2013
SOUTHERN CALIFORNIA BIGHT REGIONAL EEGLRASS SURVEYS
Alamitos Bay
San Gabriel River
Anaheim Bay/Huntington Harbour
Agua Hedionda Lagoon
Batiquitos Lagoon
San Dieguito

Prepared for:

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2013
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SUMMARY

Merkel & Associates, Inc. (M&A) was contracted by NOAA/National Marine Fisheries Services (NMFS) to conduct comprehensive eelgrass (*Zostera marina*) surveys within multiple embayments and lagoons within southern California in support of development of a superior understanding of regional eelgrass distribution patterns and, eventually, regional-scale dynamics. This contracted work is one key element to a broader effort to develop a comprehensive understanding of eelgrass distribution as a benchmark to support implementation of *Recommendations for a Southern California Regional Eelgrass Monitoring Program* (Bernstein, *et al.* 2011). Concurrent with this survey effort, there are a number of parallel efforts underway by other entities in a manner that will assist in developing the regional benchmark. While the regional monitoring program calls for a "Benchmark Year" survey for the region, funding practicalities and multiple party participation levels have not allowed for the single season completion of the full regional benchmark survey. For this reason, the benchmark will be developed across multiple seasons.

Systems surveyed under this contract include Alamitos Bay, San Gabriel River, Anaheim Bay/Huntington Harbour, Agua Hedionda Lagoon, Batiquitos Lagoon, and San Dieguito Lagoon (Figure 1). When limiting the survey areas to low intertidal and subtidal environments with the potential to support eelgrass, approximately 1,958 acres were surveyed. Within the surveyed area a total of 310 acres of eelgrass beds were mapped. This report details the surveys and results. The distribution of eelgrass identified in this survey is as outlined as follows:

System	2013 Survey Area (Acres)	2013 Eelgrass Coverage (Acres)	Percent Eelgrass of Total System Area
Alamitos Bay	386.7	23.3	6%
San Gabriel River	153.2	0.0	0%
Anaheim Bay/Huntington Harbour	800.7	89.2	11%
Agua Hedionda Lagoon	247.8	43.1	17%
Batiquitos Lagoon	258.5	122.5	47%
San Dieguito Lagoon	111.2	31.9	29%

Systems Overview Map

Southern California Bight Regional Eelgrass Surveys

Figure 1

BACKGROUND

Eelgrass is a community structuring plant that forms expansive meadows or smaller beds in both subtidal and intertidal habitats in shallow coastal bays and estuaries, as well as within semi-protected shallow soft bottom environments of the open coast. Eelgrass vegetated areas are recognized as important ecological communities because of their multiple biological and physical values (e.g. major food source in nearshore marine systems, important structural environment for resident bay and estuarine species, etc.). As a result, eelgrass is considered a "foundation", or habitat forming species. Eelgrass is a major source of primary production in nearshore marine systems, underpinning detrital-based food webs. In addition, several organisms directly graze upon eelgrass or consume epiphytes and epifauna supported by eelgrass plant structures, thus contributing to the system at multiple trophic levels. Eelgrass beds are also a source of secondary production.

Eelgrass beds function as habitat and nursery areas for commercially and recreationally important open ocean marine fish and invertebrates, and provide critical structural environments for resident bay and estuarine species, including abundant fish and invertebrates. Eelgrass supports juvenile fish as well as mature, often predatory, fish that hunt along the margins of the bed's protective structure. Besides providing important habitat for fish, eelgrass is considered to be an important resource supporting migratory birds during critical migration periods. Eelgrass is particularly important to waterfowl such as black brant that feed nearly exclusively on the plants and to a number of other species that make a diet of both eelgrass and the epiphytic growth that occurs on the leaves.

In addition to its habitat and resource value, eelgrass traps and removes suspended particulates, improves water clarity, and reduces erosion by stabilizing the sediment. Eelgrass facilitates nutrient cycling and oxygenates the water column during daylight hours. Eelgrass also has the potential to act as significant means of sequestering carbon.

Besides the critical resource values and ecosystem functions of eelgrass, it is uniquely suited to serve as a sentinel indicator of overall ecosystem condition. Eelgrass is an easily and repeatably monitored widely distributed integrator of environmental conditions that responds to natural and anthropogenic stressors that are chronic in nature. Eelgrass is robust with respect to short-term environmental fluctuations within normal or near normal environmental ranges. However, eelgrass does respond to physical damage or short-term presence of high toxicity discharge events.

Because of the ecosystem importance of eelgrass, its presence at critical land-sea coastal interface area, and its capacity to serve as an indicator of system health and regional trends, in 2010 NMFS funded the development of a regional monitoring program to track trends in eelgrass habitat as a tool to assist in management decisions and tracking effects of climate changes on critical coastal waters. Under this program, NMFS and a number of regional stakeholders worked collaboratively to develop recommendations for Southern California regional eelgrass monitoring. The ultimate result of this effort was Southern California Coastal Water Research Project Technical Report #632 *Recommendations for a Southern California Regional Eelgrass Monitoring Program* (Bernstein, *et al.* 2011).

The regional eelgrass monitoring program is strongly based on a structure similar to the adopted and presently employed eelgrass monitoring program within San Francisco Bay (Merkel & Associates 2008). The program relies on development of a comprehensive distribution map for eelgrass within the region for a "Benchmark Year" survey to which annual subsampling along fixed belt transects may be scaled. This benchmark scaling allows for tracking and assessment of eelgrass distribution patterns and variability over both spatial and temporal scales. In order to leverage multiple programs underway to develop the benchmark condition required for implementation of the regional monitoring program, NMFS funded the completion of comprehensive eelgrass surveys within multiple systems.

The immediate goal of this survey effort was to work with regional partners and the Southern California Bight Program to comprehensively survey eelgrass within various embayments and lagoons of Southern California. The contract objective was to complete surveys of a minimum of three out of five original systems in the survey program. A small amount of funding was included in the program budget to support development of partnerships with the intent of covering all of the five systems as well as encouraging partners to engage in surveying other systems within southern California. NMFS identified five systems within which it funded support for eelgrass surveys: Alamitos Bay, Anaheim Bay (including Huntington Harbour), Agua Hedionda Lagoon, Batiquitos Lagoon, and San Dieguito Lagoon. Subsequently, NMFS added the San Gabriel River estuary to the survey list as a sixth site. While the primary objective of the survey within the San Gabriel River was to identify eelgrass habitat, other subtidal habitats were to be mapped for this area in order to assist NMFS to better understand the distribution of estuary habitats with respect to the persistent use of the lower river by eastern Pacific green sea turtle (*Chelonia mydas*).

Due to funding practicalities of many agencies and regional partners, the 2013 survey participation levels have not allowed for the single season completion of the full regional benchmark survey. For this reason, the benchmark will be developed across multiple seasons. During 2013, comprehensive surveys were conducted by other entities in several other systems including Morro Bay, San Pedro Harbor, and Mission Bay. In 2014, the Navy has scheduled comprehensive eelgrass surveys for San Diego Bay and San Clemente Island. Additional system-wide surveys are anticipated, but few are confirmed at this time, and there remains an on-going need for complete benchmark inventories throughout the region.

SURVEY METHODS

SURVEY TIMING

Eelgrass surveys were conducted in all systems between April and October 2013. Surveys were conducted on the dates indicated in Table 1.

Table 1. Survey Dates for Eelgrass Survey and Ground-truthing

SYSTEM	2013 SURVEY DATES
Alamitos Bay	April 3, August 1, October 29
San Gabriel River	April 3, October 19 and 29
Anaheim/Huntington Harbor	April 3, July 30 and 31
Agua Hedionda Lagoon	April 19, July 15 and 19, September 20
Batiquitos Lagoon	April 19, July 19, September 20
San Dieguito Lagoon	April 19, June 10

Survey dates were selected to benefit from desired tides that supported the survey methods applied. Surveys were conducted over multiple dates to capture tidal conditions and integrate survey efforts with other survey activities in the same area. Typically follow-up targeted ground-truthing was conducted after the initial habitat mapping was performed in order to verify mapping in problem areas.

SPATIAL SURVEYS

Eelgrass surveys were conducted using a combination of custom flown low tide aerial photography and interferometric sidescan sonar survey.

Aerial surveys were flown during low tides on April 3 (Orange County systems) and April 19 (San Diego County systems). Photographs were processed digitally and rectified prior to digitizing visible eelgrass as a shapefile in ESRI ArcGIS geographic information systems software. Where eelgrass boundaries became unclear due to water depth, a boundary of eelgrass that could be effectively mapped from the aerial photographs was plotted on digital maps that were subsequently loaded into the navigation software for subsequent sonagraphic surveys. These boundaries provided a limit of the coverage by interferometric sidescan sonar that would ultimately be necessary to ensure full coverage of eelgrass surveys.

Sonagraphic surveys were undertaken in navigable waters using an interferometric sidescan sonar system. The interferometric sidescan system is a dual channel hull mounted sonar operating at 468 kHz that integrates a vessel motion sensor to correct for vessel pitch, heave, and roll; a sound velocity sensor that corrects for speed of sound in water related to density differences resulting from changes in temperature and salinity; and a dual antenna differential GPS that provides submeter vessel positioning and correction for vessel yaw. Because the position of the interferometric sidescan sonar head is rigidly fixed to the vessel, the positional error is dramatically reduced from that associated with other mapping methodologies, including traditional towed sidescan sonar. With the survey system utilized in this effort, absolute postitional error for eelgrass mapping is approximately ±1-2 meters. The relative positional error is estimated at ±0.5-1 meter as the GPS error is substantially nullified across short distances. The interferometric sidescan was set

to survey out 35 meters on the port and starboard channels such that the full swath width was nominally 70 meters. Surveys were conducted by navigating parallel track lines such that with each pass of the sonar swath fully the nadir gap that occurs directly below the survey vessel from the prior pass was covered with the subsequent pass.

Shallow areas were surveyed at high tides such that the sonar extended to the shoreline beyond any eelgrass beds. Within tight marinas, multiple passes were made at differing angles, and vessel thrusters were used to slowly pivot the survey vessel at the ends of dock fingers in order to obtain full and precise sonar coverage of the marina bottom. These constrained harbor environments are the most complicated to survey using standard sidescan sonar because the cabled towfish orientation is decoupled from that of the vessel at slow speeds and in tight turns or direction reversals, such as are required in marina environments.

GROUND-TRUTHING

Ground truthing was completed by a combination of shoreline visual surveys, snorkeling, SCUBA diver surveys, ROV, and drop camera verification. Ground-truthing occurred both at the time of initial survey, as well as during subsequent site reviews that were made to verify mapping at specific areas where questions existed or boundaries of eelgrass were not clear.

The intensity of ground truthing varied across the survey area based on a variety of factors. In well-surveyed wide-open systems such as Agua Hedionda Lagoon and Batiquitos Lagoon, ground-truthing was limited to areas where eelgrass mapping is most complicated such as at revetment interfaces where eelgrass transitions into rock with attached sargassum (*Sargassum muticum*). In addition, ground-truthing was done along the innermost edges of the mapped beds where eelgrass sometimes transitions to widgeon grass (*Ruppia maritima*).

At San Dieguito Lagoon, eelgrass was verified by walking the shoreline, wading, and snorkeling to inspect beds that were mapped using aerial photographs. Because mapping in this system relied extensively on aerial photographic interpretation, there was an intensive ground-truthing performed such that all areas of mapped eelgrass were visually observed. Where eelgrass integrated with other dark features in photographs, such as rock or kelp wrack, GPS coordinates were taken and printed maps were edited to correct boundaries.

Alamitos Bay and Anaheim Bay/Huntington Harbour support extensive marina and private dock facilities. Debris beneath docks and constrained survey areas can exacerbate survey error. For this reason, ground-truthing was completed using divers, drop video cameras, and an ROV. Verification was focused on areas of particular risk of erroneous mapping. These include areas where extensive debris occurs on the bottom, areas where eelgrass beds become very sparse, and areas where high reflectivity of adjacent rock interferes with bed boundary detection.

Within the San Gabriel River estuary, the survey extended upstream into areas of brackish water at the location where the soft bottom channel transitions to a concrete lined channel. Over the length of the San Gabriel River estuary, there were several features that appeared to be unique from typically encountered marine habitats. In addition, for the San Gabriel River estuary, the objective of the mapping effort was to document distribution of other benthic habitat as well as eelgrass. For this reason, ground-truthing was distributed more broadly than would be required if eelgrass

mapping was the only purpose of the investigation. On the day of the sidescan sonar survey, ground truthing was completed using a video camera on a rigid pole that could be lowered to the bottom and moved around to observe features. Subsequent to mapping, four small patches that had been identified as potentially being eelgrass were reinvestigated by camera. In addition, additional mapping work was conducted near the inlet to inventory habitats extending outside of the river mouth to the tip of the Alamitos Bay entrance jetty that was not accessible during the initial survey.

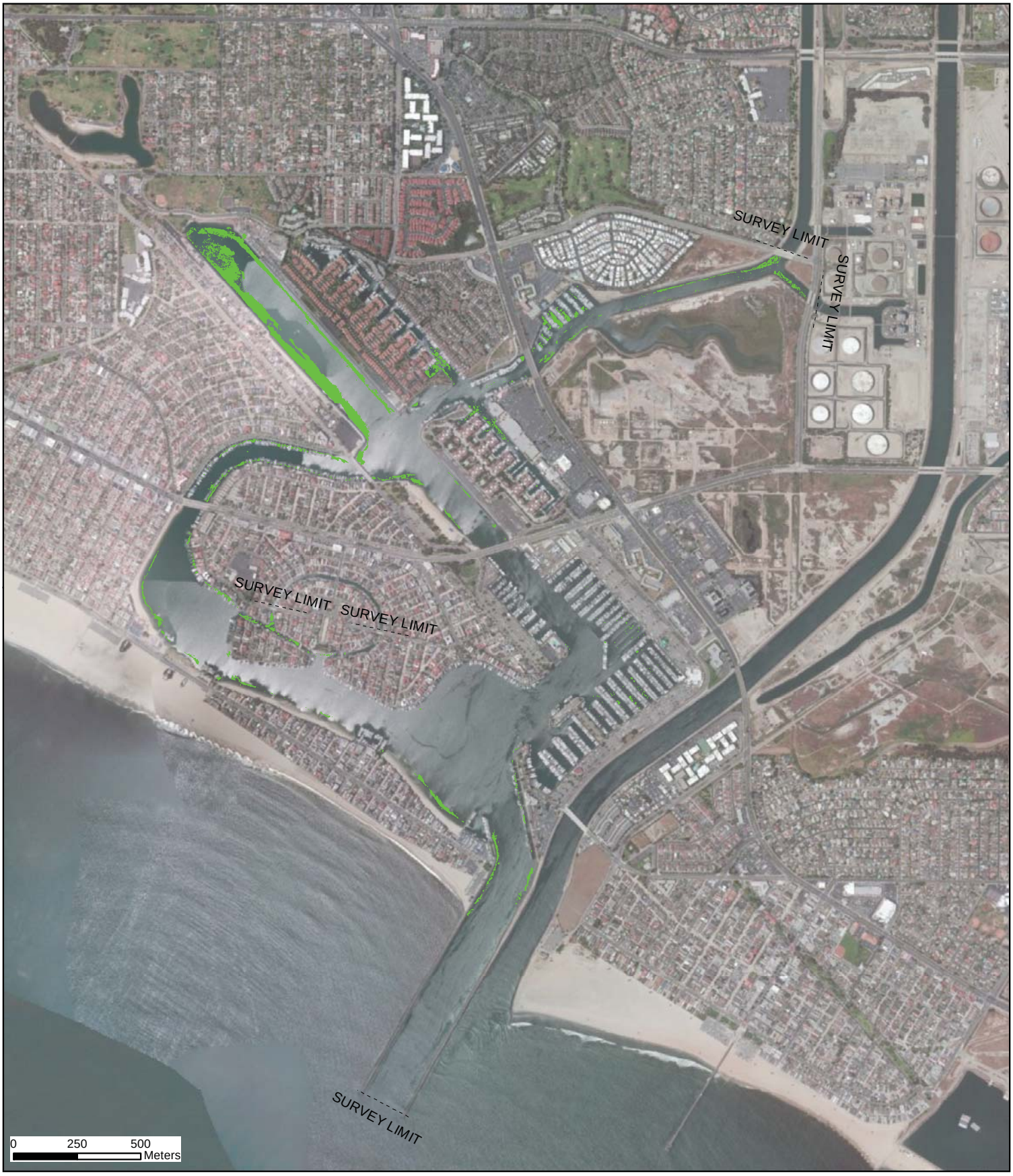
To verify the overall accuracy of eelgrass mapping, 200 points throughout the southern portion of Anaheim Bay/Huntington Harbour were selected at random and were examined by drop camera. The area was determined to support eelgrass or not support eelgrass based on the camera examination of the point. The coordinates of the individual drops were subsequently compared to the mapping of eelgrass to determine the number of times an error in classification occurred where an areas was either identified as supporting eelgrass when it did not, or an area was identified as not supporting eelgrass when it actually was determined by video to actual support eelgrass. The 200 points was selected and sampled *a priori* to the comparative test, as it would provide an expected classification error percentage by half a percent steps.

SURVEY RESULTS

ALAMITOS BAY

Alamitos Bay is a moderate sized recreational embayment within the City of Long Beach. The bay has been constructed by excavation and filling of lands that were historically the estuary of the San Gabriel River, which has subsequently been channelized to the south of Alamitos Bay. The bay has a maximum channel depth of approximately -15 feet MLLW, with much of the bay being much shallower having been excavated to serve recreational crafts. At present, the primary fluvial input to the bay is from the Los Cerritos Channel. The Channel enters from the north, and due to its principally urban setting, conveys relatively little sediment to the Bay. Smaller drains convey local run-off to the bay through a number of local storm drain outlets. Unique within the Bay is the cooling water intake for the Alamitos Generating Station. The generating station pumps water from the lower Los Cerritos Channel in upper Alamitos Bay for condenser cooling. Water is subsequently discharged to the San Gabriel River estuary. This results in a net increase in circulation of tidal water into the inner portions of Alamitos Bay over that which would occur without the power plant. Over 90 percent of the shoreline of the bay is armored with revetment stone or bulkheads such that only a few beach areas occur within the bay.

A total of 386.7 acres of the bay were surveyed for eelgrass. This constitutes all tidal waters within the bay proper that could be reached by the survey vessel. Areas excluded from the survey were the 2.2-acre Rivo Alto Canal around Naples Island north of The Toledo and 24.6 acres of tidal waters of the El Cerritos Channel above the Loynes Drive Bridge. The surveyed Alamitos Bay supported 23.3 acres of eelgrass, or 6 percent of the bay bottom supported eelgrass (Figure 2). The most significant occurrence of eelgrass was found within the Marine Stadium, however scattered eelgrass was present within a number of marinas and around private docks. A surprising amount of eelgrass was found to extend up the Los Cerritos Channel. This extent of eelgrass is likely partially related to the draw of cooling water up the channel since low circulation often limits eelgrass presence within the upper portions of dead end channels and basins.



Alamitos Bay - Eelgrass 2013

Southern California Bight Regional Eelgrass Surveys

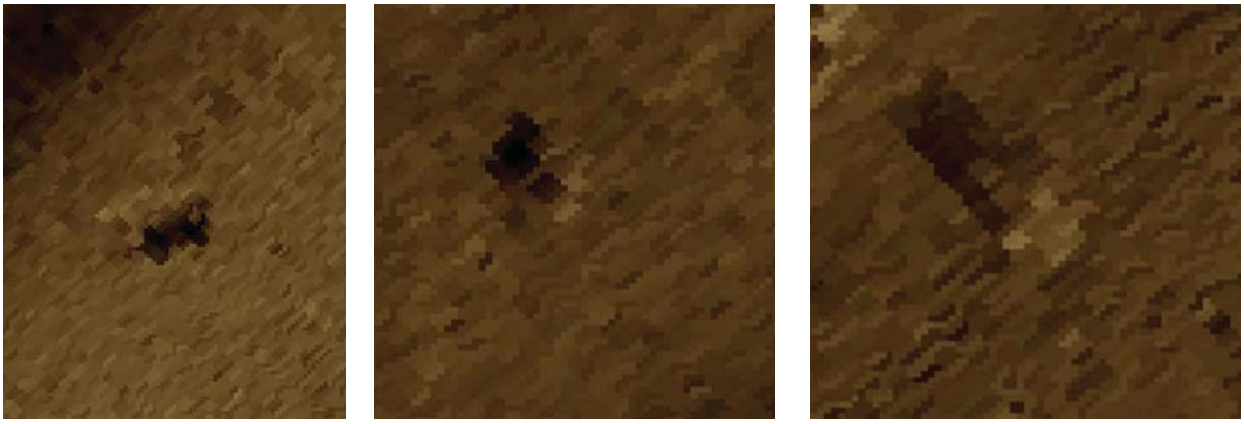
Figure 2

San Gabriel River

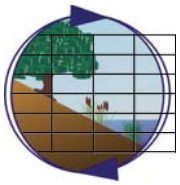
The San Gabriel River flows for almost 61 miles through southern Los Angeles County, California. Its main stem is about 43 miles long, while its farthest tributaries extend almost 18 miles. The tidal estuary of the San Gabriel River extends along a typically bank armored channel parallel to the easterly edge of Alamitos Bay. The tidal estuary extends approximately 4.0 miles inland to an elevated concrete lined channel that transitions down a rip rap slope to a soft bottomed channel. The tidal waters survey area extends from the non-tidal concrete channel section north of Interstate 405 to the open beach east of the easterly jetty of the Alamitos Bay entrance channel (Figure 3). The channel is crossed by five roadway bridges and a pipeline bridge, the cooling water discharges from the Alamitos Generating Station and the Haynes Generating Station both flow into the estuary The San Gabriel River estuary within the same segment between the East 2nd Street and East 7th Street (State Route 22) bridges. The sampling area included 153.2 acres of tidally influenced waters. No eelgrass was present within the surveyed area (Figure 3). It is somewhat surprising that eelgrass was not found in the San Gabriel River given the observed conditions, and it is anticipated that a transplant of eelgrass to the estuary would have a good potential for success in the vicinity of the Pacific Coast Highway bridge and southward towards the Marina Drive bridge.

For the San Gabriel River, the survey objectives included mapping the bottom habitats beyond the distribution of eelgrass. The benthic substrate on the estuary bottom consists of a mix of unvegetated soft bottom, mixed rubble/soft bottom, rubble/hard bottom, and engineered structures (pile butts, discharge structures, bridge abutments). Scattered debris also occurs on the bottom of the estuary, and an intertidal sand beach occurs near the mouth of the estuary on the easterly side of the channel near the open coast. Appendix 1 provides a habitat map of the San Gabriel River estuary that identifies the various features on the floor of the estuary.

The uppermost portion of the estuary supported extensive mats of cyanobacteria on the channel floor and fringing brackish marsh vegetation on the channel edges. Further downstream, more persistent marine influences began to dominate near the 7th Street Bridge and burrowing anemones and limited evidence of other burrowing organisms began to be observed on a barren mud bottom. Further down the estuary, marine influence is very pervasive and the bottom exhibits visual characteristics similar to those observed in the outer embayment entrance channels. Notable observations within the river were as many as eight to ten green sea turtles with some of the turtles being very clearly identified during the initial survey pass. The detection of turtles by sidescan sonar may provide a tool to support capturing turtles for tracking studies.



Images of turtles captured using interferometric sidescan sonar in San Gabriel River, October 19, 2013



San Gabriel River - Eelgrass 2013

Southern California Bight Regional Eelgrass Surveys

Figure 3

ANAHEIM BAY/HUNTINGTON HARBOUR

Anaheim Bay/Huntington Harbour is a semi-developed embayment historically developed within wetlands associated with the San Gabriel River estuary complex. The northerly portion of the wetland complex supports Naval Weapons Station (NWS) Seal Beach and includes both a deep-water navigation area at the NWS harbor and an expansive coastal salt marsh complex on the Station that has been designated as the Seal Beach National Wildlife Refuge (NWR). Large tidal ponds at the inner portions of the NWR were developed several years ago to serve as mitigation for Port development. These muted tidal ponds now host considerable shallow water marine habitat in the upper marsh and increase the tidal prism and circulation of marine waters through the marsh channels of the NWR.

To the south of NWS Seal Beach is the intensively developed Huntington Harbour. Huntington Harbour is comprised of a complex of narrow channels that are lined with bulkhead walls that support residential development. Private docks and a limited number of small marinas line the channel system. Bulkhead walls typically extend to a mud buttress that subsequently slopes further downward to the channel floor such that water depths along the bulkheads are shallower than the centers of the channels.

The limits of the eelgrass survey within the system were set by bridges and barriers that precluded full survey of all tidal waters. Surveys extended up the Bolsa Chica Channel to the Edinger Avenue Bridge. The Warner Avenue Bridge separating Huntington Harbour from outer Bolsa Bay was the southerly end of the survey area. There are two tidal ponds located at the northerly edge of Huntington Harbour that are separated from the harbor by submerged culverts that were not surveyed. A minor amount of eelgrass is known to occur in the unsurveyed lower portion of Bolsa Chica Channel and within outer Bolsa Bay. In addition, the Huntington Harbour ponds were the primary location of a prior infestation of *Caulerpa taxifolia* that was eradicated between 2000 and 2006, and as such, have been intensively investigated in prior years (Merkel & Associates 2006). Eelgrass is known to exist within these ponds, but occupies limited portions of the bottom.

The eelgrass survey area covered an area of 800.7 acres. Within the survey area, 89.2 acres of eelgrass were mapped (Figure 4). This constituted 11 percent of the surveyed area. A total of 91.3 percent (81.4 acres) of the eelgrass mapped within the system is located in northern Anaheim Bay within NWS Seal Beach outside of the developed channel system of Huntington Harbour, which supports 8.7 percent (7.8 acres) of the 2013 eelgrass mapped in the system.

Anaheim Bay/Huntington Harbour – Eelgrass 2013

Southern California Bight Regional Eelgrass Surveys

Figure 4

AGUA HEDIONDA LAGOON

Agua Hedionda Lagoon is located in the city of Carlsbad in San Diego County. The lagoon has three basins referred to as the outer lagoon, middle lagoon, and inner lagoon. Historically, the lagoon was a shallow flooded river valley supporting extensive tidal wetlands. In the middle of the 20th century, Agua Hedionda Lagoon was dredged to a shallow embayment to serve as a cooling water supply for the Encina Power Station (EPS), constructed in 1954. Cooling water for the EPS is drawn from the outer lagoon for once through cooling and discharged to the open coast south of the lagoon mouth. With the cooling water need, the lagoon was permanently opened to the ocean through a stabilized inlet geometry defined by two short jetties. The lagoon is now fully tidal throughout all basins.

Because of the intake to the facility, maintenance of good tidal circulation and an available pool of cool marine water is essential to the EPS; and as such, a regular maintenance dredging program occurs within the outer lagoon on a biannual cycle. In the early 1990s the maintenance dredging boundaries within the outer lagoon were established and eelgrass occurring within the maintenance dredging area was mitigate to ensure an ongoing capacity to dredge within the established footprint without requirement for recurrent mitigation. In 1998, SDG&E, then owner of EPS and the majority of the lagoon, conducted its first lagoon-wide rehabilitation dredging in all basins to restore the essential capacity to maintain available cooling water volume for the power plant in the event of a complete or partial inlet closure. As elements of the work, flood tide shoals in all basins were removed from areas adjacent to the bridge constrictions, and a deep sediment basin was excavated in the inner lagoon to accept fine sediments that had accreted since the initial lagoon construction. Sand from the basin excavation was pumped to the beach, and fine sediments from the restoration of the original 1950s dredge depths were deposited in the excavation and the basin was then capped. At the east end of the lagoon, a large in-bay sediment trap was dredged at the end of Agua Hedionda Creek to curb the amount of fluvial sediment entering that end of the lagoon. Eelgrass impacts occurred with the restoration, and these impacts were mitigated by large eelgrass restoration plantings within the east basin. Agua Hedionda eelgrass has been partially inventoried over the past three decades in association with EPS activities. Further, the intensive *Caulerpa* eradication undertaken here from 2000-2006 also provides insight into lagoon eelgrass dynamics (Merkel & Associates 2006).

The shallow depths within the lagoon and maintained inlet condition within the lagoon are ideally suited to support eelgrass. At the east end of the lagoon, the bottom depth gradually ramps up to shallower elevations, and the wind fetch across the water results in development of conditions that support regular presence of afternoon bottom feeling waves. As a result of the combination of recurrent sediment loading and regular wave suspension of deposited sediment, high turbidity persists in the back of the lagoon. The high turbidity limits eelgrass to the westerly portion of the lagoon. Periods of drought, that curtail sediment loading, have historically allowed eelgrass to extend further back in the lagoon; however, eelgrass has never been abundant in the eastern portion of the bay.

The eelgrass survey area covered an area of 247.8 acres and included all depths suitable to support eelgrass present within the lagoon, except those along the narrow channel of Agua Hedionda Creek that enters the lagoon at the far eastern end. Historically, this creek has not supported eelgrass and is not expected to support eelgrass at this time. Within the survey area, 43.1 acres of eelgrass were mapped (Figure 5). Eelgrass occurs in 17 percent of the surveyed area.

Agua Hedionda Lagoon - Eelgrass 2013

Southern California Bight Regional Eelgrass Surveys

Figure 5

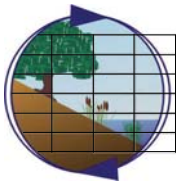
BATIQUITOS LAGOON

Batiquitos Lagoon is located in the city of Carlsbad. The lagoon is permanently open to the ocean through a stabilized inlet defined by two short jetties. Like Agua Hedionda Lagoon, Batiquitos Lagoon is geologically a flooded river valley. It has been divided into three basins by causeway fills and bridge crossings. The west basin is defined by the inlet crossing of Carlsbad Boulevard and the North County Transit District railroad trestle, the central basin is bounded by the railroad trestle and Interstate 5, and the east basin is defined by Interstate 5 and the terminal end of the lagoon at El Camino Real. The lagoon had deteriorated to a seasonally closed eutrophic system over the early and mid-20th century. Tidal circulation and lagoon depths were restored over a multi-year period as a Port of Los Angeles mitigation project to offset harbor fills in San Pedro Harbor. In 1996, the lagoon was opened to continuous tidal action.

Cordgrass and eelgrass were introduced into the lagoon through a pilot transplant program undertaken in 1997-1998. The eelgrass planting was conducted in September and October 1997, with four additional plots added in August 1998. Donor eelgrass was harvested from Mission Bay, San Diego Bay, and Agua Hedionda Lagoon. Fifteen plots, totaling approximately 0.38 acre, were planted across all three basins (Merkel & Associates 2009). From 1998 to 2006, eelgrass coverage was monitored and reached a maximum extent in 2003 at 103.97 acres. However, wide fluctuations in acreage have occurred; principally notable was the 32 percent decline in eelgrass in 2005 that was also observed to have occurred in Agua Hedionda Lagoon. This decline was localized within the central basin, and it is believed to have been related to an extremely strong and persistent red tide that occurred during the summer of 2005 (Merkel & Associates 2009).

Eelgrass in the lagoon occurs at a perched elevation as a result of tidal muting. This means the elevation range for eelgrass is higher than would typically occur in an unmuted system. While the typical upper elevation of eelgrass in southern California is at +0.5 to 0.0 feet MLLW, depending on a variety of factors, eelgrass in Batiquitos Lagoon extends to elevations of approximately +1.5 feet MLLW in the east basin where low tide drain-out is substantially constrained by inlet shoaling. With recurrent maintenance dredging that is essential to sustain the overall habitat quality of the lagoon, eelgrass is pushed lower down the slopes of the eastern basin through desiccation stress. Accumulating fine sediment within the east basin is shallowing the basin to the extent that some areas that historically supported eelgrass in 2003 no longer support eelgrass due to being too shallow a decade later. Most specifically is the northern cove at the end of Gabianno Lane that has filled with sediment and no longer supports depths suited to support eelgrass. Conversely, some areas of the more easterly channels have silted in to shallow depths that now support eelgrass. Over time, the east basin sedimentation dynamics and inlet shoaling will continue to effect eelgrass, with the ultimate effect of declining tidal prism being a reduction of eelgrass system-wide. At the present time, this expected change has not manifested.

The Batiquitos Lagoon eelgrass survey area covered an area of 258.5 acres including all depths suitable to support eelgrass that are present within the lagoon. Within the survey area, 122.5 acres of eelgrass were mapped (Figure 6). This constituted eelgrass occupancy of 47 percent of the surveyed area.



Batiquitos Lagoon - Eelgrass 2013

Southern California Bight Regional Eelgrass Surveys

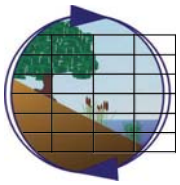
Figure 6

San Dieguito Lagoon

San Dieguito Lagoon is located in the cities of Del Mar and San Diego in San Diego County. Like the other northern San Diego County lagoons, it is geologically a flooded river valley. The lagoon has historically been heavily influenced by the large San Dieguito River, which flowed through a narrow gorge prior to discharging onto the low lying coastal plain. As a result of a combination of natural geomorphic processes and filling of the wetland margins, the lagoon had been diminished to a small coastal marshland near the lagoons non-stabilized inlet and a transitory salt marsh along a moderately incised river channel. Alkali pannes along the river margins supported coastal salt marsh as a result of a combination of overbank flooding during large river flows into an intermittently closed lagoon coupled with high groundwater salinity due to the influence of marine groundwater and agricultural irrigation and natural mineral conditions. In 1983, an approximately 70-acre basin was dredged on the southern margin of the lagoon to create tidal and subtidal habitat and to increase tidal prism. However, the inlet continued a sequence of intermittent closures and variable degrees of tidal opening.

In 2011, the San Dieguito Lagoon Restoration Project was principally completed by Southern California Edison as a component of the mitigation for San Onofre Nuclear Generating Station once through cooling water impacts. The $90 million project restored approximately 150 acres of the lower valley to tidal influence, including expansion of subtidal habitats along the river and various slough basins. An element of the restoration was maintenance of a fully open tidal inlet condition. The expanded tidal area and assured inlet condition provided a suitable environment to support eelgrass restoration. Over the past decades, a small amount of eelgrass has been present in the 70-acre basin constructed in 1983, and occasionally eelgrass and widgeon grass (*Ruppia maritima*) have occurred in the channel near San Dieguito Drive. However, eelgrass expansion in the lagoon was substantively marked following the larger restoration project. In approximately 2010, a directed planting was performed by harvesting material from the southerly channel ahead of dredging and transplanting the harvested material into the new large subtidal basin located west of Interstate 5. Over the next three years, this transplant has burgeoned and combined with natural seedling establishment, the subtidal portions of the recently constructed basin has nearly filled with eelgrass.

The San Dieguito Lagoon eelgrass survey area covered an area of 111.2 acres including all depths suitable to support eelgrass that are present within the lagoon. Within the survey area, 31.9 acres of eelgrass were mapped (Figure 6). This constituted eelgrass occupancy of 29 percent of the surveyed area.



San Dieguito Lagoon - Eelgrass 2013

Southern California Bight Regional Eelgrass Surveys

Figure 7

CONCLUSIONS

SUMMARY OF SURVEY RESULTS

The results of the 2013 eelgrass surveys conducted under this inventory effort are summarized in Table 2. In total 310 acres of eelgrass was mapped within the 1,958 acres of survey area.

Table 2. Eelgrass Coverage by System

System	2013 Survey Area (Acres)	2013 Eelgrass Coverage (Acres)	Percent Eelgrass of Total System Area
Alamitos Bay	386.7	23.3	6%
San Gabriel River	153.2	0.0	0%
Anaheim Bay/Huntington Harbour	800.7	89.2	11%
Agua Hedionda Lagoon	247.8	43.1	17%
Batiquitos Lagoon	258.5	122.5	47%
San Dieguito Lagoon	111.2	31.9	29%

Overall, the extent of eelgrass in each system is not surprising, except for the absence of eelgrass from the San Gabriel River estuary. Long-narrow channelized rivers that serve primarily as flood control facilities, such as the Los Angeles River and Ballona Creek, often lack eelgrass. However, in many areas where the river mouths are shallow and experience littoral sand accumulation, eelgrass is often present in beds that fluctuate substantially in location and scale (e.g., Santa Ana River, San Diego River, Sweetwater River). The San Gabriel River supports several shallow sand benches that would appear suited to support eelgrass, in the event establishment of eelgrass beds in the river were desirable.

GROUND-TRUTHING RESULTS

Two major questions that have been raised regarding eelgrass mapping using sidescan sonagraphic techniques relate to the overall accuracy of mapping and distinguishing eelgrass from other benthic habitat features and the effectiveness of sidescan sonar relative to other mapping tools.

Investigations specific to answering the first question were conducted in Mission Bay in 1988 (Merkel 1988) by using 254 widely distributed diver transects to classify benthic habitat as either supporting eelgrass or not supporting eelgrass and to identify species present in various portions of the bay. The point at which a diver started was determined to support eelgrass, or lack eelgrass, and the remainder of each 300-foot long transect was used to inventory typical marine species in the area. This sampling revealed a 94 percent accuracy in the classification of eelgrass and positional placement. The 1988 investigation pointed out that error is highest in patchy eelgrass occurrence due to positional accuracy of the navigation and sonar system and mapping, and error is extremely low in expansive beds where positional error is less of a factor. Notwithstanding a relatively high accuracy compared to other mapping tools of the time, it is important to note that in the 1988 survey, all of the survey technologies employed were rudimentary in comparison to today's standards. Vessel navigation was achieved by microwave triangulation positioning system with a position update rate of 0.1Hz using microwave transponders that were set on the roof tops of three large hotels. The sonar operated at 100 kHz and recorded to an analog paper chart recorder that was manually annotated with fiducial marks for subsequent manual interpretation

and scaled transfer to a vessel centerline plot. Error was estimated as the combined total of transponder positioning, microwave range accuracy, vessel position between 10-second position updates, towfish layback and motion, sonar error, and manual registration and interpolation error. Combined, the error in such mapping could be many meters as an absolute error and ±3 or more meters as a relational error. With current technology, differential dual antenna GPS, 468 kHz hull mounted interferometric sonar, integrated motion and speed of sound adjustments, and digital mosaicking software has allowed the reduction of error to ±1-2 meters as an absolute error, even in tight mapping areas where non-fixed towfish can still generate high error values.

As a result of the findings of the 1988 survey, ground-truthing over the past 25 years has focused on problem areas such as around revetment/soft bottom interfaces and debris fields, where high reflectivity of rock, or confounding signatures of *Sargassum* may hamper eelgrass detection. Greater ground-truthing has also been focused on areas of mixed beds of eelgrass and widgeon grass where it is sometimes necessary to identify site and condition specific signatures. Finally, greater ground-truthing is performed where there is a lack of hydrographic system familiarity or records of past eelgrass distribution are unavailable. By focusing on areas where classification or positional errors are likely to be made, the ground-truthing effort provides a greater benefit to cost value to the eelgrass mapping effort.

During the course of the current surveys, the question regarding absolute error was posed again. To explore the question of overall accuracy in eelgrass mapping, 200 points throughout the northern portion of Alamitos Bay, including the marine stadium and dock complexes, were selected haphazardly and were examined by drop camera. The area was determined to support eelgrass or not support eelgrass based on the camera examination of the point. The presence/absence of eelgrass determined during the individual drops were subsequently compared to the mapping of eelgrass to determine the number of times an error in classification occurred where an areas was either identified as supporting eelgrass when it did not, or an area was identified as not supporting eelgrass when it actually was determined by video to actual support eelgrass. The 200 points were selected and sampled *a priori* to the comparative test as it would provide an expected classification error percentage by half a percent steps. A total of 23 points supported eelgrass with the remaining 177 points lacking eelgrass. The post-collection analysis determined that no classification errors were made. This resulted in a 100 percent accuracy estimate; however, experience and common sense would support the fact that errors are made. When taken as a whole, error rate in mapping eelgrass on a system-wide basis would be expected to be extremely low using modern interferometric sonar. This is because of a variety of factors including the advanced high resolution technology, surveyor experience with interpretation of sonar records, the naturally limited extent of area that are considered complex within southern California bays and estuaries, and the limited number of mixed seagrass or similar signature habitat features.

Notwithstanding the low error potential in system wide mapping, it should be remembered that most areas that are surveyed for project level analyses occur within the more complicated shoreline margins and areas where tight survey quarters can introduce error into any survey methodology, including interferometric sidescan sonar, that has largely resolved most of the precision and accuracy constraints of other methods, including standard sidescan sonar.

The second question of how the methodologies employed in this survey compare to other techniques available. This question was partially addressed in the regional eelgrass monitoring

program recommendations document (Bernstein, *et al.* 2011). In this document, it was demonstrated that inferential survey methodologies such as diver transect surveys and single-beam sonar surveys can substantially overestimate eelgrass presence and coverage with errors on the order of 20-40 percent, while aerial photography alone can substantially underestimate eelgrass at deeper depths with the magnitude of error being dependent upon transparency through the water column among other factors such as photographic resolution and geo-rectification. The 2011 regional eelgrass monitoring recommendations document suggests utilizing multiple tools as most appropriate methods for completing monitoring. This hybrid methodology was employed very effectively in the 2009 baywide San Francisco Bay eelgrass using combined aerial photography with sidescan sonar (Merkel & Associates 2010).

In the current survey, eelgrass was mapped using multiple tools and ground-truthed using multiple direct observation techniques. In some instances, considerable overlap in mapping techniques was possible where low-elevation aerial photography was performed in areas that were subsequently surveyed by interferometric sidescan sonar. While the relative accuracy of the two methodologies was not directly compared, the agreement in mapping results between the two methods was examined qualitatively. This comparison indicated that near the practical depth limits for mapping from aerial photos, small voids in eelgrass beds are missed. In deeper lagoons such as Agua Hedionda, the depth and turbidity levels prevented use of aerial photographic mapping to full survey depth, so no effort was made to map beyond the lagoon margins using aerial photographs. With progressively shallower depths, the clarity of boundaries in aerial photographs increased and consistency between survey methodologies also increased with both methods distinguishing gaps in the eelgrass beds. However, due to the dark coloration of much of the detritus within gaps, there was always greater error associated with missing gaps derived from using aerial photographs than interferometric sidescan sonar.

While mapping agreement between surveys was generally very good in areas where aerial photograph clarity allowed, interferometric sidescan survey had an inherently higher resolution than photographs at a processed pixel size of 0.0625 m^2 for interferometric sonar versus a 0.25-m^2 pixel size for the photography. This meant that boundary conditions were more precisely mapped using the sidescan than the photographic survey methodologies. While there were detectible differences in the mapping, a conscious effort was always made in the mapping effort to utilize the most accurate techniques available where overlap in the surveys existed and in all cases the mapping resolution and accuracy was appropriate to the regional inventory applications for which the surveys were conducted.

LIMITATIONS ON SURVEY APPLICATIONS

The completed surveys are intended to provide a benchmark survey condition against which subsampling surveys in accordance with the 2011 regional eelgrass monitoring recommendations may be used to track trends in eelgrass on a system segment, system, and regional basis. The surveys have been conducted for resource monitoring and management purposes in a regional context. The surveys are not suited to application in project specific impact evaluations. Application of such surveys to this purpose may over or underestimate eelgrass within project areas. For this reason, users of this document are strongly cautioned regarding the applicability of the data for purposes beyond the intended use.

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APPENDIX A: SAN GABRIEL RIVER ESTUARY HABITAT MAPPING

Benthic Habitat Map
San Gabriel River Estuary

Within the San Gabriel River Estuary, surveys were conducted using interferometric sidescan sonar to identify and map eelgrass habitat. A drop video camera was used to ground-truth the mapping effort. No eelgrass was identified within the estuary, but several benthic features were identified and mapped in the system. These are as follows:

Intertidal Sand Beach – Littoral sand deposits to elevations above the lowest tides. These are found near the mouth of the river and are derived from beach sand being moved into the river estuary by tides and waves and being built to intertidal elevations by the force of waves that penetrate past the river inlet.

Unvegetated Soft Bottom – Unvegetated soft bottom includes sand bottom habitat that occurs in the river mouth and extends into areas upstream of Marina Drive, as well as mud and silt bottom habitats that dominate the benthic habitats throughout the remainder of the estuary.

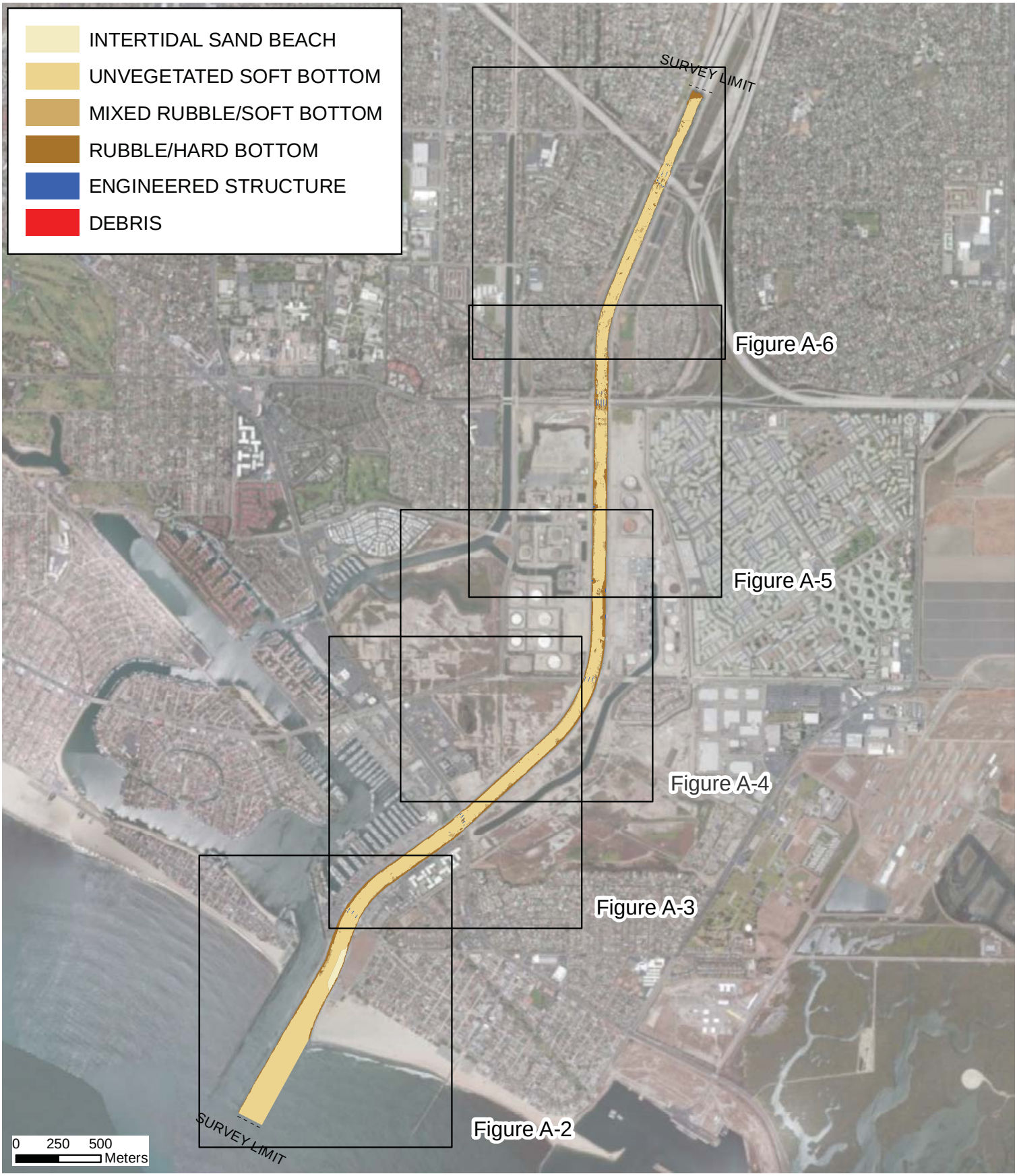
Mixed Rubble/Soft Bottom – This habitat is found at a number of locations where rubble from revetted banks, as well as energy dissipation and scour protection features, transition to soft bottom in a manner that makes separation of the hard and soft bottom habitat impractical. In some instances, the source of rubble on the bottom is not completely clear. Most of the rubble encountered is comprised of concrete; however, various chunks of asphalt and quarried rock were noted in the material.

Rubble/Hard Bottom – This habitat is principally associated with the channel banks and toes to the banks. There is a greater extent of rubble/hard bottom in areas near the discharge points from the two power plants. Rubble includes the material identified previously but includes considerable quarried rock, whereas the material that is loose and away from the structured bank revetment tends to hold less rock and more concrete rubble.

Engineered Structures – Engineered structures describes features that have been placed in the estuary channel to serve a particular function. This habitat includes current bridge abutments as well as driven wooden piles that no longer support bridges over the estuary. Structures also include outfall structures from the channel edges or emerging from the channel floor near the banks, as is the case with some of the cooling water discharge points.

Debris – Debris includes miscellaneous hard structures that are not associated with bank or scour protection or engineered structures. These include such objects as shopping carts, a small open skiff, instrument and navigational aid moorings, and various unidentified objects.

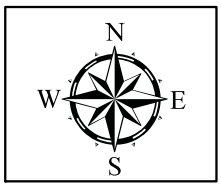
As previously discussed, the generally barren channel bottom provided a surprising backdrop over which green sea turtles could be detected with some regularity by sidescan sonar. The density differences between turtles and the bottom and between turtles and rock or rubble, provided an unexpected ability to locate turtles in the sonar record and could potentially provide a means to complete targeted turtle capture efforts.



San Gabriel River - Habitat Classification

Southern California Bight Regional Eelgrass Surveys

Figure A-1



San Gabriel River - Habitat Classification

Southern California Bight Regional Eelgrass Surveys

Figure A-2

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San Gabriel River - Habitat Classification

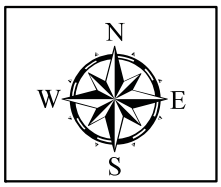
Southern California Bight Regional Eelgrass Surveys

Figure A-3

San Gabriel River - Habitat Classification

Southern California Bight Regional Eelgrass Surveys

Figure A-4



San Gabriel River - Habitat Classification

Southern California Bight Regional Eelgrass Surveys

Figure A-5

San Gabriel River - Habitat Classification

Southern California Bight Regional Eelgrass Surveys

Figure A-6