Appendix 2: Wetland Classification

of the *Wetlands on the Edge: The Future of Southern California's Wetlands Regional Strategy 2018*

Written by *Regional Strategy 2018* Authors

The *Regional Strategy 2018* wetland classification system is based on subregion and wetland archetype. The subregion addresses the wetland's physical location in the region, while the archetype groups wetlands by geomorphology and ecosystem processes.

Landscape Setting of the Subregions

Landscape and climate are major factors in determining the form of the Southern California estuaries and landscape setting varies by subregion. The diversity of coastal wetlands in part reflects the former shorelines of the Bight, general uplift along the coast, sea-level rise, and the processes of littoral transport, wave erosion and sediment accumulation. It also reflects the semi-arid Mediterranean climate characterized by a low annual rainfall in combination with high mean temperature; there are seasonal and annual changes in rainfall—with a dry summer and a winter rainy season— as well as wet and dry years. This variable precipitation leads to seasonal and episodic river flow which, together with an abundance of sediment and relatively high and constant wave energy, means many of the estuaries in Southern California have intermittent connections to the ocean as the tidal inlet opens and closes.

There are two main types of shoreline in the Bight (Jacobs et al, 2011). There are steep terraced shorelines, which are eroding and retreating, and there are progradational shorelines which are accreting and infilling the estuaries.

Table 1. Landscape setting and wave exposure characteristics of the five subregions.

Subregion	From	To	Landscape Setting	Wave Exposure
Santa Barbara Coast	Point Conception	Rincon Point	Steep Terraced	Low
Ventura Coast	Rincon Point	Point Mugu	Prograding	High
Santa Monica Bay	Point Mugu	Topanga Creek	Steep Terraced	Low
	Topanga Creek	Palo Verdes	Prograding	High
San Pedro Bay	Palo Verdes	Dana Point	Prograding	High
San Diego Coast	Dana Point	La Jolla	Steep Terraced	High
	La Jolla	U.S. Border	Prograding	High

Steep terraced shorelines

These shorelines are characterized by a series of eroding terraces that were cut by waves at former sea levels (Figure 1). As these terraces were uplifted over time, valleys formed across them. With sea-level relatively stable for the last 6,000 years, there has been considerable erosion of the uplifted terraces that has straightened the coastline and created stretches of steep coasts and headlands, often with cliffs facing the sea. Terraced coasts often have small, steep watersheds and valleys with stream-mouth estuaries. In addition, there has been continued infilling of the small estuaries with sediment, which leads to the creation of wetlands.

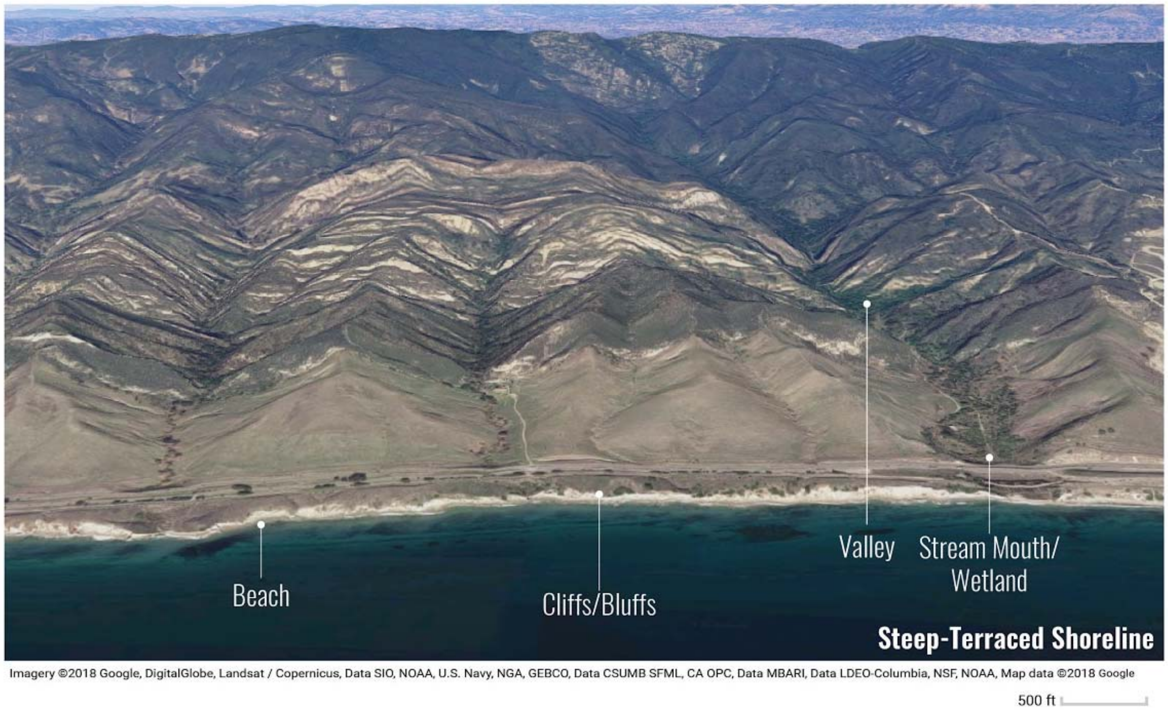

Figure 1. An image from the Gaviota Coast depicting a steep-terraced shoreline and associated attributes.

Prograding shorelines

During the early Pleistocene there were very extensive embayments that penetrated inland in the Los Angeles basin and the Santa Clara Valley. These areas are associated with high sediment-producing watersheds and large rivers. Over time, embayments were filled with sediment carried down by rivers, and also with sediment driven by waves alongshore from adjacent eroding terraced shorelines. This infilling, together with the general uplift of the coast, reduced the size of the embayments and moved their shoreline seaward. The seaward limit of the shoreline is likely set by littoral processes transporting sediment downdrift. The large, relatively flat floodplains of these embayments were created during floods, when rivers would migrate, cutting distributary channels and depositing sediment. This has resulted in the floodplains being continuously reworked, with channels and wetlands being cut, moved and abandoned over time.

Figure 2. An example image of a prograding shoreline in Southern California (San Mateo Point) and associated attributes.

Archetype Classification Methods

The *Regional Strategy* (2018) will support restoration of an integrated set of more than 103 coastal wetlands of different sizes and settings. A clear and relatively concise organizational structure is a useful approach for creating a cohesive strategy that accommodates the diversity of systems in the Bight, yet provides the necessary flexibility for site-specific planning to proceed in consideration of local constraints and opportunities. We have elected to use the archetype concept, built off previous work focused on historical wetlands (Grossinger et al. 2011; Stein et al. 2014), as an organizational structure to articulate relationships between landscape settings and drivers (e.g. watershed size, littoral position) and wetland composition and structure in order to support development of regional objectives.

Overview

The archetype classification is an organizational structure to articulate relationships among wetlands that share similar landscape and climatic settings and wetland composition and structure. In this way, they help simplify analysis and communication, and provide a mechanism to generalize or extrapolate knowledge about a given system to similar types of systems.

To aid in the analysis of sea-level rise effects, and to support the *Regional Strategy* (2018), we aimed to develop a set of coastal wetland archetypes for Southern California. Our goal was to define less than 10 archetypes that met the following criteria:

- Based on contemporary wetland boundaries and structure
- Strive for mutually exclusive classes
- Defined mainly by the physical processes that control form and structure
- Reflect functions and services specific to the archetype
- Can be readily mapped

Approach to Defining Archetypes

The archetypes were defined using the following general process:

1. Identify discrete wetlands along the coast of the southern California Bight from Pt. Conception to the U.S.-Mexico border
2. Compile physical structure and process variables for each system
3. Compile vegetation/plant community data for each system
4. Filter wetlands based on completeness of the data for each system and remove systems from analysis with poor data coverage
5. Perform cluster analysis to identify preliminary archetypes
6. Perform discriminate function analysis to identify key predictor variables
7. Overlay vegetation/habitat layers on top of preliminary archetypes
8. Test bias of archetypes to ensure good regional representations
9. "Validate" archetypes against best professional judgement of the Science Advisory Panel (SAP)

Previous wetland mapping was used to define 103 discrete wetlands along the southern California coast. These were identified as follows:

1. All wetlands mapped as estuarine polygons (E1 or E2) by the most recent National Wetlands Inventory (NWI)/California State University, Northridge (CSUN) mapping
2. Additional wetlands were added to this list by the project team based on best professional judgement—these include small wetlands not mapped by NWI
3. The resulting list of wetlands was refined and systems were lumped or split based on consultations with the Science Advisory Panel

We compiled a series of 40 variables related to physical conditions/drivers for each wetland. These variables generally fell into one of five categories (see Table 2):

- Catchment properties (proxy for inputs of water and sediment)
- Wetland dimensions, such as size, slope, ratio of dimensions, etc.
- Proportion of subtidal vs intertidal area
- Inlet dimensions and condition
- Wetland volume/capacity

Table 2. List of variables used in cluster analysis to define archetypes.

Variable	Variable Definitions
AltitudeIndex	"a proxy for flow"
Area	area of the wetland
Area	wetland area
ChanLength	length of the wetland's main channel
ChanSlope	slope of the wetland's main channel
DYNRATIO	square root(Area)/mean depth--relates to proportion of bottom areas dominated by erosion and transport processes vs deposition
E1AB	subtidal aquatic bed area (NWI)
E1TOT	total subtidal habitat area (NWI)
E1US	subtidal unconsolidated sediment area (NWI)
E2AB	intertidal aquatic bed area (NWI)
E2EM	emergent marsh area (NWI)
E2TOT	total intertidal area (NWI)
E2US	intertidal unconsolidated sediment area (NWI)
E2US_E2AB	intertidal unconsolidated sediment plus aquatic bed area (NWI)
ELEVatMAXVOL	elevation, relative to sea level, at which water starts spilling into floodplain
ELEVBOT	the elevation of the estuary thalweg relative to sea level
EXPORATIO_merged	100 x cross-section area at mouth/area of estuary
GEOFORM	wetland type: 1 = enclosed bay; 2 = lagoon; 3 = river mouth
INLET	condition of inlet: 1 = perennially tidal; 2 = intermittently tidal; 3 = ephemerally tidal
MAXAREA_3d	the area of the wetland at the point where overflowing water would start spilling into floodplain
MaxElev	maximum elevation of the catchment
maxMouthWidth_m	max mouth width (m)
MAXVOL	volume of the estuary at maximum capacity (cutoff of 7.6 ft above MSL if it's an open system--varies with how high the rim is for closed systems)
MEANMOELEV	mean mouth elevation relative to MSL
MEANMWIDTH	mean mouth width
MeanPercImpervious	mean percent impervious surfaces within catchment
MinElev	minimum elevation of the catchment
MOUTHAREA	cross-sectional area of the mouth
PercBarren	proportion of area inside system's polygon that is the category Barren (from Calveg), which we believe is mudflat
percDEEPSUB	physical habitat distribution (not NWI) - percent of wetland that is deep subtidal (>2m deep at mean low low tide)
percNaturalBuffer	% "natural" land in 500m buffer around system

Table 2. List of variables used in cluster analysis to define archetypes (continued).

percOpenWaterProp	proportion of area inside system's polygon that is the category Water (from Calveg)
percTimeMouthOpen_CONSOLIDATED	proportion of time that mouth is open
riverAssociated	"1"= input from a river; "0"= no river
Slope	rise/run from mouth to furthest afield
slopeSTD	STD of pixel slopes integrated across polygon (from Abel GIS)
WatershedSlopeMax	maximum catchment slope
WatershedSlopeMean	mean catchment slope (proxy for rainfall runoff relationship and also sediment supply)
WatershedSlopeSTD	STD of the slope of the watershed

Of the 103 wetlands, we had sufficient data for 46, which were retained for the cluster analysis. Data was then transformed for normality using approaches appropriate for each data type (typically log, square root, or arcsine root). A K-Means Cluster Analysis was run using the "self-organizing map" option in order to weed out any variables that don't contribute to the model solution. A variety of cluster numbers were tested with the goal of creating 4-8 clusters that maximized separation, minimized misclassification rates, and had roughly balanced sizes. Once the final clusters were defined, we ran a Discriminant Function Analysis to determine the subset of predictor variables that generated the greatest accuracy of classification. We then examined the distributions of the predictor variables by cluster, as assigned in the original cluster membership using K-means, in order to characterize each archetype. Finally, we mapped habitat data from the National Wetlands Inventory (NWI) and CalVeg onto the clusters to produce habitat associations for each archetype.

The provisional archetypes were evaluated in two ways. First we analyzed the bias in each cluster by producing density plots that compared the distribution of wetlands that 1) were included in the cluster analysis, and which did end up in cluster 2) were included in the cluster analysis, but which did not end up in cluster 3) were not included in the cluster analysis in the first place. We performed bias analysis using each of the key predictor variables to ensure adequate representation of all wetlands vs. just the 47 that were included in the cluster analysis. Second, we asked individual SAP to assign attributes to each wetland based on their knowledge and best professional judgement (see Table 2 for the list of attributes provided to the SAP members). The SAP members were also allowed to add modifiers to each wetland based on mouth armoring, mouth migration potential, and/or presence of engineered channels. We then grouped wetlands based on the attributes assigned by the SAP and compared those groupings to the clusters defined through the quantitative analysis.

Table 3. Attributes provided to the SAP for qualitative exercise for a comparison to the quantitative cluster analysis.

Size
small (< 10 ha)
medium (10-100 ha)
large (> 100 ha)
Geoform
river/canyon mouth
structural/tectonic basin
Bar Position/Closure
perched (mostly closed)
intertidal (intermittently closed)
subtidal or engineered (mostly open)
Migration Potential
low (constrained or developed)
moderate (some ability)
high (ample adjacent space)

Finally, we assigned each of the 103 wetlands to the archetypes to determine if each system could be classified in a mutually exclusive manner. This final step provided an opportunity to refine the final set of archetypes to ensure they represent all wetland systems in the Bight.

Results of Cluster Analysis

We identified a five-cluster solution that maximized separation and minimized misclassification between clusters, and from this cluster analysis assigned five initial archetypes (Figure 3). The first two canonical axis explained 88% and 9% of the variability in the data set, respectively. Nine predictor variables explained the majority of the variability between clusters:

- wetland area
- area/depth (erosion area)
- slope from mouth to head
- integrated slope (STD of pixel slope)
- mouth elevation relative to MSL
- mean mouth width
- total area inundated at spill height
- percent wetland >2m at low tide
- total percent subtidal

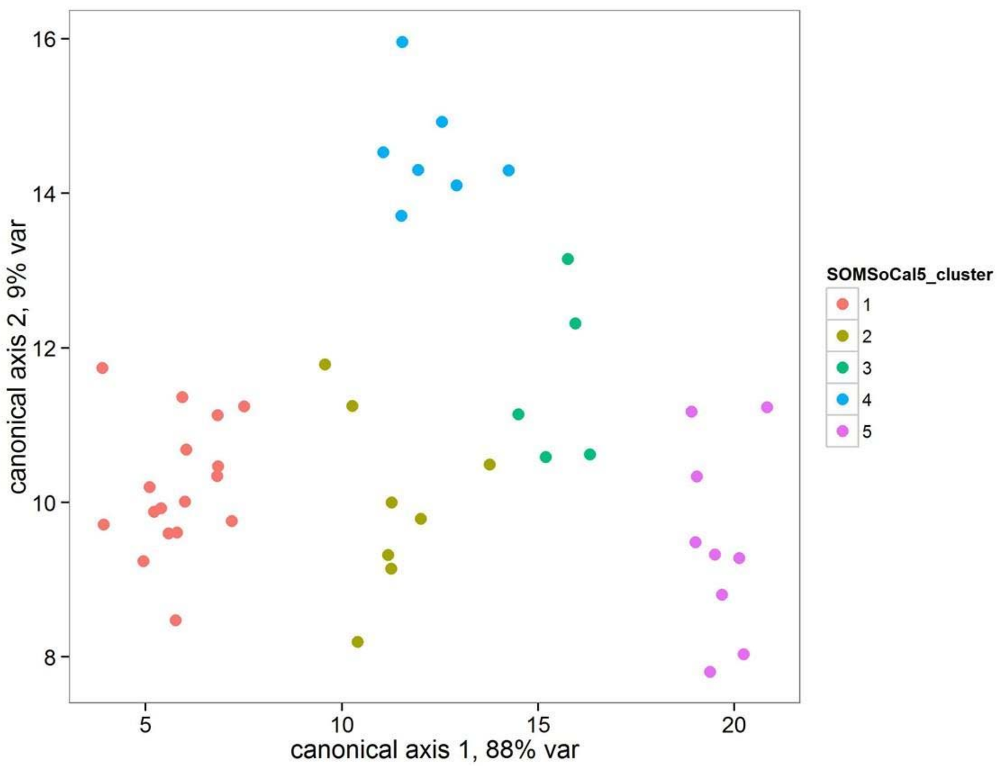

Figure 3. Five cluster solution for grouping of coastal wetlands.

The first canonical axis (which explains 88% of the variability) is defined by wetland area, mean mouth width, mouth elevation relative to MSL, and the percent subtidal habitat.

Results of the bias analysis showed that the five clusters generally represented all wetlands in the region. Most of the wetlands that are under-represented are small wetlands that often consist of a coastal lagoon without an associated coastal drainage. In some cases the lack of an associated coastal drainage is natural, in others it is the result of anthropogenic activities that have converted the historic coastal drainage to a storm drain. Based on discussions with the SAP, a sixth archetype was added to accommodate small coastal wetlands without an associated stream.

In order to check the results of the cluster analysis the SAP attempted to assign archetypes to the 103 mapped coastal wetlands. Through this exercise it became apparent that some historical large depositional river valleys have been fragmented into hydrologically disconnected wetlands that are often mapped or managed separately. A final, seventh, archetype was added in recognition of historically connected depositional river valleys that may be restored through the regional recovery efforts. Discussions with the SAP also resulted in clarifying that intertidal or supratidal wetlands that fringe archetypes that may be predominantly open water (e.g. small lagoons, open bays and harbors) should be considered a component of that archetype and not be separated out as distinct systems for the purposes of classification. The final seven archetypes are described in Table 3.

Table 4. Seven wetland archetypes and their associated habitats.

Archetype	General Description	Associated Habitats	Example Systems
Small Creek	small creek systems; minimal subtidal habitat area; generally higher gradient	intertidal (Cowardin), Riparian marsh and meadow (CalVeg)	Example Systems
Small Lagoon	Small coastal lagoon without an associated creek	Intertidal and subtidal habi-tats. May have fringing riparian marsh	Aliso Canyon Creek, Ar-royo Sequit
Intermediate Estuary	Intermittently closing river mouth estuaries	intertidal (Cowardin), Riparian marsh and meadow (CalVeg)	Dume Lagoon, Andree Clark Bird Refugee
Large Perennially-Open Lagoon	open basin, extensive subtidal habitat, fringing intertidal;	intertidal emergent, pickle-weed and/or cordgrass habitats (CalVeg)	Malibu Creek, Ventura River System
Large River Valley Estuary	large, depositional river valleys, fringing marsh; high dynamic ratio	intertidal emergent, pickle-weed and/or cordgrass habitats (CalVeg), moderate subtidal area (Cowardin)	Carpinteria Salt Marsh, Bolsa Chica Fully Tidal
Fragmented River Valley Estuary	Currently fragmented large depositional river valley; opportunities for reconnection	intertidal emergent, pickle-weed and/or cordgrass habitats (CalVeg), moderate subtidal area (Cowardin)	Goleta Slough, Tijuana River Estuary

Hydrodynamic Influence

The concept of grouping wetland systems into similar archetypes builds off previous classification systems for west coast estuaries that focus on the relative degree of influence of the hydrodynamic forcing mechanisms of waves, tides, and rivers (Gleason 2011) and the characteristics of the tidal inlet, specifically the intermittency of opening and closing (Jacobs et al. 2011). These classifications were extended for the *Regional Strategy (2018)*.

The WRP's seven archetypes can be classified by inlet behavior, size and forcing, as shown in Table 4.

Table 5. The seven wetland archetypes separated by size and dominance of each water source.

<table>
<tr><th rowspan="2">Inlet Behavior</th><th rowspan="2">Relative Size</th><th colspan="3">Dominance</th></tr>
<tr><th>Tidal</th><th>River</th><th>Wave</th></tr>
<tr><td rowspan="3">More Closed

Varying degrees of intermittent opening

More Open</td><td>Small</td><td></td><td>Small Creek</td><td>Small Lagoon</td></tr>
<tr><td>Intermediate</td><td></td><td colspan="2">Intermediate Estuary</td></tr>
<tr><td>Large</td><td></td><td>Large River Valley Estuary

and

Fragmented River Valley Estuary (where applicable)</td><td>Large Lagoon</td></tr>
<tr><td>Permanently Open Inlet</td><td>Very Large</td><td>Open Bays/Harbors</td><td></td><td></td></tr>
</table>

Wetland Archetypes

Southern California wetlands have been categorized into seven different wetland archetypes based on a cluster analysis of wetland area, mean inlet width, inlet elevation, and the percent subtidal habitat. The characteristics of each archetype can be found below. Tables 5 and 6 provide a complete list of the 103 contemporary wetlands with their archetype designations.

Small Creeks

Small Creeks generally occur on eroding terraced shorelines where the steep watersheds and narrow valleys control the size of the creeks and the area available for wetlands. They have relatively high sediment inputs and small accommodation volume. Over the period of the Holocene sea-level still-stand, they have generally filled in with sediment resulting in fewer subtidal areas. This lack of accommodation volume also reduces their tidal prism. Thus, the small systems tend to have small and highly variable river flow and low tidal prisms in comparison to the incident wave power. Consequently, the tidal inlet may be closed or perched more often than some of the larger systems.

In many small creeks, the tidal prism has been reduced by filling, and the creek has been separated from its floodplain. Coastal highways and railroads cross many of the mouths of the creeks so that they are subsequently constrained by bridge abutments, armoring or culverts. Figure 4 shows the tidal inlet of Canada de la Gaviota Creek in the Gaviota Creek State Park and illustrates some of these modifications and constraints.

Figure 4. Past alterations to small creeks illustrated by Canada de la Gaviota Creek - railroad crossing, jetty, inlet armoring and parking lot fill (Photo: California Coastal Records Project, 2013).

Restoration of small creeks is complicated by the lack of availability of low-lying areas. In addition, most of the modifications are due to fill, which has raised the land and would have to be removed. The steep sides of the valleys reduce the amount of upland adjacent to the creeks, although in many cases this upland has not been developed. The main opportunities for adapting to sea-level rise appear to be migration along the axis of the valley. However, in some cases this is constrained by the presence of a culvert, or similar structure, allowing water to pass beneath a highway or railroad. Widening these hydraulic structures may allow the wetlands to migrate.

Large and Small Lagoons

Large and small lagoons are shallow basins usually created by a beach berm or barrier, which traps the lagoon between the ocean and uplands (Figure 5). Since they are trapped features, they do not necessarily have an associated creek or river connected to a watershed. The large lagoons have larger tidal prisms than the smaller lagoons but not necessarily a larger watershed and any river flow may be relatively small and intermittent, water and sediment input may be more from the local catchment or from the ocean. The inlet may be closed or “perched” due to continued wave-driven littoral drift maintaining a bar across the tidal inlet; the tidal prism and seasonal river flows are relatively small to keep the inlet open. With the inlet closed, limited oceanic waves or tides can enter the lagoon. The inlet may occasionally be opened by flood events, for several days or weeks allowing tidal exchange with the ocean. Wind- and thermally-driven two-dimensional circulation and mixing occur and locally generated wind-waves may be a major driver of sedimentation processes (Winant 2004, Largier 1996).

Sedimentation from the watershed may be limited compared to accommodation volume and deposited as an alluvial fan in the lagoon; oceanic sediment may be deposited as a flood delta in the mouth. These estuaries may, therefore, have small areas of intertidal, and may only have fringing marsh. Due to the propensity to close, the lagoon flats may dry out completely due to evapotranspiration and salt flats can develop. These flats can flood to become shallow ponds when the inlet is open.

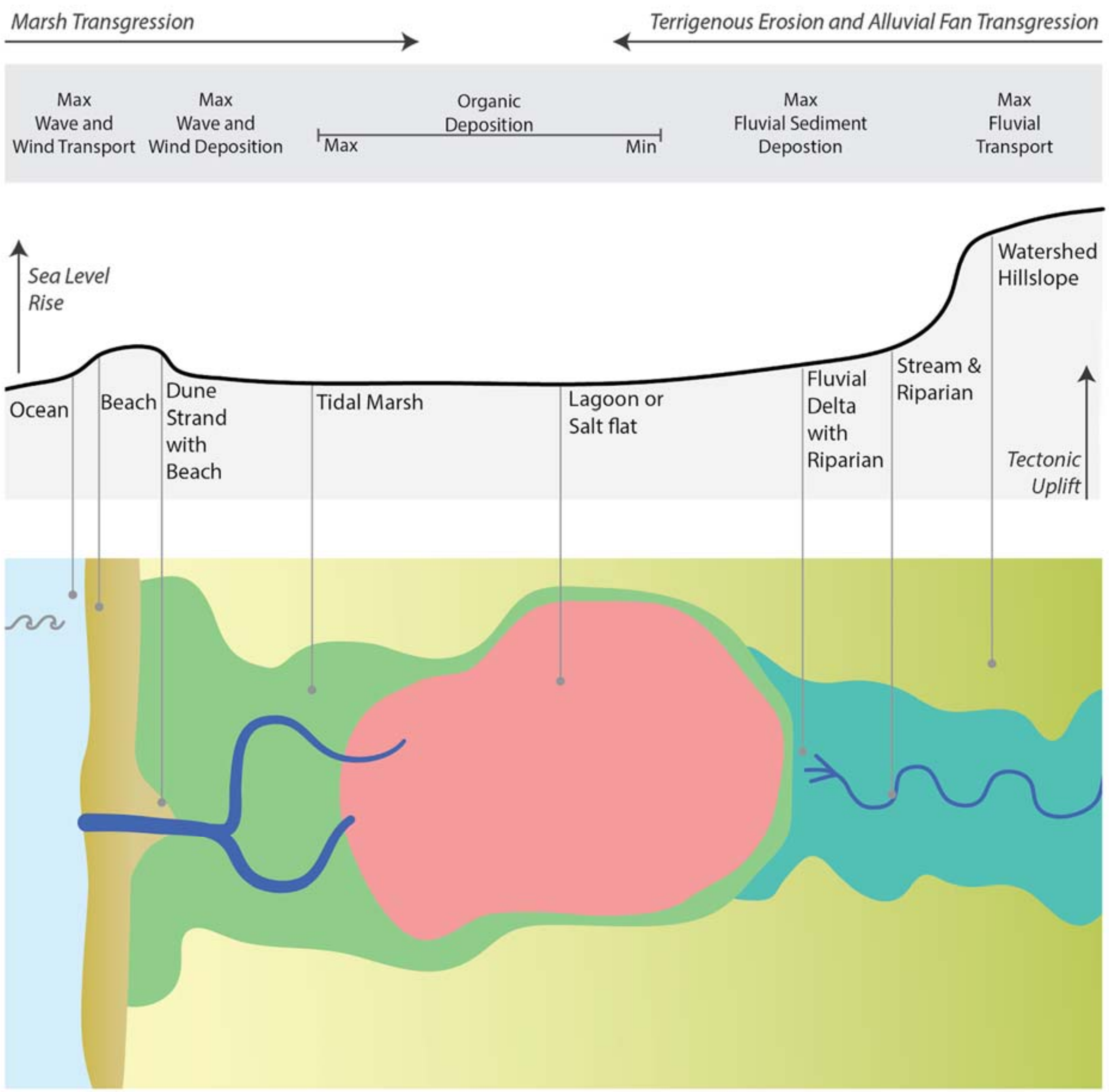

Figure 5. Conceptual model of the features and processed of historical small and large lagoons.

Many of the lagoons have been altered by filling and draining together with the construction of berms, and changes in the hydrology (fluvial inputs) associated with development in the watershed. Tidal inlets have been stabilized by the construction of jetties and armoring of the inlets (Figure 6). The barrier that creates the lagoon has often been stabilized and built upon, and often serves as the route of coastal highways. The changes have had a significant effect on the habitats within the lagoons. In many cases, the salt flats have been lost either due to diking or due to the more regular connection to the ocean as the tidal inlet is managed with structures. Freshwater input may occur throughout the year and reduce water quality; flows from the local catchment that do enter the lagoons have often passed through urban areas and entered the stormwater system. Freshwater input may also limit the ability of seasonal salt flat formation and in some cases has lead to a conversion of salt marsh habitat to freshwater habitat in areas where it didn’t existing before (e.g., Los Penasquitos Lagoon).

Figure 6. Alterations at Batiquitos Lagoon (Photo: California Coastal Records Project, 2013). Roads, railroad, and jetties have significantly changed the natural cycles at this wetland. The jetties were built as part of a previous project to restore wetland habitat at the lagoon.

The potential to modify the tidal inlets by removing constraints such as jetties, is tempered by the need to maintain flood risk management and water quality expectations of the urban developments that have occurred around the lagoons. A tidal inlet is often held open to prevent water being trapped in the lagoon and flooding adjacent areas. Also, the tidal prism may be much smaller than what occurred historically due to the amount of fill and infrastructure that has bisected lagoons and reduced tidal flow. It may not be possible to re-create the same pattern of inlet opening and closing. Historically lagoons had relatively low sediment supply from the watershed and may have relied more on oceanic sources of sediment. Present day sediment supply has been altered by development in the watersheds increasing erosion, by the trapping of sediment behind dams, and by the presence of structures, such as jetties, at the tidal inlet. With rising sea level the barrier which has trapped the lagoon may migrate landward reducing the size of the lagoon, unless it has already been stabilized by development. The ability of the wetlands to migrate with sea-level rise is dependent upon the steepness of the surrounding topography.

Intermediate Estuaries

Many of Southern California's wetlands have, or historically had, dynamic connections with the ocean that varied seasonally reflecting annual patterns of precipitation and river discharge, as well as multi-year patterns of wet and dry years. The dynamic nature of these inlets is an important characteristic of many Southern California wetlands that was captured in the archetype classification. Wetlands that are defined by dynamic tidal inlets are variously referred to as Intermittently Open Estuaries (IOE) (Strydom 2003) and Bar-Built Estuaries (BBE) (Largier et al. 1992), and in the archetype classification mostly occur in the "Intermediate Estuary" category. Intermediate estuaries reflect a balance between the river and wave forces on the continuum of tidal inlet conditions. All of the wetland archetypes lie on a continuum of inlet state, ranging between mainly closed to perched to mainly open, depending upon the balance of river flow to wave energy, from fluvial-dominated river mouth estuaries, to wave-dominated lagoons (Gleason et al. 2011). The tidal inlet state is also dependent upon wetland size. A large river system, where flow persists for weeks or months, is more likely to stay open and less likely to close compared to a small creek, which only has flow following rainfall, given the same wave exposure. Similarly, a large lagoon system is more likely to stay open and less likely to close compared to a small lagoon in similar circumstances.

Figure 7. Intermediate estuary - San Luis Rey River with a tidal inlet highly controlled by the Pacific Street bridge. (Photo: California Coastal Records Project, 2013)

Intermediate estuaries lie between the large and small systems and have significant tidal prism and river flows. Water levels within these estuaries when they are closed are affected by river flow, if present; by runoff from the immediate watershed; by waves that overtop the berm; by tides which affect groundwater elevations; by seepage through the berm from the ocean; by evapotranspiration; and by overtopping on extreme tides. All of these processes are likely to affect water levels within the estuary and affect the likelihood and duration of opening/ perching/ closing. Another controlling factor, tidal prism, similarly affects water levels and the probability and duration of inlet opening (Harvey et al. 2018, *in preparation*). Tidal prism is a measure of the amount of water entering the estuary on each tide when it is connected to the ocean; a decrease in the tidal prism due to sedimentation will make the inlet more susceptible to closure in the next high wave event. Changes to the tidal prism through sedimentation, or lack of it, may result in a small tidal prism and the inlet perching more often or alternatively a large tidal prism and the inlet remaining open for longer.

As with lagoons, these systems have been altered by filling and draining of wetlands and stabilizing the tidal inlet, and changes in the hydrology (e.g., fluvial inputs) associated with development in the watershed. In addition, the timing and magnitude of river flows have been affected by damming higher up in the watershed and by the construction of flood control channels.

Large River Valley Estuary and Fragmented Large River Valley Estuary

These wetland systems formed on the large depositional plains associated with rivers such as the Santa Clara, Los Angeles, San Gabriel, Santa Ana and San Diego. The rivers crossed over these plains as they shifted course during floods, depositing sediment, creating new distributary channels, reworking the remnants of previous floods and altering the pattern of wetlands. These systems were connected to large watersheds with significant flows of water and sediment during the floods and were large enough to have flowed in drier periods of the year. Some of the large rivers have been rerouted over time naturally, due to river capture or uplift of terraces changing drainage patterns, (e.g., Newport Bay, San Gabriel River, Los Angeles River), or artificially by the construction of a flood channel in a different location (e.g., Santa Ana River). In these cases, the present river or creek is not necessarily the one that formed the floodplain and its features, and the floodplain was already fragmented by the historical pattern of relict distributary channels (e.g., the Oxnard plain and the Santa Clara River). While these do not necessarily function as they have in the past, there may be opportunities to reconnect and the fragments should be considered as part of a larger system.

These large, relatively flat and easily drained plains have also been very attractive for development. As a result, they have been drained, diked, and developed, fragmenting the floodplain and wetlands (Figure 8). Some river channels have been completely rerouted to facilitate this drainage and to improve flood protection. This has led to the fragmentation of the large river valley estuaries where remnants of the floodplain have been dissected by into small units (e.g., Santa Ana River, Huntington Beach wetlands and Santa Ana River; Ballona Creek, Ballona wetlands and Del Rey Lagoon). Even where the wetlands remain connected, larger rivers that fed these wetlands have tended to be dammed - trapping water and sediment. Some of the diked lands have been used for industrial and urban land use, rather than agricultural, which may make restoration of tidal flows more difficult.

Figure 8. Past alterations to large river valley estuaries - Santa Ana River rerouted and the Santa Ana wetlands fragmented by the construction of the flood control channel. (Photo: California Coastal Records Project, 2004)

Given the constraints associated with urban development, perhaps the main opportunities for migration are up the river valley rather than along the coast. In some cases, this will be facilitated by reconnecting fragments of existing wetlands and the restoration of agricultural areas along the river channel (e.g. Santa Clara River). In some cases, the fragmented wetlands are in proximity and could be reconnected morphologically. In other places the fragments are more dispersed due to the highly urbanized nature of the floodplain so that reconnection may be more concerning water and sediment flows and species movement. It is also important to consider improving the connectivity of the watersheds to the river and the coastal floodplain. In some cases fragments will have to remain isolated regarding water, sediment and migration space (e.g. Seal Beach) and artificial measures such as sediment nourishment will be needed to maintain wetlands in their present location. Given their large floodplains, the historical transition zone may be quite a distance from the river. This may require the construction of manmade transition adjacent to the wetlands to provide some space for both transition zone habitat and marsh migration.

Open Bays and Harbors

Open bays and harbors are tidally-dominated, have large tidal prisms, small river inputs, significant subtidal areas, relatively little intertidal wetlands and permanently open inlets. Many have hardened mouth infrastructure to help maintain tidal action, reduce sedimentation and provide for safe harbor usage. These archetypes are relatively large compared to their sediment supply and have not filled in – such as San Diego Bay, Los Angeles Harbor, and Long Beach Beach Harbor. In other words, their inlets and tidal prisms are too large for them to close.

Table 6. Archetype assignment resulting from cluster analysis of 46 wetlands.

Site Name	Current Archetype	Historical Archetype
Aliso Canyon Creek	Small Creek	Small Creek
Arroyo Paredon Creek	Small Creek	Small Creek
Arroyo Quemado	Small Creek	Small Creek
Arroyo San Augustin	Small Creek	Small Creek
Bell Canyon Creek	Small Creek	Small Creek
Las Flores Creek	Small Creek	Small Creek
Mandalay Power Station Outfall	Small Creek	N/A - did not exist
Big Sycamore Canyon	Small Creek	Small Creek
Rincon Creek	Small Creek	Small Creek
Tecolate Canyon Creek	Small Creek	Small Creek
Topanga Creek	Small Creek	Small Creek
Andree Clark Bird Refugee	Small Lagoon	Small Creek
Las Pulgas Canyon	Small Lagoon	N/A - did not exist
Malibu Lagoon	Intermediate Estuary	Intermediate Estuary
San Juan Creek	Intermediate Estuary	Intermediate Estuary
San Luis Rey Estuary	Intermediate Estuary	Intermediate Estuary
San Mateo Lagoon	Intermediate Estuary	Intermediate Estuary
Ventura River Estuary	Intermediate Estuary	Large River Valley Estuary
Agua Hedionda	Large Lagoon	Large Lagoon
Anaheim Bay	Large Lagoon	Large Lagoon
Batiquitos Lagoon	Large Lagoon	Large Lagoon
Bolsa Chica Fully Tidal	Large Lagoon	Large Lagoon
Buena Vista Lagoon	Large Lagoon	Large Lagoon
UCSB Lagoon	Large Lagoon	Large Lagoon
Los Penasquitos	Large River Valley Estuary	Large River Valley Estuary
San Diego River Estuary	Large River Valley Estuary	Large River Valley Estuary
San Dieguito Lagoon	Large River Valley Estuary	Large River Valley Estuary
San Elijo Lagoon	Large River Valley Estuary	Large River Valley Estuary
Santa Margarita Estuary	Large River Valley Estuary	Large River Valley Estuary
Tijuana River Estuary	Large River Valley Estuary	Large River Valley Estuary
Dana Point Harbor	Open Bay/Harbor	N/A - did not exist
Los Angeles Harbor	Open Bay/Harbor	N/A - did not exist
Marina Del Rey	Open Bay/Harbor	Intermediate Estuary
Mission Bay	Open Bay/Harbor	Large River Valley Estuary
Newport Harbor	Open Bay/Harbor	Open Bay/Harbor
Oceanside Harbor	Open Bay/Harbor	Large River Valley Estuary
San Diego Bay	Open Bay/Harbor	Open Bay/Harbor
Upper Newport Bay	Open Bay/Harbor	Open Bay/Harbor

Table 7. Archetype assignment for all other wetlands not included in the cluster analysis.

Site	Current Archetype	Historical Archetype
Aliso Creek Estuary	Small Creek	Small Creek
Arroyo de las Aguas	Small Creek	Small Creek
Tajiguas Creek	Small Lagoon	Small Creek
Camino Capistrano	Small Creek	Small Creek
Damsite Canyon	Small Creek	Small Creek
Dume Lagoon	Small Creek	Small Creek
Solstice Canyon	Small Creek	Small Creek
Los Trancos Canyon	Small Creek	Small Creek
Eagle Canyon	Small Creek	Small Creek
Las Llagas Canyon Creek	Small Creek	Small Creek
Hollister Ranch Creek	Small Creek	Small Creek
Las Flores Canyon	Small Creek	Small Creek
Arroyo Sequit	Small Creek	Small Creek
Loma Alta Slough	Small Creek	Large Lagoon
Los Cerritos Channel	Fragmented River Valley Estuary	Large River Valley Estuary
Mission Creek Lagoon	Small Creek	Intermediate Estuary
Salt Creek	Small Creek	Small Creek
Sycamore Creek	Small Creek	Small Creek
Santa Monica Canyon	Small Creek	N/A - did not exist
Canada del Agua	Small Creek	Small Creek
Pendleton Outfall	Small Creek	N/A - did not exist
Arroyo Burro Creek Estuary	Small Creek	Small Creek
Arroyo el Bulito	Small Creek	Small Creek
Canada del Refugio	Small Creek	Small Creek
Canada del Santa Anita	Small Creek	Small Creek
Creek at Corona del Mar Beach	Small Creek	Small Creek
Trancas Lagoon	Small Creek	Small Creek
Wintersburg Channel	Small Creek	Large Lagoon
Cockleburr Canyon	Small Lagoon	Small Lagoon
French Lagoon (Canyon)	Small Lagoon	Small Lagoon
San Buena Ventura	Small Lagoon	Small Creek
Ballona Creek	Intermediate Estuary	Fragmented River Valley Estuary
Bolsa Chica Channel	Intermediate Estuary	Large Lagoon
Dominguez Channel	Intermediate Estuary	N/A - did not exist
Canada de la Gaviota Creek	Intermediate Estuary	Intermediate Estuary
North Mission Bay Wetlands	Intermediate Estuary	Open Bay/Harbor
San Onofre Creek	Intermediate Estuary	Intermediate Estuary
Otay River Estuary	Intermediate Estuary	Open Bay/Harbor

Sweetwater Marsh	Intermediate Estuary	Open Bay/Harbor
Ballona Lagoon	Fragmented River Valley Estuary	Intermediate Estuary
Bolsa Bay	Large Lagoon	Large Lagoon
Carpinteria Salt Marsh	Intermediate Estuary	Intermediate Estuary
Carpinteria Creek	Small Creek	Small Creek
Del Rey Lagoon	Fragmented River Valley	Intermediate Estuary
Devereux Lagoon	Large Lagoon	Large Lagoon
McGrath Lake	Fragmented River Valley	Large River Valley Estuary
Mugu Lagoon	Intermediate Estuary	Intermediate Estuary
Santa Ana River Wetlands	Fragmented River Valley	Large River Valley Estuary
Huntington Beach Wetlands	Fragmented River Valley	Large River Valley Estuary
Goleta Slough	Large River Valley Estuary	Large River Valley Estuary
San Gabriel River	Fragmented River Valley Estuary	Large River Valley Estuary
Santa Ana River	Fragmented River Valley Estuary	Large River Valley Estuary
Alamitos Bay	Fragmented River Valley	Large River Valley Estuary
Ballona Wetlands	Fragmented River Valley Estuary	Intermediate Estuary
Los Angeles River	Fragmented River Valley Estuary	Large River Valley Estuary
Ormond Beach	Fragmented River Valley Estuary	Large River Valley
Santa Clara River	Fragmented River Valley Estuary	Large River Valley Estuary
Los Cerritos Wetlands	Fragmented River Valley Estuary	Large River Valley Estuary
Cabrillo Marina	Open Bay/Harbor	N/A - did not exist
Huntington Harbor	Open Bay/Harbor	Large Lagoon
Long Beach Harbor 1	Open Bay/Harbor	N/A - did not exist
Long Beach Harbor 2	Open Bay/Harbor	N/A - did not exist
Long Beach Harbor 3	Open Bay/Harbor	N/A - did not exist
Long Beach Marina	Open Bay/Harbor	N/A - did not exist
Redondo Beach King Harbor	Open Bay/Harbor	N/A - did not exist
Santa Barbara Harbor	Open Bay/Harbor	N/A - did not exist
Ventura Marina	Open Bay/Harbor	Large River Valley Estuary

References

Harvey, M., S. N. Giddings, E. D. Stein, J. Crooks, R. Ambrose, C. Whitcraft, T. Gallien, L, Tiefenthaler, H. Meltzer, K. Thorne, K. Johnston. 2018. Effects of the 2015-2016 El Niño on Water Levels in Southern California Estuaries and Implications for Elevated Sea Levels. Manuscript in Preparation.

Largier, J.L., J.H. Slinger,and S. Taljaard. 1992. The Stratified Hydrodynamics of the Palmiet-A Prototypical Bar-Built Estuary. Dynamics and exchanges in estuaries and the coastal zone. 40: 135-153.

Largier, J. L., C. J. Hearn, and D. B. Chadwick. 2013. "Density Structures in 'Low Inflow Estuaries.'" In Buoyancy Effects on Coastal and Estuarine Dynamics, edited by D. G. Aubrey and C. T. Friedrichs, 53:227–41. Coastal and Estuarine Studies.

Strydom, N.A. 2003. Occurrence of larval and early juvenile fishes in the surf zone adjacent to two intermittently open estuaries, South Africa. Environmental Biology of Fishes. 66(4): 349-359.

Winant, Clinton D. 2004. "Three-Dimensional Wind-Driven Flow in an Elongated, Rotating Basin." Journal of Physical Oceanography 34 (2). American Meteorological Society: 462–76.