San Elijo Ocean Outfall
2017 Annual Inspection Report

Prepared for San Elijo Joint Powers Authority
Cardiff by the Sea, CA
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PROJECT SUMMARY

Undersea Graphics, Inc. (UGI) performed the Year 2017 San Elijo Ocean Outfall annual inspection at the request of the San Elijo Joint Powers Authority (SEJPA), completing the requested work with two separate inspections which were performed in July 2017 and inshore diving in December 2017. UGI has been in the outfall inspection industry since the 1950's. In 1969 UGI launched its first manned submersible. And then in 1981 UGI launched its support vessel Mother Goose. UGI is committed to providing thorough inspections of underwater outfalls, which include HD video and pictures of the pipeline. The inspection involved piloted submersible examination of the outfall from the end of the ocean outfall structure (End Structure, Station 81-00) to Porthole #3 (Station 27-00) and then diver examination from Porthole #3 (Station 27+00) to the beach where the pipe becomes buried under sand (Station 8+00). The inspection included evaluation of exposed portholes, evaluation of cathodic protection at exposed anodes, a pile support survey, kelp clearing, and a multibeam survey with generated pipeline cross sections.

Photo and video documentation were collected along the entire outfall. The purpose of the inspection was to look for evidence of spalling of the exposed concrete surfaces, cracks or other signs of wear or degradation of the outfall structure. This includes inspecting joint integrity for leaks or evidence of degradation, inspecting diffuser flow, evaluating for other potential hazards and checking attrition or the loss of efficacy of the pipe ballast material.

In general, the San Elijo Ocean Outfall was found to be in excellent overall condition. All areas of the pipeline were stable and the ballast showed minimal signs of movement based on the diver and multibeam data. The outfall showed no signs of spalling, rust staining, or cracking and there was no leakage detected from pipe joints or any other locations on the outfall. Anodes on the exposed manholes were in good condition and have greater than 50% remaining life expectancy. The pile support section of the outfall was about two-thirds buried with sand. All exposed metallic structures are currently protected.

FORWARD

The San Elijo Ocean Outfall was commissioned in 1965 to discharge treated effluent from the San Elijo Water Reclamation Facility (formally known as the San Elijo Water Pollution Control Facility). In 1974, the Hale Avenue Resource Recovery Facility was connected to the original outfall structure, and the outfall was extended to its current length of 8,000 feet. Given environmental regulations regarding discharges into marine waters and increasing demands on the infrastructure over the past 5 decades, it has been imperative that the pipeline be maintained and monitored for potential damage or required maintenance. To this end, the San Elijo Joint Powers Authority (SEJPA) has contracted numerous surveys of the outfall pipeline. This report presents the results of the 2017 annual survey performed by Undersea Graphics, Inc. (UGI). Given the large volume of information collected during previous monitoring events, it would be inappropriate to compile this report without including data and information presented in previous reports. For this reason, some of the language, figures, and data presented in this report originated from previous monitoring reports prepared for the SEJPA. The contribution of numerous individual Thales reports are acknowledged here but are not cited in this document. The reports and their contents are the property of the SEJPA.

INTRODUCTION

The SEJPA contracted UGI to complete the Year 2017 San Elijo Ocean Outfall annual inspection. Diving operations were conducted in July 2017 and December 2017. Data analyses immediately followed the field effort. The inspection effort included the following elements:

- General diver overview inspection of the outfall from the end structure to burial inshore attentive to the following criteria: Evidence of spalling of the exposed concrete surfaces, cracks or other deficiencies in the outfall, joint integrity, leaks or evidence of degradation, potential hazards, attrition or the loss of efficacy of the ballast material as a result of physical, biological, or geological processes, scouring of the nearby marine sediments, and manmade debris and marine life;
- Inspection of portholes;
- Evaluation of cathodic protection at exposed anodes;
- Clearing kelp that hindered inspection activities or threatened the ballast material;
- Photographic and video documentation;
- Pile support inspection;
- Multibeam survey of the entire outfall structure; and
- Generation of cross sections from the multibeam data every 100 feet starting from Station 8+00.

Procedures, results, analyses, and implications are reviewed here for all elements comprising this project. This report also contains background information regarding the San Elijo Ocean Outfall and a discussion of oceanographic processes (Appendix A) that could affect its structural integrity. Digital video and still images support written descriptions. Full copies of the video records are included on a thumb drive with this report.

Outfall Configuration

The San Elijo Ocean Outfall carries treated secondary effluent from the San Elijo Water Reclamation Facility and the Hale Avenue Resource Recovery Facility. It is then transported through the outfall and discharged into the ocean; the discharge is approximately one-and one-half miles from shore at an approximate water depth of 150 feet. The general location of the outfall is shown in Figure 2.

Construction of the original San Elijo Ocean Outfall was completed in 1965. It consisted of a 30-inch internal diameter reinforced concrete pipeline terminating approximately 4,000 feet offshore. Effluent was discharged through two diffuser legs at a water depth of 60 feet below the Mean Lower Low Water (MLLW) datum. In 1974, the outfall was extended to a water depth of 150-feet MLLW, approximately 8,000 feet offshore using 48-inch internal diameter reinforced concrete pipe. The diffuser ports in the original 30-inch diameter line were blocked with fiberglass covers at the completion of the extension. Effluent is presently discharged through a single 1,176-foot long diffuser section that is composed of two hundred individual two-inch nominal diameter diffuser ports at the end of the 48-inch extension.

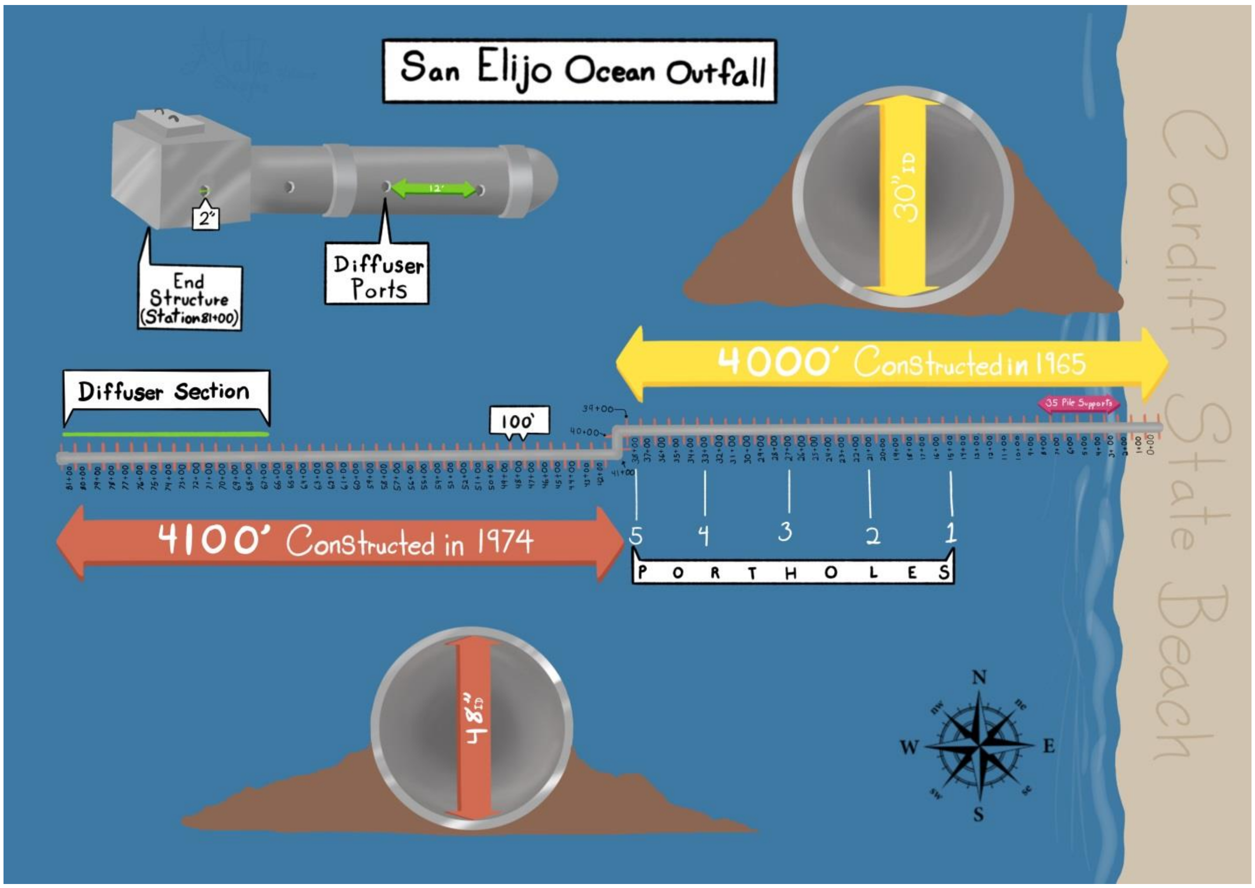


Figure 1. San Elijo Ocean Outfall

Several projects have been executed to keep the outfall in a stable, clean, and efficient operating condition. Reballasting projects were conducted inshore of the 55-foot isobath in 1982, 1987, 1993, 1996 and 2005 to replace ballast that had been moved away from the outfall by ocean processes. The erosion of beach sediments from the shoreline, which is occurring all along the southern California coast, has caused exposure and undermining of the most inshore portion of the outfall that was previously buried well beneath the beach sand. To secure this vulnerable stretch of pipe, the pipe was clamped to piles driven into the surrounding sediments in the summer of 1992. In late 1993, additional ballast was placed around the pipe between the water depths of 55 and 85 feet. This 1993 reballasting spans the deepest portion of the 30-inch pipe, including the old diffuser section, and the shallow portion of the 48-inch pipe. The new large ballast replenished and augmented the original four-inch quarry rock that was placed around the outfall at the installation of the pipeline. Prior to placing the ballast in 1993, the fiberglass covers that had previously sealed the diffuser ports in the 30-inch leg of the outfall were all replaced by titanium expansion plugs.

The 1996 reballasting project stabilized the inshore zone of the ballast pile where a significant drop in the sand level had caused the ballast to move away from a protective position around the pipe. The zone where the pipeline support transitions from pile/clamp assemblies to rip-rap ballast was significantly enhanced, creating an overlap between the two support systems. In addition, several areas within two hundred feet of this transition that had exhibited low ballast coverage were augmented.

The 2005 reballasting project included the replacement of zinc anodes used to protect metal supports and access ports, replacement of ballast rock that had shifted away from the structure due to ocean currents and wave energy and the cleaning of the diffuser ports at the end of the structure. Construction commenced in September 2005 and was completed by mid-October 2005. More than 7,365 tons of ballast rock was placed along the length of the outfall and the outfall's 200 diffuser ports were cleaned.

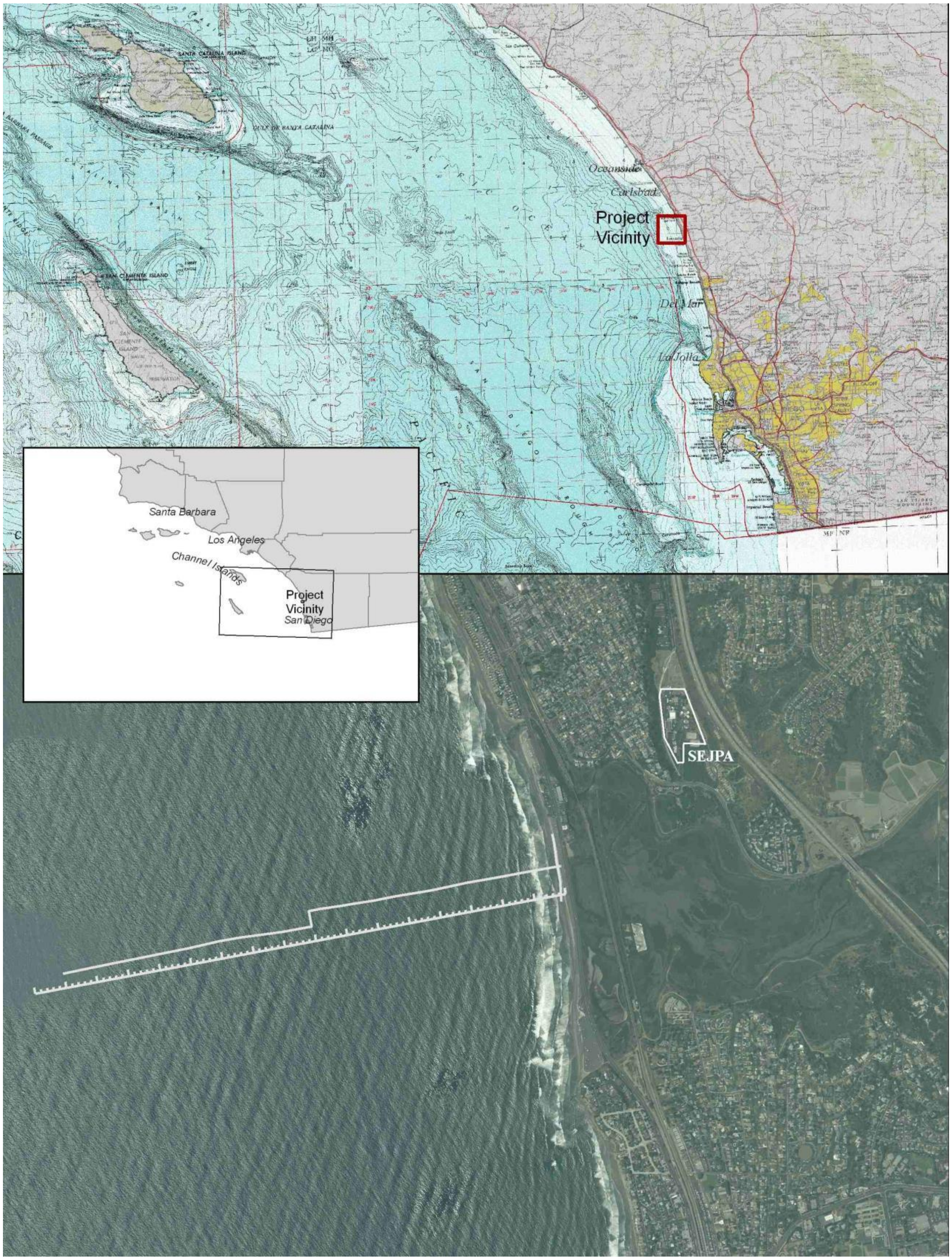


Figure 2. Map displaying San Elijo Joint Powers Authority (SEJPA) location relative to project vicinity

METHODS AND MATERIALS

Undersea Graphics traveled from Los Angeles Harbor in July, 2017 and stayed in Oceanside Harbor while the diving/field work was performed for both San Elijo Ocean Outfall and Encina Wastewater Authority. UGI utilized its custom-built submersible, Snooper 2, for most underwater diving. The submersible allows for extended bottom time at all depths with continuous video documentation and narration. UGI revisited the inshore section of the outfall this December with a smaller towable boat. Generally, dive staff worked from deep water to shallow in the interest of maximizing daily bottom time.

Vessel

Undersea Graphics, Inc. has both a support vessel, the “Mother Goose,” and a 2-man submersible, “Snooper 2.” The “Mother Goose” is a 41-foot, twin diesel workboat/sub tender. The vessel was custom designed to fit the unique needs of being a submarine tender. The vessel is equipped with all essential diving, navigational and inspection equipment.

“Snooper 2,” launched in 2011 as a dry two-man submersible. It is usually occupied by one person. “Snooper 2” keeps its occupants at one atmosphere at all times. When launched it is untethered. It is 14.5 feet in length, 50 inches in width and 60 inches high. It weighs 4500 pounds on the deck and about 40 pounds in the salt water. It has a working depth of up to 600 feet, averaging dives from 2 to 5 hours. The high-power floodlights assist in videotaping where sunlight does not penetrate.

General Diver Inspection

UGI conducted a general overview inspection of the entire exposed portion of the outfall from the End Structure (Station 81+00) to the beach. During operations, diving staff was attentive to the following criteria:

- Evidence of spalling of the exposed concrete surfaces;
- Cracks or other deficiencies in the outfall;
- Joint integrity;
- Leaks or evidence of degradation;
- Potential hazards;
- Attrition or the loss of efficacy of the ballast materials as a result of physical, biological, or geologic processes;
- Grading of ballast according to size as a result of oceanographic forces;
- Scour of the nearby marine sediments
- Man-made debris; and
- Marine life

General pipeline inspection was achieved by piloted submersible. Anywhere below sea level, through water acoustics, the Snooper 2 pilot and those on board the support ship are in constant communication through the 8 kHz and 32.5 kHz hydrophones. The submersible's location is constantly monitored through the Link Quest underwater tracking system by our onboard attendant. When the sub is on the water's surface, communication is conducted through VHF radio. When diving, UGI uses continuous video coverage with a HD Sony NEX-VG10 camera.

Figure 3. Support Vessel Mother Goose

Figure 4. The submersible, Snooper, on deck

Porthole Inspection

A visual evaluation was conducted of the exposed surfaces for mechanical/structural integrity including examination for leaks, fractures, gasket seal integrity, concrete spalling, etc. The sacrificial anodes were inspected for signs of unusual degradation. There are five portholes along the original 30-inch diameter portion of San Elijo Ocean Outfall. These portholes consist of a circular, Niresist plate bolted to a flanged riser. A 5/16-inch thick gasket, composed of neoprene, creates a seal between the cover and the flange. Sacrificial zinc anodes provide cathodic protection to the exposed metallic surfaces of the porthole covers and risers. Portholes 1, 2, and 3 were inspected and are in good condition. Portholes 4 and 5 were covered by a layer of gravel and sand that has moved down from the adjacent ballast rock placed in 1993. Divers in both July and December were unable to locate these portholes due to sand coverage, but inspected the area and saw no abnormalities.

Pile Support Survey

In 1993, thirty-five pile-support assemblies were installed around the pipe between stations 4+41 and 9+69. Piles were driven through the sand to underlying bedrock on both sides of the pipe. Clamps between each pair of pile supports were bolted securely around the pipe and grouted to the piles in pile boxes. Anodes were welded to the pile boxes to provide cathodic protection to the metallic clamps and the piles. In 2005 additional anodes were clamped onto exposed pile supports but broke loose (possibly due to the method of construction). Each year broken or exhausted anodes are replaced. A complete visual inspection of the exposed pile supports was performed with this present survey to check for structural integrity. These piles and the metal pipe shield adjacent to support #35 were all surveyed and found to be cathodically protected and the anodes have enough life expectancy to last through the next annual survey.

Hydrographic Survey

The multibeam hydrographic survey was performed by CLE Engineering, Inc. (CLE). CLE utilized the *S/V Data Cat which* is especially suited for inshore and nearshore survey work. The vessel was totally refitted in 2005 with new engines, gears, shafts, and propellers. All of the electrical, steering and engine control systems were either replaced or rebuilt. Features include surveyor station with swing out monitor and keyboard rack, in hull 200-ohm transducers in both 24 and 200 KHZ, and a large dive platform at the stern. Other notable features include tunneled propellers for reduced draft and full length skegs to protect the propellers. This vessel has its own trailer and is truckable behind a 1-ton pickup. In 2010 all machinery was again upgraded to meet the California Harbor Craft regulations for EPA Tier 2 Engines. The field crew consisted of James Kulpa, Chief Hydrographer (CLE), Mike Campagnone, Certified Hydrographer (CLE) and Kyle Berger, Survey Technician (CLE). The multibeam data was collected with a Kongsberg EM3002 sonar system. The system included the multibeam transducer, the multibeam processor, a ships motion reference unit, RTK-GPS unit, a sound velocity sensor. Data collection occurred on September 28, 2017. Weather during the survey was SW wind 1-5 knots and clear. Depths were referenced relative to Mean Lower Low Water (MLLW) in feet. The horizontal datum was State Plane, Zone 6, in feet. Cross sections were generated from the multibeam data.

RESULTS

General Diver and Deep Inspection

During this inspection, a visual examination of San Elijo Ocean Outfall's reinforced concrete pipeline could only be completed on exposed portions. The condition of the visible portions of the pipeline was generally found to be good. There was no evidence of spalling, cracking or other deficiencies in the concrete pipe. All observed joints were in alignment with no evidence of leaks. There were minimal debris items that could potentially affect the pipeline. There was an abundance of aquatic life found along the pipeline. To the extent possible, the kelp was cleared per the contract to eliminate the threat of continued ballast movement from the considerable buoyancy of the kelp. Finally, there was no evidence of oceanographic impacts to marine sediments or ballast along the pipeline.

Porthole Inspection

Portholes 1, 2, and 3 were inspected. Visual inspection of the portholes revealed the portholes and associated zinc anodes to be in fair to good condition (Figure 3). There were no signs of concrete spalling, leaks, or fractures. Cathodic protection (CP) readings on zinc anodes were also conducted. Data from the 2017 survey, as well as for CP readings from the previous three years of surveys, are presented in Table 1. The areas of portholes 4 and 5 were visually inspected but the portholes themselves were not located due to sand buildup in this area. Again, there were no signs of concrete spalling, leaks, or fractures in these areas. Two numbers in the "% Estimated Remaining Anode Mass" column indicate that two anodes are connected to a single porthole.

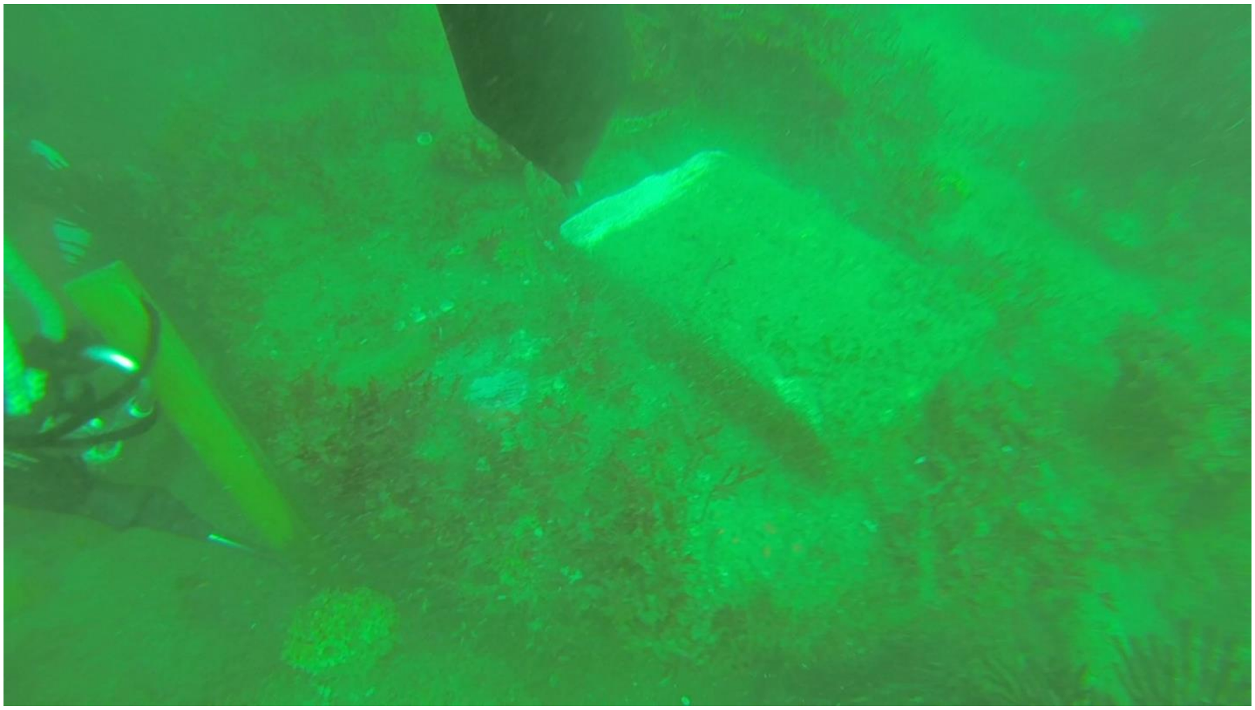


Figure 5. Porthole cover with zinc with approximately 90% remaining life expectancy.

Table 1. Cathodic protection (CP) readings and associated % estimated remaining anode mass results from the 2013-2017 porthole surveys.

Port hole #	2013		2014		2015		2016		2017	
	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass
1	-1.010	>80%	-1.010	>80%	-0.970	>65%	-1.130	>60%	-1.035	90%
2	-1.027	>80%	-1.010	>80%	-0.990	>65%	-0.980	>60%	-1.025	90%/90%
3	-0.975	>80%	-0.970	>80%	-0.940	>65%	-1.040	>60%	-0.993	90%/50%
4	-0.994	>80%	-1.000	>80%	-0.935	>65%	-0.970	>60%	Buried	Buried
5	-0.960	>70%	-1.020	>70%	-0.975	>65%	-0.950	>60%	Buried	Buried

Pile Support Survey

In July, efforts were made to locate pile supports, but none were exposed as migratory sand covered all pile supports. In December, the inspection team was able to locate and inspect 5 of the 35 pile supports. All of the exposed pile supports have good working anodes attached. Cathodic protection (CP) reading data from the 2017 survey, as well as for CP readings from the previous four years of surveys, are presented in Table 2. Two numbers in the "% Estimated Remaining Anode Mass" column indicate that two anodes are connected to a single pile support.

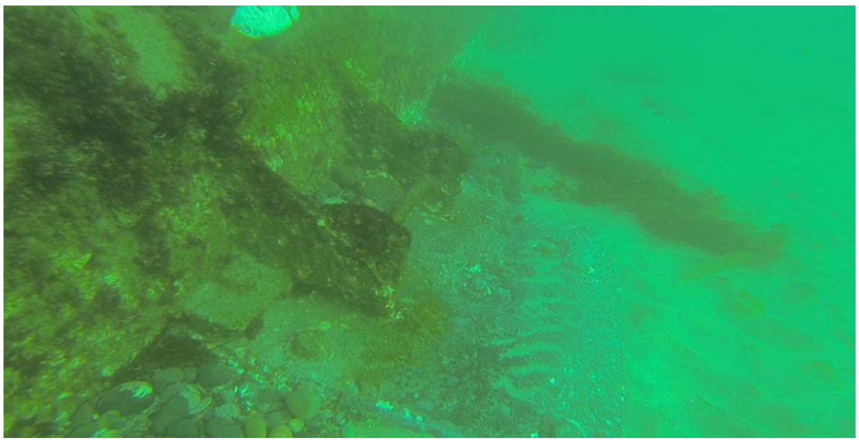


Figure 6. Exposed pile support

Table 2. Cathodic protection (CP) readings and associated % estimated remaining anode mass results from the 2013-2017 pile support surveys.

Pile Support #	2013		2014		2015		2016		2017	
	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass
1	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
2	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
3	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
4	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
5	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried

Pile Support #	2013		2014		2015		2016		2017	
	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass	CP VDC	% Estimated Remaining Anode Mass
6	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
7	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
8	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
9	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
10	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
11	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
12	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
13	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
14	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
15	-1.010*	Buried	Buried	Buried	-0.990*	>80%	Buried	Buried	Buried	Buried
16	Buried	Buried	Buried	Buried	-0.965*	>80%	Buried	Buried	Buried	Buried
17	-0.981*	Buried	Buried	Buried	-0.970*	>80%	Buried	Buried	Buried	Buried
18	Buried	Buried	Buried	Buried	-0.910*	>80%	Buried	Buried	Buried	Buried
19	-0.958*	Buried	Buried	Buried	-0.905*	>80%	Buried	Buried	Buried	Buried
20	-1.011*	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
21	-0.967*	Buried	Buried	Buried	-0.900*	>80%	Buried	Buried	Buried	Buried
22	-1.035*	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
23	-1.023*	>80%	Buried	Buried	-0.900*	>80%	-1.010*	>70/70%	Buried	Buried
24	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried	Buried
25	-1.019*	>80%	-0.980*	Buried	-0.910*	>60%	-0.980*	>80/80%	Buried	Buried
26	Buried	Buried	-0.780*	Buried	Buried	Buried	Buried	Buried	Buried	Buried

Pile Support #	2013		2014		2015		2016		2017	
	CP VDC	**% Estimated Remaining Anode Mass**	**CP VDC**	**% Estimated Remaining Anode Mass**	**CP VDC**	**% Estimated Remaining Anode Mass**	**CP VDC**	**% Estimated Remaining Anode Mass**	**CP VDC**	**% Estimated Remaining Anode Mass**
27	-0.946*	>80%	-0.930*	>80%	-0.890*	>80%	-0.940*	>90/30%	Buried	Buried
28	-0.710*	>80%	-0.860*	Buried	-1.010*	>80%	Buried	Buried	Buried	Buried
29	-0.982*	>70%	-1.000*	>90%	-0.895*	>80%	-0.910*	>70/70% Plus old ones at >20/20%	Buried	Buried
30	-0.975*	>80%	-0.870*	Buried	-0.955*	>80%	Buried	Buried	Buried	Buried
31	-0.960*	>65%	-0.980*	>90%	-0.905*	>80%	-0.950*	>50/50%	-.0950	>40/50%
32	Buried	Buried	-0.840*	>90%	-0.955*	>80%	-0.930*	>50/50%	-.0939	>50/50%
33	-0.642*	0%	-0.910*	>90%	-0.910*	>80%	-0.950*	>40/40%	-0.950	>40/40%
34	Buried	Buried	-0.930*	Buried	-0.925*	>60%	Buried	Buried	-1.005	>50/50%
35	-0.998*	>80%	-0.990*	>80%	-0.950*	>80%	-1.000*	>50/50%	-.0950	>40/40%
Pipe Protection Cowling	-0.849*	>80%	-0.950*	>80%	-0.900*	>50%	-0.890*	>40%	-0.872	>30%

*Piles buried. CP readings taken from nearest metal adjunct to the pile box.


Figure 7. View of protective cowling

Hydrographic Survey

The CLE multibeam hydrographic survey was completed on September 28, 2017. (See Appendix C) The survey crew was able to locate and survey the pipeline from where it emerged from the sand just offshore to its terminus (Figure 8). The survey area included a small amount of area inshore of where the pipeline emerged from the sand due to calm conditions during the survey.

The cross sections for stations referenced above and for all stations along the length of the exposed pipeline are included in Appendix C. Appendix C provides the entirety of the survey result as provided by CLE. The cross sections generally show close agreement between the 2014, 2015, 2016, and 2017 surveys. The cross-section results combined with diver observations indicate that the ballast material was relatively stable between 2014 and 2017.

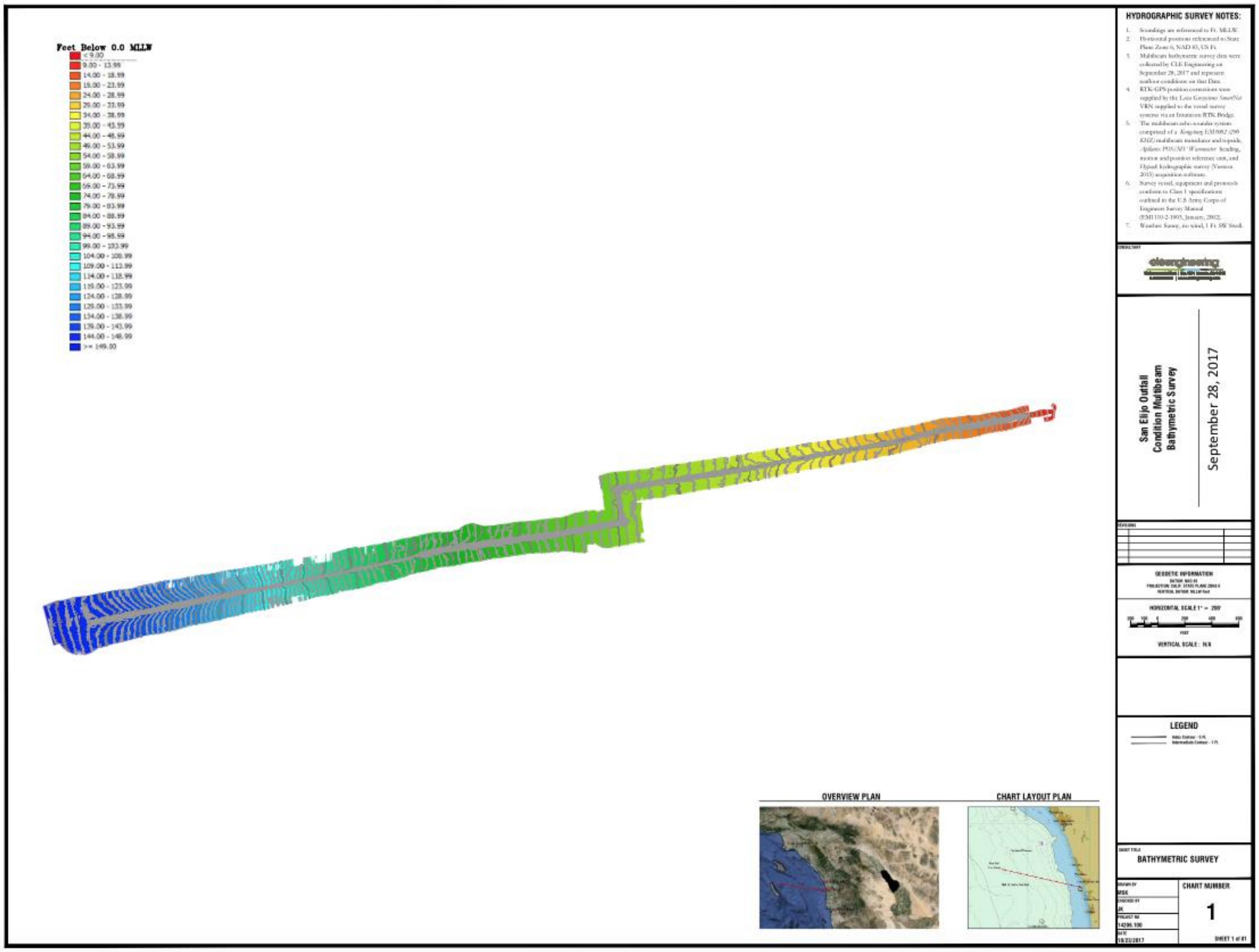


Figure 8. Overview of the CLE hydrographic survey of Ocean Outfall

SUMMARY AND RECOMMENDATIONS

The following points summarize the major findings of this inspection:

- In general, the San Elijo Ocean Outfall was found to be in excellent overall condition.
- Ballast rock on the pipeline showed no significant signs of movement since the last reballasting project.
- The outfall showed no signs of spalling, rust staining, or cracking and there was no leakage observed from pipe joints or any other location on the outfall.
- Anodes were in good condition and have greater than 30% remaining life expectancy where these were visible and could be inspected.
- Overgrown kelp that was starting to lift ballast from the pipeline was removed to the extent possible from over the pipe.
- The five exposed pile supports surveyed during this inspection were found to be completely protected with cathodic protection.
- There was abundant aquatic life found along the outfall

The following items are recommendations for continued structural integrity and environmentally safe operation of the San Elijo Ocean Outfall. Some of the comments made below were mentioned in previous reports, but are included again because they are still valid points.

Specific Recommendations

- Complete a Submersible, ROV or rebreather-based dive survey of the diffuser section of the outfall pipe each year to clear any blocked ports.
- Continue to cut kelp on the pipeline and ballast pile so further ballast is not moved away from the pipeline.
- Monitor for re-emergence of all 35 pile support structures and complete structural inspection and addition of anodes once these re-emerge from the littoral sands. Pile supports seem to be the most exposed in the winter months.
- There is ¼ to ½ inch of growth or biofouling around the diffuser ports. This is not obstructing flow at this point. This can be addressed in the future. (See Appendix B)

General Recommendations

- During future inspections, anodes should be replaced when they become ineffective against preventing corrosion to pipe and pile structures.
- Continue preventative maintenance and detailed annual inspections of the entire pipeline using Submersible, SCUBA, rebreather, and/or ROV surveys.
- Monitor Station 58+00 for possible future undermining

APPENDIX A

Important Oceanographic Processes

General Oceanographic Forces and Processes

(Adapted from prior Thales GeoSolutions Pacific, Inc. reports)

Several phenomena within the ocean environment exert a significant influence on the San Elijo outfall and ballast material. These processes include the hydrodynamic forces due to waves, longshore currents, and sediment transport. The arrival of large waves from local or distant storms increases localized water particle velocities, amplifies the effects of these processes and is capable of damaging the outfall. Each of these phenomena will be discussed in general terms and as they might apply to the San Elijo Ocean Outfall.

Waves and Currents

Beneath deep-water waves, water particles move in a circular orbit. The water particle velocity decreases with depth; the maximum depth of wave-induced particle motion is a function of wave height and period. The larger the wave and longer the period, the deeper the effects of the wave are felt in the water column. As a wave advances toward shore and enters shallow water, it begins to experience the effects of friction with seafloor. The frictional interaction of waves with the seafloor modifies the waveform, causing the wave height to increase, the wavelength to decrease, and the circular orbit of the particles to become increasingly elliptical. As each wave progresses into shallower water, it eventually reaches a height where the wave will break, which typically occurs in a depth of water with is nearly 1.3 times the height of the wave. The highest energy release occurs where waves are breaking. It is in this high-energy area that a pipeline is most likely to be damaged during a storm.

In addition to the wave-induced oscillatory particle motion, waves approaching a straight coastline at an angle can generate a steady longshore current. This longshore current is largely responsible for the erosion and longshore transport of sediment. The impact of this current and sediment load directly affects any structure, which could interrupt the current flow. At San Elijo, current is generally southward from November through April due to the arrival of waves generated by persistent north and northwest winds from large North Pacific storm systems. The longshore current direction occasionally reverses itself during the remaining months due to exposure to Southern Hemisphere swell or infrequent tropical storms. Other components of the nearshore current include tidal currents with semi-diurnal reversing of the onshore/offshore and upcoast/downcoast flow, regional oceanic circulation patterns, and currents produced by local winds such as sea breeze or thunderstorms and squalls. The combination of these wave- and current-related forces make the nearshore a very dynamic environment in terms of sediment transport and generating forces with act on costal structures.

Hydrodynamic Forces

Dynamic forces acting on a submerged object are comprised of the direct impact of the water particles against the object, varying hydrostatic pressure as a wave passes, and the lift/drag forces caused by increased fluid velocities over and around the object. Currents generated by waves can cause movement of the entire water mass, which can cause forces similar to a flowing river. The flow over the top of the San Elijo outfall can cause lift forces due to pressure gradients and drag on the pipe in the direction of the current flow. The lift caused by currents, coupled with the increased oscillation lift associated with localized water particle velocities and drag forces, can cause large objects such as ballast rock to move as a wave passes.

Liquefaction

Shock from breaking ocean waves or earthquake surface waves can cause unconsolidated, water-saturated sediments to go into suspension. This process, called liquefaction, results in the sediment losing its shear strength and therefore it ability to support higher density objects. This process causes objects such as ballast rock resting on the liquefied area to settle.

Sediment Scour and Transport

The forces discussed in previous sections apply to sediments as well as to an ocean outfall pipe. Longshore sediment transport and seasonal beach migration (inshore/offshore) occur when the water particle velocity is great enough to suspend sediment particles and transport them in agitated water as suspended-load and bed-load. The suspension and movement of unconsolidated sediments in the water column may result in lower bottom elevation. Eroded sand may or may not be re-deposited at the same level, depending on the resultant mean current and the up-current sediment supply.

Coastal Sediment Transport and Erosion

The transport of sediment parallel to the shore along Southern California beaches is due primarily to the longshore current generated by waves breaking at an angle to the coastline. The majority of the transport occurs within the littoral zone, extending from shore to just beyond the seaward limits of the breaker zone. The Southern California coast can be divided into a series of cells between the natural features of headlands and submarine canyons (Figure 5-1). At a headland or promontory, the upcoast supply of sand is effectively blocked or deflected offshore into deeper water and lost to the system. Similarly, submarine canyons capture the beach sand and channel it offshore into deeper water where it is also permanently lost to beach replenishment.

The local littoral sediment budget determines whether the coast is likely to experience net erosion or deposition. A beach may be considered to be in a state of equilibrium if the longshore transport into a cell or coastal segment equals the transport out of the cell. However, the coast is a dynamic environment with naturally occurring periods of erosion and deposition. Thus, an imbalance in the budget is difficult to predict due to uncertainty in estimating the magnitude of the various sediment sources and losses. The primary sources of beach material are longshore transport from upcoast segments, river transport, sea cliff erosion, onshore transport, dredging, and sand bypass at harbor entrances. The primary losses of beach material are longshore transport out of area, offshore transport, deposition within submarine canyons, accumulations at harbor entrances, and mining. In general, the contribution of sediment from river transport and runoff has been significantly reduced by the construction of dams and reservoirs. Lagoons normally contribute little to the coastal sediment budget and many actually constitute a net sediment loss. River-transported sediments deposited in shallow coastal lagoons are not normally available to nearby beaches unless there is sufficient tidal exchange to suspend and transport sand-size particles. In some instances, tidal currents may carry sediment into a lagoon where it is deposited due to lower velocity. The exception to this may occur after periods of heavy rainfall when the increased flow due to excessive runoff and coastal flooding may flush deposited sediments onto adjacent beaches.

The Oceanside Littoral Cell extends from Dana Point to the Scripps-La Jolla Submarine Canyon, which is a distance of approximately 50 miles. Within this cell, the net annual transport is toward the south due to the prevailing wind and wave direction from the northwest during October/November through April/May. During the summer months, the arrival of swell from Southern Hemisphere or tropical storms can reverse the longshore current, producing periods of northward longshore transport. The estimated annual transport offshore through Scripps-La Jolla Submarine Canyon of 260,000 cubic yards is roughly equivalent to the total littoral transport reaching the adjacent upcoast beach (Chamberlain, 1964). Surveys within the Carlsbad Submarine Canyon concluded that it was not currently an active site of beach material loss. No other canyons affect the Oceanside Littoral Cell.

U.S. Army Corps of Engineers studies have suggested the division of littoral cells into segments or subcells based on the following criteria:

Distinctive sediment characteristics due to natural or man-influenced processes such as beach nourishment programs; Known natural (lagoons and submarine canyons) or man-made (jetties and breakwaters) barriers to littoral sand transport.

The eight-mile-long costal segment between San Marcos Creek at Batiquitos Lagoon and the San Dieguito River includes the communities of Leucadia, Encinitas, Cardiff and Solana Beach. Based on data from 1954 through 1988, the sea cliffs in this area have retreated an average of approximately 0.1 to 0.2 feet per year. This sediment source contributes relatively small amounts of sand, gravel and cobble to the coastal sediment budget. Analysis of aerial photographs and beach profiles for the 50-year interval from 1938 through 1988 showed a nearly stable shoreline position, indicating a close balance in the sediment budget. The normal seasonal onshore/offshore sediment transport and localized changes near the outfall due to the effects of severe storm events or scour are not reflected in the long-term average.

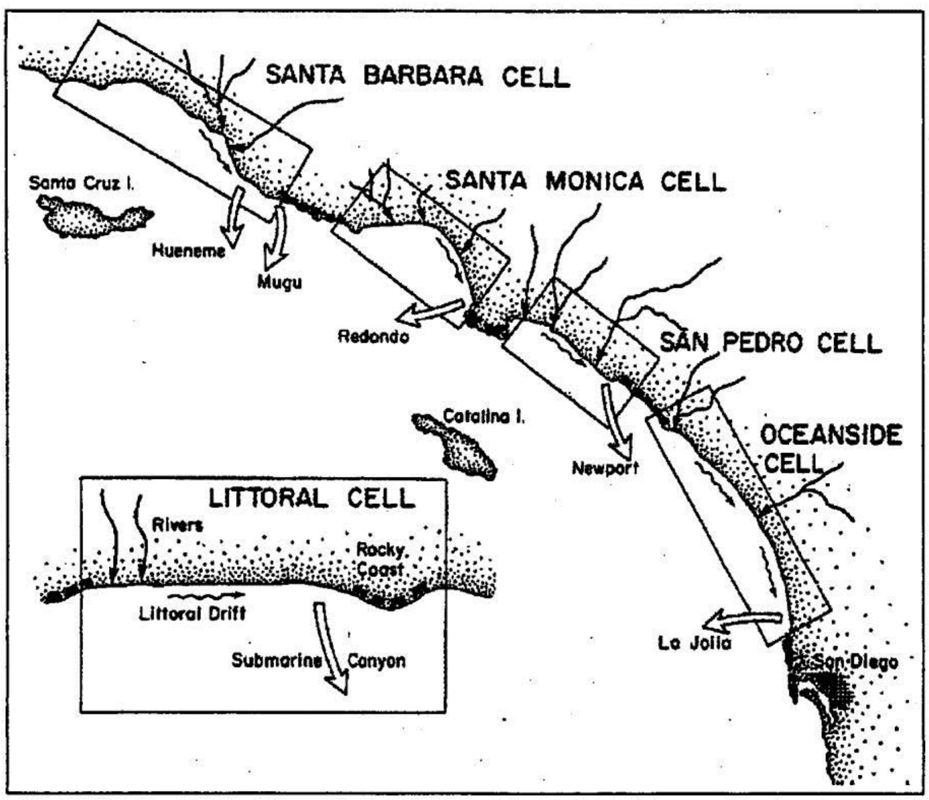


Figure 5-1 Southern California Coast Littoral Transportation Cells

Scour

Depletion of sediment occurs adjacent to offshore structures that have readily transportable sediment near their perimeters. This localized depletion of sediment around an object is called scour. Flow velocity increases as it passes around the edge of a structure, causing a localized increase in the energy proportional to the square of the velocity. This increased energy allows water to transport more sediment and larger size particles. In the case of the San Elijo Ocean Outfall, the sediment typically available for transport is sand. Therefore, at the toe end of a ballast pile, or the outfall terminus, flow passes around stationary or non-transportable material, the area will be more susceptible to scour.

Scour around an outfall can also be noted on a larger scale as differences in bottom elevation of the nearfield sediment distribution around a pipe and ballast pile. On the up-current side of the pipe, the seawater slows down as it approaches the ballast pile and loses some of its energy. As a result, its ability to transport sediment is reduced, thus causing deposition on the up-current side of the pipe. As fluid passes over the pipe and ballast pile it gains energy but not enough to displace correctly designed ballast. As the seawater leaves the down-current edge of the ballast pile, its energy is increased because of the turbulence around the ballast pile and a return to non-deflected flow. This increased energy level enhances the ability to transport sediment. Thus, sediment deposited at the ballast pile is re-suspended and transported away, which results in a lower level of sand on the down-current side. This same phenomenon is typically visible around a jetty where the up-current side experiences buildup of material and the down-current side shows a loss of material.

Scour results in the loss of sand around the toe of the ballast pile, around the pipe, and supporting structures where no ballast exists. Excessive scour can lead to ballast pile setting or collapse and weakened support foundation, which eventually may result in unsupported spans of pipe.

Metallic Corrosion

The galvanic process commonly referred to as corrosion arises when two dissimilar metallic alloys or different areas of the same metal are immersed in an electrolyte (e.g., generally a liquid capable of conducting electricity such as seawater). The connection created between the two metals that has a sufficient voltage potential different to initiate an oxidation reaction. The location of this reaction is known as the anode and is characterized by a negative charge. Once liberated, electrons flow as current through the metallic pathway to a more positively charged region within the cell and begin to generate a reductive reaction at an area known as the cathode.

The circuit is completed by the migration of hydroxide ions from the cathodic region to the anode. The major point of interest is that the rate at which these reactions occur is governed in large part by the rate at which oxygen can be reduced at the cathode. In basic terms, this means that the reduction rate and thus the rate of corrosion are controlled by the amount of dissolved oxygen available in the water column.

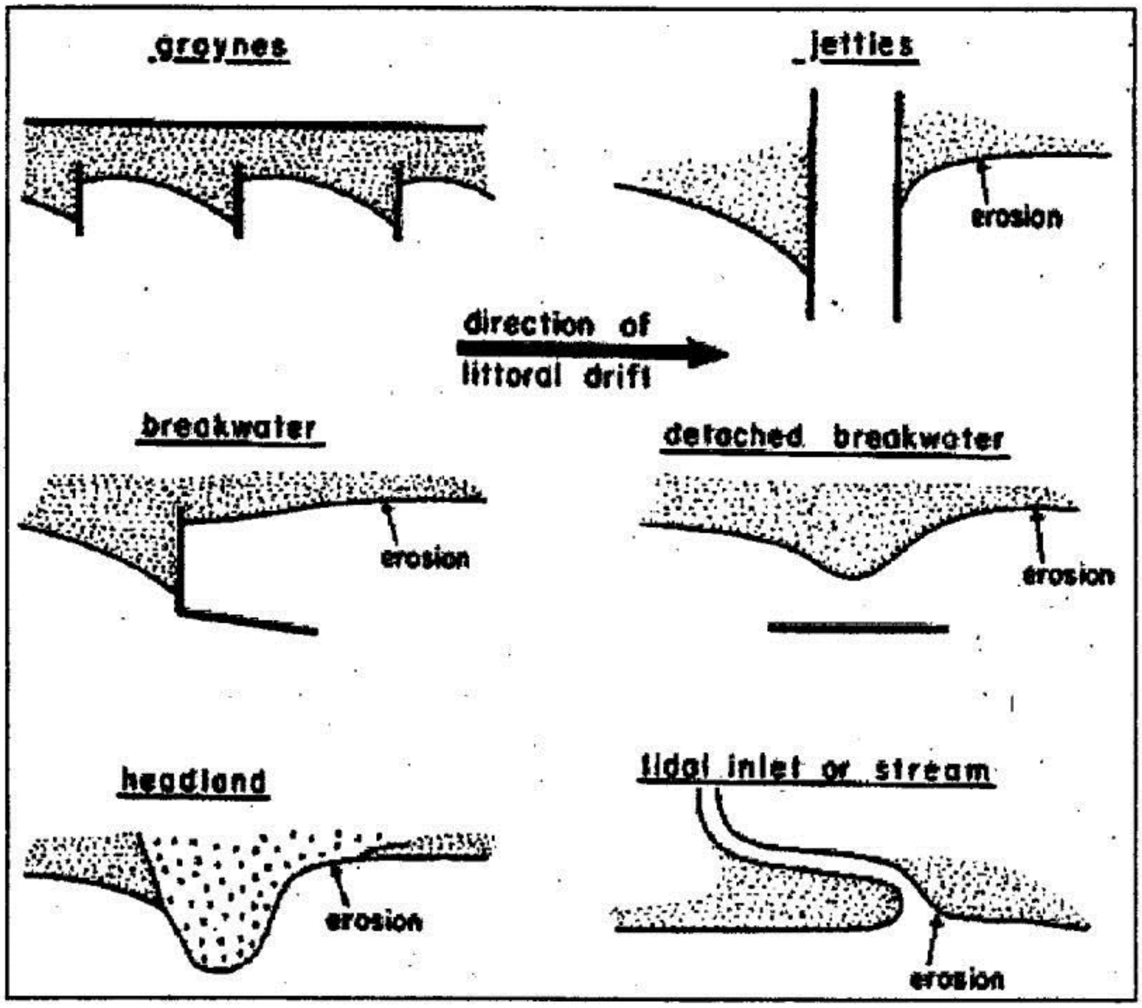


Figure 5-2 Deposition and erosion due to interruption of longshore transport

Metals immersed in seawater are susceptible to corrosion due to galvanic action, which produces an electrical current in an electrolyte (conducting) solution. Seawater is an electrolyte since it contains a significant percentage of chlorine ions found in solution. More specifically, there are approximately 35 grams of dissolved salt per kilogram of seawater. Sites on the surface of the metal where corrosion or oxidation (electron loss) is occurring are referred to as anodes. The chemical reaction at an anode results in the production of metal ions and free electrons. These electrons pass through the seawater to other sites (referred to as cathodes) where a reaction (electron gain) is occurring. Metal ions can go into solution or react to form corrosion products such as oxides on the surface of the metal, forming the classic reddish-brown rust commonly observed.

All exposed metallic fixtures on the outfall, including the steel pipeline, are susceptible to corrosion. The rate of corrosion can be significantly reduced by attachment of sacrificial zinc alloy anodes. Zinc has a higher corrosion potential than most metals and therefore the resulting loss of material is from the zinc anode and protected parts remain relatively inert.

Kelp Settlement and Growth

Kelp (*Macrocystis sp*.) is a marine alga, which grows in the Shallow Littoral Zone. It grows on hard substrate such as rocks, boulders, outcrops, concrete, and pipeline ballast rock. Substrate attachment is by means of a rhizome-like base called a holdfast. Under suitable nutrient, light, and thermal conditions, kelp plants grow to lengths in excess of 200 feet, with daily growth rates in excess of one percent of plant size. The major parts of a kelp plant are:

Holdfast – Base that anchors the kelp to the ocean floor; *Stipe* – A stem-like section that connects the pneumocysts and blades to the holdfast; *Pneumatocyst* – A small, ball-like, gas-filled float between the stipe and the blades, which provides buoyancy; *Blades* – Leaflike sections, 0.8 feet to 1.3 feet long and approximately 0.2 feet wide.

Multiple stipes can grow from a single holdfast clump. Kelp has considerable buoyancy and drag potential in the water column.

The entire kelp plant is quite elastic, allowing it to survive high-energy sea conditions. However, under extreme wave and current conditions, a stipe may break and the plant will float away if the stipe elasticity and strength are exceeded by drag forces. Under certain conditions at very low ocean-energy levels, the entire kelp plant, including the holdfast, can be transported away. This occurs when the substrate to which the kelp has attached has insufficient mass to anchor the kelp. Obviously, the smaller the ballast rock, the easier it is for individual kelp plants to carry it away from an outfall. While inspecting San Elijo outfall prior to the most recent reballasting, previous inspectors witnessed kelp growing on small units of ballast in the sand field away from the pipeline. Following reversal of tidal current direction, those same plants were found alongside the pipeline. By this process, a ballast pile can be significantly depleted even during moderate wave conditions if the ballast is not of a suitable size to prevent its removal by kelp drag.

APPENDIX B

San Elijo Ocean Outfall
2017 Diffuser Port Book

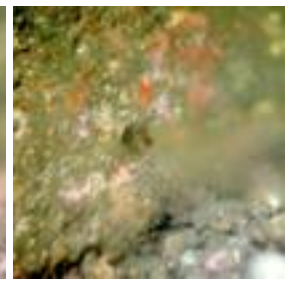
The following port book consists of a photograph of each of the 200 ports. They are labeled 1N-100N, which indicates the north side of the outfall and 1S-100S indicating the south side of the outfall. Both 1N and 1S are the most inshore diffuser ports around Station 66+00; whereas 100N and 100S are the most offshore diffuser ports at Station 81+00.

Ports 1N-100N


1N


2N


3N


4N


5N


6N


7N


8N


9N


10N

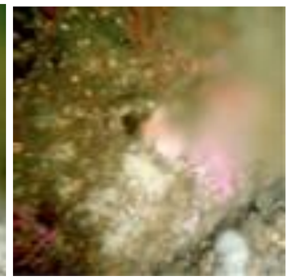

11N


12N


13N


14N


15N


16N


17N


18N


19N


20N


21N


22N


23N


24N


25N

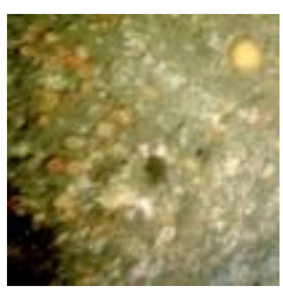

26N


27N


28N


29N


30N


31N


32N


33N


34N


35N


36N


37N


38N


39N


40N

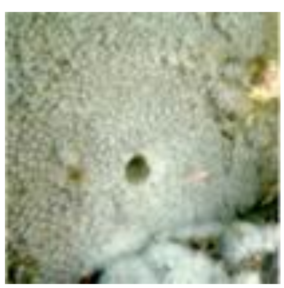

41N


42N


43N


44N


45N


46N


47N


48N


49N


50N


51N


52N


53N

54N

55N

56N

57N

58N

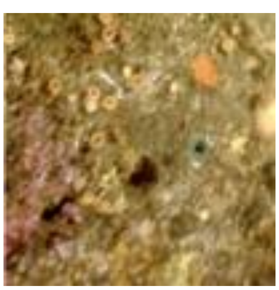
59N

60N

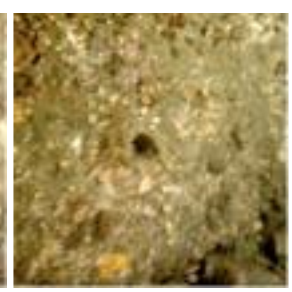
61N

62N

63N

64N

65N

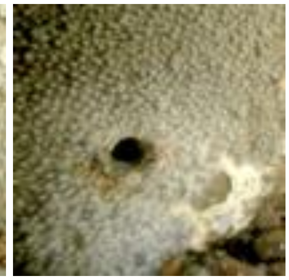
66N

67N

68N


69N

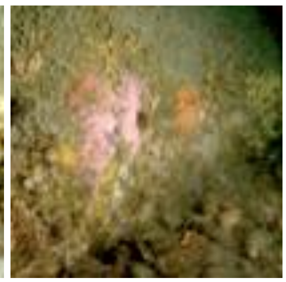

70N


71N


72N


73N


74N


75N


76N


77N


78N


79N


80N


81N


82N


83N


84N


85N


86N

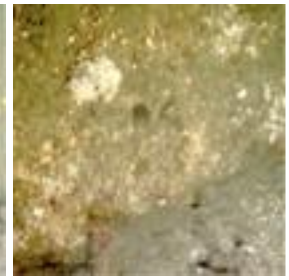

87N


88N


89N


90N

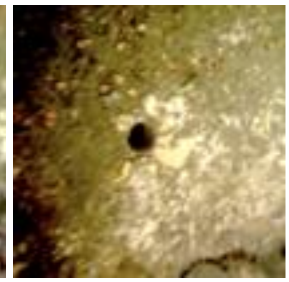

91N


92N


93N


94N


95N


96N


97N


98N

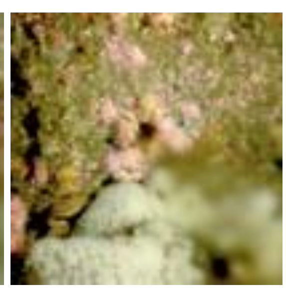

99N


100N

Ports 1S-100S


1S


2S

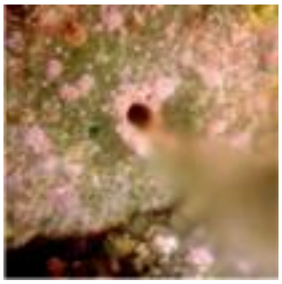

3S

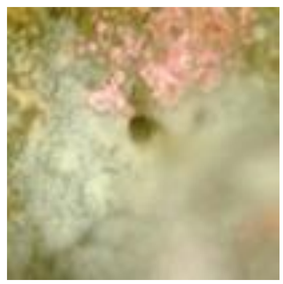
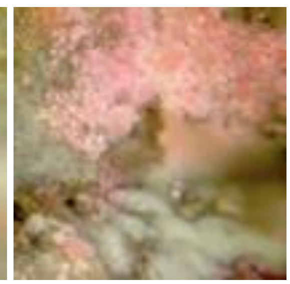

4S


5S

6S

7S

8S

9S

10S

11S

12S

13S

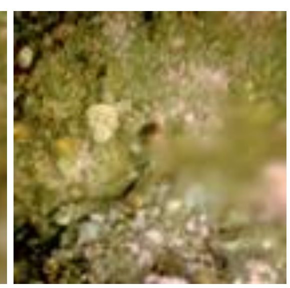
14S

15S

16S

17S

18S

19S

20S

21S

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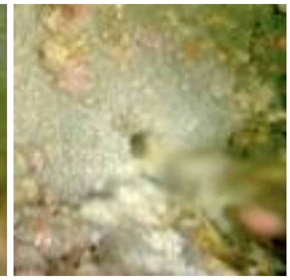
45S


46S


47S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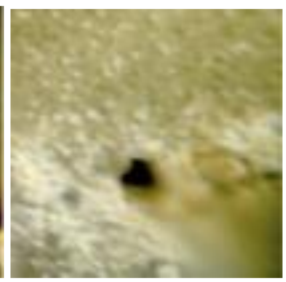
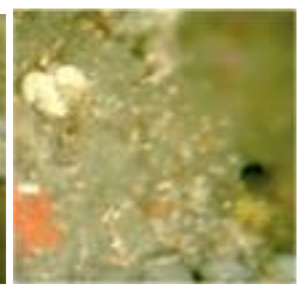
52S


53S


54S


55S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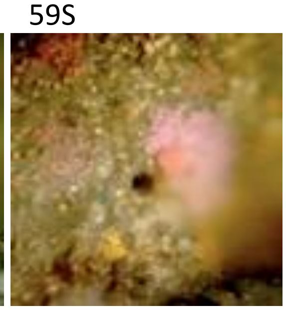
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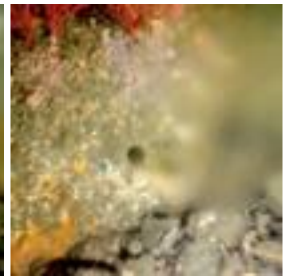
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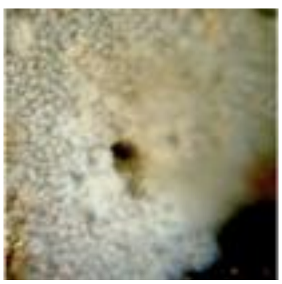
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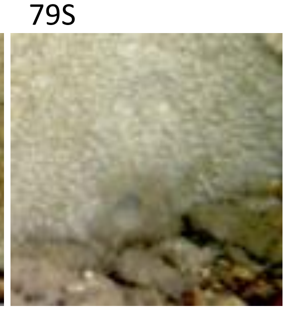
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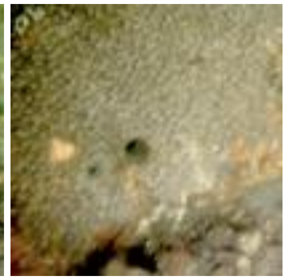
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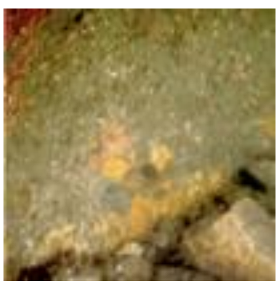
93S


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95S


96S


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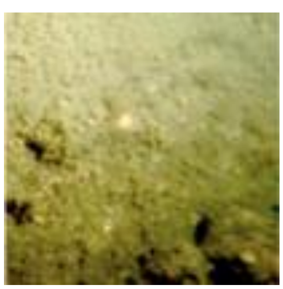
98S


99S


100S

APPENDIX C

HYDROGRAPHIC SURVEY