon ranging in quantities from 500,000 to 1 million gallons per day from three different wastewater treatment plants until 1972 1965: Construction of I-5 1983: Construction of the North Beach Parking Lot significantly altered the Lagoon's hydrology[32]
Restoration History	1985: The California State Coastal Conservancy and LPLF prepared the Los Peñasquitos Lagoon Enhancement Plan to open the Lagoon mouth during periods of low tide, low surf, and lagoon high-water levels because sedimentation caused the Lagoon to rarely stay open.[67] A Lagoon management program is now in place to monitor water quality and manage sand and debris removal. LPLF implements the Enhancement Plan in coordination with State Parks and the State Coastal Conservancy.[67] 2018: The Enhancement Plan was updated because the Lagoon and its watershed have undergone land use change, especially with the expansion of urban and industrial areas. The new plan focuses on a watershed-approach to address hydrology and geomorphology, native habitats and species, water quality, public health, climate change and more. The final plan can be found here.[67] 2015: A Water Quality Improvement Plan (WQIP) developed for the Los Peñasquitos Watershed by the City of San Diego. 2021: Los Peñasquitos Lagoon Restoration Project was approved. The project includes wetland and habitat creation, water quality mitigation, and flood control. It will take part in two phases. Phase 1 will restore at least 23 acres of salt marsh. Phase 2 will restore the remaining acres. The goal is to restore 364 acres of salt marsh by 2035.[32]

Current Status	Los Peñasquitos Lagoon is one of the few remaining native salt marsh lagoons.[32] Today, the salt marsh only occupies approximately 160 acres in comparison to its historic 270 acres. Freshwater/brackish marsh expanded 150% to over 190 acres. This process was largely driven by sewage discharge in the 1960s and 1970s and the increased runoff and sedimentation associated with rapid urbanization. The salt flats have also disappeared, with only about less than 5 acres remaining, largely replaced by salt marsh.[32]
Ongoing Issues	Los Peñasquitos Lagoon suffers from major disturbances from tidal and freshwater flow, sedimentation, and other impacts from rapid urbanization. Continual and rapid development in the second half of the 20th century has caused increased sediment and water delivery to the Lagoon. As a result of human activities and land use change, the Lagoon has lost over half of its historic habitats.[68] Beginning with large-scale cattle ranching in Los Peñasquitos Canyon in the 1800s, urban development and land use change within the watershed has altered native landscapes, degraded water quality, and modified hydrology and geomorphology.[69] Sedimentation remains a big problem. Thousands of acres were graded, paved, and overall degraded for urban development. Tidal channels have filled in and sedimentation has caused loss of salt marsh. In its place, coastal scrub or riparian habitat have been created. The Lagoon lacks natural succession.[32] Due to sedimentation and siltation, the Lagoon is listed as a Category 5 impaired body of water under section 303(d) of the CWA. Originally, it was identified as impaired for sediment on the 1996 CWA Section 303(d) List of Water Quality Limited Segments.[70] The construction of the Santa Fe Railroad caused major disturbance to tidal flows. Today, this railroad is still in use daily. The embankment severely restricts normal lagoon drainage and changes tidal flow. Additionally, Highway 1 constricted the Lagoon mouth, leading to Lagoon mouth closure and, therefore, increased salinity.[32]

Mission Bay

Characteristics	Mission Bay is a saltwater bay with habitats including open water/mudflats, eelgrass, coastal salt marsh, coastal sage scrub, and saltwater bay habitats.[6] Its main tributaries are Tecolote and Rose Creeks. Its watershed serves the City and County of San Diego.[35]
Size	It encompasses 2,299-acre tidal estuary; 40 acre of wetland habitat remain within Kendall-Frost Marsh Reserve and Northern Wildlife Preserve.[33]
Location	County of San Diego, South of Pacific Beach

Owner	City of San Diego, Regents of the University of California (UC)
Land Managers	City of San Diego, UC Natural Reserve System
Non-Profit Partners	Friends of Mission Bay Marshes; Friends of Famosa Slough
Past Inhabitants	The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[33] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[33] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon the Kumeyaay, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	Historically, Mission Bay was a contiguous and extensive marsh, encompassing 4,000 acres of wetland habitats including lagoons, estuaries, tidal marshes, and saltwater bays surrounded by upland habitats.[6, 71] 1542: Originally named “False Bay" by Juan Rodriguez Cabrillo because it was close (and mistaken for) San Diego Bay[72] 1790s: European invasion begins 1852: U.S. Army Corps of Engineers (ACOE) constructed "Derby's Dike to divert the flows of San Diego River into Mission Bay to protect San Diego Bay from sedimentation; sedimentation in Mission Bay formed newly formed, large sandbars and mudflats. 1887: "Derby's Dike' failed so the city erected a permanent dam that straightened the river channel to the sea, which remains today. 1920: Flooding in previous years straightened out Rose Creek in the northeast corner of Mission Bay, which cut off freshwater, nutrient, and sediment supply to the main channel 1944: Chamber of Commerce Committee initiates plans to convert Mission Bay into a tourist/recreational center to diversify the economy 1952: University of California acquired parcels of the upper wetlands in Mission Bay from the Kendall and Frost families

	1956: The ACOE channelized the San Diego River to bypass Mission Bay. As a result, only Rose Creek and Tecolote Creek remained as tributaries to the Bay. 1961: Dredging and filling activities created islands, peninsulas, and deeper water to develop today's Mission Bay Park 1965: The Kendall-Frost Marsh Reserve was established; officially incorporated into the Natural Lands and Waters Reserve System[72]
Restoration History	1989: Creek Stabilization Project by the City of San Diego to reduce erosion from urban stormwater in Tecolote Creek. 2021: City of San Diego approved wetland restoration in De Anza Cove. Restoration will begin in 2022.[35] Ongoing: ReWild Mission Bay is a project led by the San Diego Audubon Society to identify feasible wetland restoration alternatives to enhance and restore tidal wetland habitat in the northeast corner of Mission Bay at the mouth of Rose Creek, contiguous with KFMR/NWP. Efforts to implement the project are underway.[35]
Current Status	Today, Mission Bay is characterized as an urban, enclosed bay that houses only 1% of its historic wetland habitats.[39] It receives terrestrial and urban inputs from the San Diego River watershed and Rose creek. The Bay is dominated by tidal flushing and receives minimal freshwater.[39] The 40 acres of wetland habitat that remains lies within KFMR/NWP.[33] While small in size, it supports a diverse wildlife. Mission Bay Park is a 4,600-acre aquatic playground, and the largest man-made aquatic park in the country.[72] It is surrounded by shorelines, inlets, islets, and beaches. Mission Bay is now fundamentally recreational including facilities like the MB golf course, MB Yacht Club, SeaWorld, Aqua Adventures, the MB Cross Country Course, Belmont Park.[72]
Ongoing Issues	The development of the Mission Bay Park critically changed the ecology of the Bay. Today, it suffers from poor water quality, sedimentation, and impacts from highly urbanized surroundings.[35] The redirection of the San Diego River in 1852 aimed to prevent the port facilities in San Diego from silting in and impeding water flow. In turn, this made "False Bay" an estuary outlet for the San Diego River drainage and began 150 years of large-scale alterations harming the system. Sediment eventually filled Mission Bay, creating much shallow habitats. Due to intense urbanization, tributary streams carry urban pollutants, like oil and fertilizer, and high sediment loads into the back Bay which has poor circulation. This allows accumulation of pollutants.

	The development of Mission Bay Park required 25 million cubic yards of sand and silt to be dredged which replaced marsh habitats. The dredge spoils were used to build lands within the Bay and to construct levees for a new river channel. The outcome created Mission Bay Park, a complex of recreational islands, beaches, and waterways, and the San Diego River flood control channel that bear minimal resemblance to its historic form. ACOE rerouted the San Diego River from San Diego Bay to drain into what is now Mission Bay with "Derby's Dike." [35]

San Diego Bay

Characteristics	San Diego Bay is a tidal estuary, and its habitats include open water, marsh, mudflats, and salt ponds.[6] San Diego Bay National Wildlife Refuge lies within the Bay including Sweetwater Marsh and South San Diego Bay Units.[73] Its main tributaries are Sweetwater and Otay Rivers and Chollas and Paradise creeks.[6] Its watershed serves the Cities of San Diego, Coronado, National City, Chula Vista, Imperial Beach, La Mesa, Lemon Grove, and El Cajon as well as the County of San Diego.
Size	12,530 acres[6]
Location	San Diego County, City of San Diego, Coronado, National City, Chula Vista, and Imperial Beach
Owner	U.S. Navy, Port of San Diego; San Diego Bay National Wildlife Refuge: California State Lands Commission
Land Managers	Port of San Diego: San Diego Bay National Wildlife Refuge: U.S. Fish and Wildlife Service
Non-Profit Partners	Unidentified.
Past Inhabitants	The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[6] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[6] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon the Kumeyaay, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]

Development History	Historically, San Diego Bay was an estuary outlet for San Diego River drainage.[6] The River is not constrained by levees and no longer connects. The earliest maps of the Bay showed mudflats around the shorelines and marshes filled the mouths of the rivers and creeks. The bay was shallow, with large wetlands areas, and received an abundance of freshwater. 1769: Spanish colonization begins, San Diego Bay was chosen as the site of their first northern colony to use as a harbor 1830s: Whaling became a significant operation in the Bay 1852: The U.S. Army Corps of Engineers (ACOE) constructed "Derby's Dike to divert the flows of San Diego River into Mission Bay to protect San Diego Bay from sedimentation; sedimentation in Mission Bay formed newly formed, large sandbars and mudflats 1871: The whaling industry peaked, with the near extinction of the gray whale. 1887: "Derby's Dike' failed so the city erected a permanent dam that straightened the river channel to the sea, which remains today. 1888: Construction of dam on Sweetwater River to provide drinking and irrigation water 1919: Construction of dam on Otay River 1962: San Diego Unified Port District was created, now called the Port of San Diego to manage the Bay and surrounding waterfront land 1969: Creation of the San Diego-Coronado Bridge.[6]
Restoration History	1989: Enhancement plan for the lower river floodplain led by the Conservancy and local governments.[6] 2011: The South San Diego Bay Coastal Wetland Restoration Project restored approximately 300 acres of estuarine habitat in South San Diego Bay including the western salt ponds, the Chula Vista Wildlife Reserve, and Emory Cove.[74] The project transformed degraded uplands to intertidal and subtidal habitats, salt ponds to tidal channels, and lowered levees to restore tidal flow.[74] 2016: South Bay Restoration Program engaged low-income families from National City to restore 6 acres of wetland, upland, and riverine habitats within the Refuge.[75]

Current Status	Today, San Diego Bay is a home port for major assets of the US Pacific Fleet and major naval facilities and the Port of San Diego which includes two container ship facilities and two cruise ship terminals. It is also home to resorts, hotels, museums, the San Diego Yacht Club, and other recreational facilities. It is the largest tidal estuary in California south of Morro Bay. It has experienced significant changes throughout the years. Its salt marshes and intertidal flats have declined to 15% of their historic area as of 1996.[7] Of the marshes that once bordered the Bay, only 10% remained, primarily at the Sweetwater and Paradise Marsh complex.[6] San Diego Bay National Wildlife Refuge contains the remainder of San Diego Bay's historic coastal salt marsh and intertidal mudflat habitats at Sweetwater Marsh, South San Diego Bay Units, and some salt ponds.[6]
Ongoing Issues	San Diego Bay was developed into a major military and domestic port which destroyed most of its wetlands. Most shoreline development sits on fill. In fact, by 1989, 27% of the bay's tidal areas had been filled.[6] These extensive modifications greatly impact normal wetland functions and habitat health. Today, the Bay is now much narrower and deeper than in its unfilled and dredged state.[76] The construction of dams greatly reduced freshwater inflows, making the Bay mainly a saline system, similar to ocean levels. The dredging and filling also widened beaches. The development for military activities dredged up to 140 million cubic yards of sediment.[76] Within the Bay, Western Salt Ponds initiated the construction of large, shallow evaporation ponds that were alternately flooded and dried to harvest salt.[77] These areas are good opportunities for wetland restoration to more productive systems. As a result of urbanization, the Bay experienced water quality issues. In the 1940s and 1950s, raw or minimally treated sewage flowed directly into the Bay.[6] Other contaminants are now predominantly the issue, stemming from urban drool, and marine waste from commercial and military shipping and shipbuilding.

San Dieguito Lagoon

Characteristics	San Dieguito Lagoon is the endpoint of the San Dieguito River, a lagoon dominated primarily by salt marsh.[6] Its habitats include southern California coastal sage scrub, riparian communities, and coastal wetland communities. Its watershed source originates in Volcan Mountain (Julian, CA). One of the largest watersheds at approximately 350 square miles or 224,000 acres.[32]

Size	500 acres
Location	San Diego County, northern edge of the City of Del Mar
Owner	California Department of Transportation (Caltrans); San Dieguito River Parks Joint Powers Authority (JPA); State of California; Southern California Edison Company
Land Managers	Caltrans; San Dieguito River Parks JPA; State of California (State Lands Commission); Southern California Edison Company
Non-Profit Partners	San Dieguito River Valley Conservancy
Past Inhabitants	The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[32] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[32] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon the Kumeyaay, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	Historically, the lagoon occupied almost 600 acres at the mouth of the San Dieguito River Valley.[32] It was dominated by an approximately 540-acre salt marsh, extending over a mile inland, with 90% pickleweed. Its southern edge extended over what is now I-5. On the east side, freshwater and brackish wetlands dominated. 1790s: European invasion begins 1853: Construction of East San Pasqual Ditch, one of the earliest irrigation projects in the San Dieguito Watershed 1895: Lake Wohlford Dam constructed overlapping with the Lagoon 1918: Lake Hodges Dam constructed overlapping with the Lagoon 1915: Portion of lagoon filled for construction of PCH

	1918: Portion of lagoon filled for construction of Lake Hodges Dam 1920s: U.S. Navy established the San Dieguito Airfield as an emergency landing field. 1937: Portion of lagoon filled for construction of Del Mar Fairground 1938: Portion of lagoon filled for construction of Del Mar Airfield 1940s-70s: Sewage effluent discharged directly into Lagoon 1959: Del Mar airport closed and transferred property to the State of California for development of I-5[78] 1967: Portion of lagoon filled for construction of I-5, bisected lagoon into two, isolated wetlands 1986: San Dieguito River Valley Conservancy established 1988: San Dieguito Lagoon Ecological Reserve designated[78] 1989: San Dieguito River Park JPA established[78]
Restoration History	1978: The San Dieguito River Valley Conservancy began an enhancement project to restore tidal flows.[6] 1983: A portion of the lagoon was restored as a dredged tidal basin to remove accumulated sediment and recreate tidal habitats.[6] 2011: San Dieguito Wetland Restoration Project began in 2006 and was completed by 2011.[78] The project created the South Overflow Lot, which was excavated to remove the fill, contoured to support tidal flow, and developed for the creation of vegetation zones. Project also involved the construction of berms, dredging of the river mouth and tidal channel, and the creation of new subtidal basins.
Current Status	One of the largest watersheds in the County of San Diego; of the 500 acres, San Dieguito Lagoon Ecological Reserve encompasses 110 acres. The reserve is owned and managed by the California Department of Fish and Wildlife. Within the San Dieguito Lagoon Ecological Reserve, the San Dieguito Lagoon State Marine Conservation Area (SMCA) consists of waters below mean high tide.[79] It's designation as a SMCA prohibits take of all living marine resources (except the recreational take of Finfish by hook-and-line only from shore and the Grand Avenue Bridge), boating, swimming, wading, and diving, entry on the California least tern nesting island, entry between 8pm to 5pm.[79] Phase II of the 2011 San Dieguito Wetlands Restoration Project began in early 2022 to create a new trail connection, enhance and expand

	riparian habitats, and convert former agricultural fields and degraded land into tidal wetlands. Phase II is a partnership between Caltrans, San Diego Association of Governments (SANDAG), and the San Dieguito River Park JPA.[80]
Ongoing Issues	Today, the Lagoon faces issues from decades of development which greatly reduced the estuary's area from its historic extent.[32] The construction of dams, highways, and roads, specifically Lake Hodges and Lake Sutherland Dam, dramatically changed the watershed, reducing continuous flow and water volume.[32] Filling activities also contributed to loss of coverage and changes in the wetland's drainage pattern as it has eliminated natural habitat. The construction of Del Mar Fairgrounds is one example, located on 81 ha of fill in the wetland.[20] Wetland loss increased dramatically in the last century. From 1928 to1994, the wetland cover decreased from 50% to 15%, corresponding with the national decline in wetland loss.[20] The greatest loss occurred from the period between 1928 and 1945. From 1945 to 1975, wetland loss continued, mainly attributed to the expansion of agricultural fields, the construction of Interstate 5, the realignment of Jimmy Durante Boulevard, and commercial and industrial development.[20] Within that time period, 200,000 to 300,00 gallons of sewage effluent were discharged into treatment ponds in western area of the lagoon. Then, from 1975 to 1994, wetland loss was driven by the southern migration of the San Dieguito River and the conversion of wetland to agricultural land.[32] Overall, much of the Lagoon has been converted to different land use areas with a few exceptions being portions of the tidal channel network, salt marshes, and small ponds on the eastern margin. Substantial salt marsh area, particularly on the north side where the Del Mar Fairground is located, and upland freshwater/brackish wetland has been lost.

San Elijo Lagoon

Characteristics	San Elijo Lagoon is a shallow-water estuary, dominated by shallow-water brackish wetlands.[32] Its habitats include coastal strand, salt marsh, riparian scrub, coastal sage scrub, freshwater/brackish marsh, and mixed chaparral.[32] Its main tributaries are Escondido and La Orilla creeks and its watershed serves San Diego County and Cities of Encinitas, Solana Beach, and Escondido.[6]
Size	979 acres
Location	San Diego County, City of Encinitas and Solana Beach
Owner	California Department of Fish and Wildlife, County of San Diego, and the Nature Collective (formerly San Elijo Lagoon Conservancy); San Elijo Ecological Reserve owned by County of San Diego, the Nature Collective, and California Department of Fish and Wildlife
Land Managers	California Department of Fish and Wildlife, County of San Diego, California State Parks, the Nature Collective

Non-Profit Partners	The Nature Collective
Past Inhabitants	The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[32] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[32] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon the Kumeyaay, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	Historically, San Elijo Lagoon was one a fully tidal system, covering approximately 520 acres of which about 43% (220 acres) was salt marsh, 51% (270 acres) was seasonally flooded salt flats, and 6% (30 acres) was mud flat and open water.[32] Salt marsh dominated the western side and the salt flats occupied most of the eastern half. The Lagoon was connected to the ocean via a network of ponds and tidal channels. Upstream, the Lagoon had traditional freshwater/brackish wetlands.[32] 1790s: European invasion begins 1880: Beginning of a series of constructed dikes and levees on the Lagoon for duck ponds, roads, and sewage treatment ponds. Many remain today. 1887: Construction of the Santa Fe Railroad, intersecting with the Lagoon 1895: Construction of Lake Wohlford 1915: Construction of the PCH, intersecting with the Lagoon 1943: City of Escondido began discharging wastewater into the Lagoon until 1973 1965: Construction of I-5, intersecting with the Lagoon 1971: Construction of Lake Dixon Dam

	1981: Development of water management infrastructure, including dikes, fates, and spillways, constructed in the east basin. 1983: San Elijo Lagoon Ecological Reserve designated 1987: San Elijo Lagoon Conservancy established[32]
Restoration History	1989: the County Parks Department. began opening the lagoon mouth to increase tidal flows to the lagoon. Railroad and Highway 1 bridge constrained the Lagoon mouth, making it difficult to maintain an open channel.[32] 2017: The Nature Collective's $120 million restoration project, "Reviving Your Wetlands - San Elijo Lagoon Restoration" began in 2017 and is ongoing.[81] It is one of the largest wetland restorations in California. Efforts include new mudflats and tidal dredging in the East, Central, and West Basins. The enhanced tidal channels and wider bridge spans aim to support tidal flow. As of 2022, the project entered its final phase which involves removal of accumulated sand from the Lagoon channel under the new I-5 bridge. Monitoring of progress will continue over the next 10 years.[81]
Current Status	Today, San Elijo Lagoon is one of the largest remaining coastal wetlands in San Diego.[32] It has retained more of its historical habitat than other lagoons in North County. Much of the channel network is still intact, and salt marsh still exists in over half of the areas where it existed historically. However, only 18% of the historic salt flat habitats remain today. It has been replaced by freshwater/ brackish wetlands or salt marshes, driven by land use changes and development. Freshwater/ brackish wetlands have increased by nearly 60% and salt marsh has increased by ~27%.[32] The Lagoon is divided into 3 basins because of the construction of Santa Fe Railroad, Highway 101, and I-5.[32]
Ongoing Issues	San Elijo Lagoon suffers from patchwork habitat, sedimentation, and overall historic habitat loss.[32] The development of highways, roads, and railroads dissected the lagoon, reducing its natural exchange with the ocean. Additionally, the large fills for these developments reduced stormwater velocities and increased the rate of sediment deposition. Former uses of the lagoon have left many levees and dikes-off ponds. Highway 1, specifically, created a large dike along the western boundary which severely restricts the entrance channel and tidal flows. It also isolates habitats and establishes poor connectivity amongst the wetlands.[32] Urban development has also caused some sedimentation issues by impacting water and sediment supply flowing from the Escondido Creek Floodplain.[32]

San Luis Rey Lagoon

Characteristics	San Luis Rey Lagoon is an estuary, dominated by riparian habitat.[6] Other habitats include arid rivers, floodplains, riparian habitats, and small marsh areas at the river's mouth.[6] Its headwaters are in the Palomar and Hot Spring Mountains in eastern San Diego County.[82] The River eventually discharges into the Pacific Ocean near the City of Oceanside.[82]
Size	360,000 acres in its entirety; 164 acres of wetland habitat; and the San Luis Rive spans 69 miles
Location	San Diego County, City of Oceanside
Owner	City of Oceanside and San Diego County
Land Managers	San Diego Water Authority
Non-Profit Partners	Unidentified.
Past Inhabitants	Both the Payómkawichum and Kumeyaay inhabited the area around San Luis Rey Lagoon. The Payómkawichum inhabited the region for many centuries before the Spanish invaded the land.[32] Payómkawichum territory extended from Agua Hedionda Lagoon north to Riverside County. Estimates of their population range from 5,000 to 10,000. The Payómkawichum occupied a smaller area than the Kumeyaay, thus, their population densities were higher despite higher estimates of the Kumeyaay population.[32] Some portions of the estuary overlap with the Kumeyaay Nation. The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[32] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[32] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon indigenous peoples, including the Kumeyaay and Payómkawichum, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the indigenous lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]

Current Inhabitants	The Payómkawichum remain displaced from their ancestral lands, many living within tribal reservations. The Payómkawichum are made up of seven bands: Pechanga, Pauma, Pala, Rincon, San Luis Rey, La Jolla, and Soboba.[48] The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	Pre-colonial invasion, the San Luis Rey River flowed into a 100-acre estuary before reaching the sea[83] The river valley was filled with wetlands, marshes from bluff to buff, and other freshwater marsh and riparian forests[83] 1790s: European invasion begins[32] 1798: Establishment of the Mission San Luis Rey de Francia marked the start of the European settlements in the area; floodplain wetlands in the region were claimed for agriculture[6] 1923: Construction of Henshaw Dam, impacting river hydrology[83] 1960s: Groundwater level reached an extreme low after years of steady decline; excessive pumping of water for agriculture and export led to seawater intrusion into the groundwater basin 1965: Construction of I-5, cross over San Luis Rey River 1988: City of Oceanside and U.S. Army Corps of Engineers conducted a large flood-control project on the lower 7 miles of the San Luis Rey River to address flooding of the river over its own floodplain; similar and consecutive flood control projects have continued since[84]
Restoration History	1964: San Luis Rey River mouth was dredged to create the Oceanside Harbor.[6] 2015: Wildlands, Inc. established the San Luis Rey Wetland Mitigation bank along the River in the City of Oceanside.[85] This effort was led by the ACOE, Los Angeles District, and California Department of Fish and Wildlife South Coast Region. The project provides mitigation credits for "unavoidable permitted impacts" to federal and state jurisdictional wetland habitats. The Mitigation Bank encompasses 56.6acres and was designed to establish wetland functions, historic floodplains, and increase riparian vegetation.[85] Other projects have restored most of its upland habitats.

Current Status	At present, the estuary supports some of the most extensive riparian habitat in Southern California.[86] The River is largely unchannelized and relatively undisturbed.[83] After the River enters the City of Oceanside, it becomes channelized to protect the higher-density residential areas from flooding. This channelized portion remains dry for most of the time except during large rain events.[83] For most of the year, the San Luis Rey River terminates in a lagoon.[83]
Ongoing Issues	San Luis Rey River suffers primarily from water quality issues and flooding. In the watershed, land use is mainly residential and agricultural. Development in the lower floodplain increased vulnerability to flooding. Local property owners responded with self-built levees and other mitigation tactics, which has led to a loss of riparian habitats. Agricultural uses have introduced many pollutants into the river, which degraded water quality including causing high levels of chloride and total dissolved solids.[82] The mouth of the river has had historical bacterial exceedances. [82] The river also experienced continuous groundwater level decline until an extreme low in the early 1960s.[87] Water was pumped from the lower 11 miles of the river valley for agriculture and export to Carlsbad and Oceanside. The excessive pumping led to seawater intrusion into the groundwater basin which was addressed by the City of Oceanside through treated wastewater into the San Luis Rey River from 1958 to 1974. Additionally, water was eventually imported to reduce the need to pump groundwater, however, increased development and irrigation with imported water still led to increased salt loading and deteriorated groundwater quality.[87] Lastly, construction of roads, highways, and dams in the mid-1900s, greatly changed the hydrology of the rivers and restricted tidal flow.[87] Specifically, Henshaw Dam cut off access to upstream spawning and rearing habitats for steelhead trout populations and reduced transport and deposition of sand along the coast. Within the San Luis Rey River watershed, sand replenishment along the beach remains an issue.[87]

Santa Margarita Lagoon

Characteristics	The Santa Margarita Lagoon is characterized as an estuary with a low, coastal river.[6] A portion of the Lagoon includes the Santa Margarita Ecological Reserve (SMER) which is dominated by upland and riparian habitats including coastal sage scrub, southern mixed chaparral, and native grasslands.[90] Its tributaries include the Murrieta and Temecula Creeks. Its watershed serves Camp Pendleton Marine Base, San Diego County, and Riverside County, and the lower Santa Margarita River flows through the Marine Corps Base Camp Pendleton which discharges to the Pacific Ocean through the Santa Margarita Estuary.
Size	The estuary encompasses 480,000 acres entirely; approximately 200 acres of wetland habitat remain at the Estuary.[6] The SMER encompasses 4,344 acres.[90]

Location	San Diego County, Camp Pendleton Marine Base
Owner	Majority owned by U.S. Marine Corps. The SMER owned by San Diego State University (SDSU), SDSU Research Foundation, U.S. Bureau of Land Management, California Department of Fish and Wildlife, and the Nature Conservancy.[88]
Land Managers	U.S. Marine Corps and SDSU
Non-Profit Partners	Unidentified.
Past Inhabitants	The Payómkawichum, Kumeyaay, and Acjachemen people inhabited the area around Santa Margarita River Estuary. The Juaneño Band of Mission Indians, Acjachemen Nation inhabited lands now within Orange, San Diego, Los Angeles and Riverside Counties.[46] They have inhabited the area for over 10,000 years.[46] The Band of Mission Indians, Acjachemen Nation, is a State-recognized Native American Indian Tribe.[46] The Juaneño are not federally recognized, which prevents them from accessing and protecting their ancestral lands and land for a reservation. The Payómkawichum inhabited the region for many centuries before the Spanish invaded the land.[46] Payómkawichum territory extended from Agua Hedionda Lagoon north to Riverside County. Estimates of their population range from 5,000 to 10,000. The Payómkawichum occupied a smaller area than the Kumeyaay, thus, their population densities were higher despite higher estimates of the Kumeyaay population.[46] The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[46] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[6] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon indigenous peoples, including the Kumeyaay, Payómkawichum, and Acjachemen, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the indigenous lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Payómkawichum remain displaced from their ancestral lands, many living within tribal reservations. The Payómkawichum are made up of seven bands: Pechanga, Pauma, Pala, Rincon, San Luis Rey, La Jolla, and Soboba. [48] The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]

	The Santa Margarita Watershed also includes portions of the Pechanga Band of Luiseño Indians and Cahuilla Indian Reservations.[48] The Juaneño do not have any reservations as a result of not being federally recognized.
Development History	Historically, Santa Margarita Estuary comprised approximately 370 acres of tidal channels and marshes, extending south nearly to present-day Oceanside Harbor.[6] It once contained the most extensive riparian habitat corridor in the County and was one of the only rivers unimpeded by dams.[6] 1790s: European invasion begins 1942: Camp Pendleton established; Del Mar Boat Basin constructed, destroying 153 acres in the southern portion of the estuary 1962: Santa Margarita Ecological Reserve established 1970: Years of wastewater discharge into the estuary ceased 1986: Santa Margarita Estuary was added to the Clean Water Act (CWA) Section 303(d) List of Water Quality Limited Segments for eutrophic conditions.[88] 2012: Santa Margarita River was added to the 303(d) list for nitrogen and phosphorus 2018: After 303(d) list designation, an alternative to a Total Maximum Daily Load (TMDL) was adopted to address eutrophication through the adoption of waste load allocations into municipal separate stormwater (MS4) permits, national pollutant discharge elimination system (NPDES) permits, agricultural waste discharge requirements (WDRs), and working with the primary dischargers to reduce nutrient loads.[88]
Restoration History	1965: Santa Margarita River channel was dredged deeper to support waterfowl populations.[6] 1971: Brackish marsh habitats along the north side of the Estuary were dredged, transforming it into a salt marsh.[6] 1985: A 1-acre nesting island was constructed in the salt flat area of the estuary for the endangered Least Tern, the Estuary provides critical habitat for many threatened and endangered species.[6] 2020: Santa Margarita River Fish Passage Project worked to inform selection of fish passage enhancement alternatives, specifically the remediation of two key steelhead passage barriers on the Santa Margarita River.[91]

Current Status	Santa Margarita River is the least disturbed and one of the last free-flowing river systems on the Southern California Coast.[89] The SMER continues to act as a Research Field State of SDSU and the SDSU Foundation, to preserve the natural state of the property.[90]
Ongoing Issues	The Estuary mainly suffers with issues of reduced tidal prism, sedimentation, and poor water quality. Development activities caused month-long closures to the Estuary which caused a lost portion of the tidal prism. The development of Oceanside Harbor in 1963 blocked sand movement, causing buildup along the Estuary channel.[6] While the lower river and Estuary have largely escaped development like other estuaries, it faces significant water impairment issues. The Santa Margarita River Lagoon is considered eutrophic, and the lower Santa Margarita River is listed as impaired for enterococcus, coliform bacteria, phosphorus, and nitrogen.[90] The San Diego Water Board first identified nutrient impairments in the Santa Margarita Watershed in the 1980s.[90] In 1986, the Estuary was added to the CWA Section 303(d) List. Eutrophic conditions within the Estuary cause dissolved oxygen concentrations to fall to low levels that make it difficult to support healthy aquatic life. The eutrophic condition is the result of excess nutrient inputs, mainly from urban and agricultural runoff, causing overabundant algal growth and the algal life cycle consuming more oxygen than it produces.[90]

Tijuana Estuary

Characteristics	It is an intermittent estuary with intertidal coastal wetlands, dominated by salt marshes. Its habitats include beach, dune, mudflat, salt marsh, riparian, coastal sage scrub, and upland habitats.[34] Its watershed serves the Cities of San Diego and Imperial Beach, the County of San Diego, and the State of Baja California Norte, Mexico.[92]
Size	1320 acres
Location	Southwestern-most corner of the continental U.S., entirely within San Diego County with three-fourths of its watershed is within Mexico; surrounded by cities of San Diego, Imperial Beach, and Tijuana.[92]
Owner	TRNERR is a composite of lands and waters owned by a variety of local, state, and federal agencies. The major federal landowners are the U.S. Fish and Wildlife Service and the U.S. Navy (USN). Other owners include the State of California (State Parks) and the City and County of San Diego.[92]
Land Managers	TRNERR is managed by the U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration's (NOAA) National Estuarine Research Reserve System, and California State Parks.[92]
Non-Profit Partners	TRNERR non-profit partners are Southwest Wetlands Interpretive Association and the Friends of the San Diego Wildlife Refuges.

Past Inhabitants	The Kumeyaay are San Diego's first people, living in the region dating back more than 10,000 years.[32] Historically, the boundaries of the Kumeyaay lands extended from Ensenada, Mexico up North near Warner Springs Valley. Estimates of the Kumeyaay population range from 10,000 to 20,000.[32] The European invasion, beginning with the arrival of the Spanish in the late 1700s, inflicted violence upon the Kumeyaay, forced them off their ancestral lands, and detrimentally changed their connections, traditions, and way of life. From this point onward, nearly all the Kumeyaay lands were taken into private ownership or under U.S. government jurisdiction.[47] Today, the Kumeyaay remain displaced from their ancestral lands. Kumeyaay governments have jurisdiction over approximately 70,000 acres concentrated in El Cajon, Lakeside, Poway, and Ramona, San Diego as well as part of the desert. However, El Capitan Reservoir, making up 15,000 acres of the total acreage, is unusable as it was removed from their jurisdiction.[47]
Current Inhabitants	The Kumeyaay remain displaced from their ancestral lands, many living within tribal reservations. The Kumeyaay tribal members are divided into 12 separate bands: Barona, Campo, Ewiiaapaayp, Inaja-Cosmit, Jamul, LaPosta, Manzanita, Mesa Grande, San Pasqual, Santa Ysabel, Sycuan, and Viejas.[47]
Development History	1790s: European invasion begins[32] 1970s: Completions of the development of several residential buildings on vegetated dunes, resulting in sand moving into the northern marsh and entrance channel; eventually the river mouth closed and had to be dredged[34] 1980s: Increased sewage flows 1982: Designation as a National Estuarine Sanctuary by NOAA 1984: Inlet closure, led to episodic sedimentation from dune destabilization and over wash 1993: Winter storms resulted in heavy flooding that bifurcated the Tijuana River at Hollister Street, creating a new channel to the north of the existing channel 1996: U.S. Congress approved construction of border fence along the U.S.-Mexico border, beginning at the Pacific Ocean at Tijuana Estuary and extending 14 miles eastward in San Diego County 1997: Construction of a permanent bridge to replace the temporary "Bailey Bridge" 1997: Construction of an international wastewater treatment plant near the U.S.-Mexico Border boundary led to occasional sewage flows 2009: Partial inlet closure due to migration of inlet 600 meters south of its typical mid-estuary position[34]
Restoration History	1984: The main tidal channel, Oneonta Slough, was dredged to restore tidal flushing, following an 8-month closure which was rare for the mainly tidal estuary. The dredged sand was used to recreate the dunes which became part of a continuing dune management program in the

	northern arm.[71] 1986: Another dredging project in the southern arm to maintain the channel and restore dunes.[34] 2010: The completion of the Tijuana Estuary Tidal Restoration Program I restored up to 500 acres of major habitat processes that have been lost and to increase tidal flushing, improve water quality, and control sedimentation. 2005: Construction of sedimentation basins to capture major sources of sediment. 2005: The Tijuana Estuary Tidal Restoration Program was drafted to restore approximately 496 acres of wetland habitat in the south arm of the estuary, funded by the State Coastal Conservancy. Phase I of this project constructed the Goat Canyon sediment retention basins, which was designed to capture approximately 60,000 cubic yards of sediment and debris. The basin requires yearly maintenance to be emptied due to their small capacity. The project was successful in capturing and removing sediment before it could reach the estuary as well as restoring approximately 20 acres of mule-fat scrub and 1.6 acres of southern willow scrub and upland habitats as mitigation for project impacts. 2009: USFWS funded removal of sand deposited by winter storms which blocked most tidal flows to the south arm. The removed sand was placed on adjacent dunes. This succeeded in restoring tidal flows to the south arm. 2017: USFWS removed sand from the inlet on five occasions because the inlet became closed or partially closed. Many restoration projects have been conducted at this site. A full timeline and look at these restoration projects can be found at the 40 Years of Restoration at Tijuana Estuary, California: Lessons Learned Report by Chris Nordby.[34]
Current Status	San Diego's and Southern California's largest coastal wetland.[34] It is one of the few estuaries that has natural, daily tidal flushing due to avoiding dissection from roadways and highways like its neighboring estuaries.[34] In 1982, the Tijuana Estuary was designated a National Estuarine Sanctuary by NOAA and later renamed the Tijuana River National Estuarine Research Reserve (TRNERR). The TRNERR encompasses approximately 2,531 acres, protecting the resources of the Tijuana River Estuary.[92] Also, a part of the estuary is the Tijuana Slough National Wildlife Refuge, which lies in the northern half of the TRNERR. It is owned and managed by the USFWS.[92] Today, the estuary is usually dominated by sea water and thus supports organisms well-adapted to saline waters and soils.[4]

Ongoing Issues	Since 1852, Tijuana Estuary has lost approximately 80% of its tidal prism. Additionally, its shallow-water habitats, salt marsh and intertidal flats, have declined to 15% of its historic extent as of 1996.[34] Today, its main issues stem from sedimentation from watershed erosion, wash over of sand from denuded dunes, and sewage discharge. Unlike other estuaries in the County, development has mainly occurred alongside the estuary.[6,71] However, it has been affected by land uses like most Southern California coastal wetlands. As it is located downstream from highly populated areas, it is influenced by urban land uses and receives runoff from agricultural fields. Imperial Beach and Tijuana have faced issues from land use practices on both sides of the border for decades, tracing back to the 1848 Treaty of Guadalupe.[34] Both areas have a high-density human population, inadequate sewer systems, unstable slopes and soils, and agricultural activities, which has severely impacted the estuary's water quality and sedimentation.[34] Another big concern is the degradation of its protective dune system. Dunes have been destabilized from development and land use change, resulting in waves washing sand directly into marsh. Its historic tidal prism has been diminished by chronic and episodic sedimentation.[6] Due to adjacency with highly urbanized areas, poor agricultural practices, and inadequate sewer systems, it has been impacted by chronic and episodic sewage flows.[34] Natural upland adjacent habitats and upland transition zones have been disturbed and developed. The construction of the border fence exacerbated habitat loss and fragmentation as well as providing an additional source of sedimentation. The southern arm of the estuary has been heavily impacted by sedimentation as well as filling and diking for agriculture and military use.[34] In the future, the combination of these issues as well as its location on the coasts makes the Tijuana Estuary vulnerable to sea level rise.[34]

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