Evaluation of Potential Environmental Impacts of the Export and Discharge of Salton Sea Water to the Gulf of California or Pacific Ocean

\- - - -

Charles Keene

INTRODUCTION

The Salton Sea is a below sea-level hypersaline lake located in a closed desert depression east of Los Angeles and San Diego. Absent a natural outlet, evaporation is the only escape for water entering this, the largest inland body of water in California. Over time, this condition has resulted in the continued accumulation of salts, nutrients, and other contaminants within the Sea and its sediments. The resulting degradation of water quality is associated with negative impacts on the Sea's biota (e.g., fish kills) and aesthetic qualities (e.g., algal blooms and noxious odors). These and other impacts have resulted in restoration of the Sea becoming a subject of renewed focus. Stabilization and reduction of salinity levels, which have now reached 44 parts-per-thousand (ppt), is one of the major actions being pursued. One of several possible actions being evaluated for salinity control is to pump water out of the Salton Sea to the upper Gulf of California or to the Pacific Ocean. This would provide an outlet for the Sea and a means for the removal of salts and some nutrients. The purpose of this report is to assess the potential environmental impacts associated with the transport and discharge of Salton Sea waters into the upper Gulf of California or to the Pacific Ocean.

PROPOSED ACTIONS

The U.S. Bureau of Reclamation (USBR) and the Salton Sea Authority are evaluating two different possibilities for pumping water out of the Salton Sea as part of their Phase 2 restoration alternatives (Figure 1) (USBR, 1999). The Phase 2 alternative actions, if approved, could be operational by 2015. One possibility involves pumping water to the Gulf of California by one of two different water conveyance routes: (1) exporting water from the Sea to the east side of the Gulf through a 140-mile long pipeline that would terminate near El Golfo de Santa Clara and outside the core of the Biosphere Reserve; and (2) exporting water from the Sea to the west side of the Gulf through a 177-mile long pipeline that would terminate approximately one mile into the Gulf near San Felipe (Figure 2). Much of the upper Gulf of California is protected by its status as a Biosphere Reserve. Neither route violates the core of the Reserve, but the eastern route invades the buffer zone around the core area.

The second possibility being considered involves pumping water to the Pacific Ocean off the coast of southern California by one of two different conveyance routes: (1) exporting water from the Sea to the Pacific Ocean through a 101-mile long pipeline/tunnel that would terminate at an outfall site near Oceanside (Camp Pendleton); and (2) exporting water from the Sea to the Pacific Ocean through a 108-mile long pipeline/tunnel that would terminate at an outfall site near San Diego (Point Loma) (Figure 3).

Each of the Gulf of California export routes would utilize a 112-inch diameter, polymer-lined, steel pipe to convey nearly 223 million gallons per day (250,000 acre-feet per year) of water from the Salton Sea to the selected terminus point. Each route would require two or more pumping plants to lift water over small grades along the pipeline alignment.

Because of the need to cross the rugged San Jacinto Mountains at different points, the proposed design details of the two Pacific Ocean export routes differ from one another. Each route, however, would consist of two variable diameter pipeline segments, or reaches, interconnected by a concrete-lined tunnel segment beneath the mountains. Depending on the export route, as many as nine pumping plants and eight powerplants would be needed at specific points

Evaluation of Potential Environmental Impacts of the Export and Discharge of Salton Sea Water to the Gulf of California or Pacific Ocean

- - - -

Salton Sea Science Subcommittee

INTRODUCTION

The Salton Sea is a below sea-level hypersaline lake located in a closed desert depression east of Los Angeles and San Diego. Absent a natural outlet, evaporation is the only escape for water entering this, the largest inland body of water in California. Over time, this condition has resulted in the continued accumulation of salts, nutrients, and other contaminants within the Sea and its sediments. The resulting degradation of water quality is associated with negative impacts on the Sea's biota (e.g., fish kills) and aesthetic qualities (e.g., algal blooms and noxious odors). These and other impacts have resulted in restoration of the Sea becoming a subject of renewed focus. Stabilization and reduction of salinity levels, which have now reached 44 parts-per-thousand (ppt), is one of the major actions being pursued. One of several possible actions being evaluated for salinity control is to pump water out of the Salton Sea to the upper Gulf of California or to the Pacific Ocean. This would provide an outlet for the Sea and a means for the removal of salts and some nutrients. The purpose of this report is to assess the potential environmental impacts associated with the transport and discharge of Salton Sea waters into the upper Gulf of California or to the Pacific Ocean.

PROPOSED ACTIONS

The U.S. Bureau of Reclamation (USBR) and the Salton Sea Authority are evaluating two different possibilities for pumping water out of the Salton Sea as part of their Phase 2 restoration alternatives (Figure 1) (USBR, 1999). The Phase 2 alternative actions, if approved, could be operational by 2015. One possibility involves pumping water to the Gulf of California by one of two different water conveyance routes: (1) exporting water from the Sea to the east side of the Gulf through a 140-mile long pipeline that would terminate near El Golfo de Santa Clara and outside the core of the Biosphere Reserve; and (2) exporting water from the Sea to the west side of the Gulf through a 177-mile long pipeline that would terminate approximately one mile into the Gulf near San Felipe (Figure 2). Much of the upper Gulf of California is protected by its status as a Biosphere Reserve. Neither route violates the core of the Reserve, but the eastern route invades the buffer zone around the core area.

The second possibility being considered involves pumping water to the Pacific Ocean off the coast of southern California by one of two different conveyance routes: (1) exporting water from the Sea to the Pacific Ocean through a 101-mile long pipeline/tunnel that would terminate at an outfall site near Oceanside (Camp Pendleton); and (2) exporting water from the Sea to the Pacific Ocean through a 108-mile long pipeline/tunnel that would terminate at an outfall site near San Diego (Point Loma) (Figure 3).

Each of the Gulf of California export routes would utilize a 112-inch diameter, polymer-lined, steel pipe to convey nearly 223 million gallons per day (250,000 acre-feet per year) of water from the Salton Sea to the selected terminus point. Each route would require two or more pumping plants to lift water over small grades along the pipeline alignment.

Because of the need to cross the rugged San Jacinto Mountains at different points, the proposed design details of the two Pacific Ocean export routes differ from one another. Each route, however, would consist of two variable diameter pipeline segments, or reaches, interconnected by a concrete-lined tunnel segment beneath the mountains. Depending on the export route, as many as nine pumping plants and eight powerplants would be needed at specific points along the route alignment to lift water over small grades and/or to recover power. Each route would convey about 223 million gallons of water per day (250,000 acre-feet per year) from the Sea to the selected ocean outfall locations.

The average water velocity in the pipelines and/or tunnels would be approximately 5 feet per second, thereby requiring nearly 41 hours and 52 hours for conveyance time from the Salton Sea to El Golfo de Santa Clara and San Felipe, respectively. Transit time to probable Pacific Ocean outfalls would be approximately 30 hours and 32 hours for conveyance to Oceanside and San Diego, respectively. The average water temperature within the pipeline during transit to the Gulf or to the Pacific Ocean will be similar to that of Salton Sea water at the point of intake (with minor adjustments for potential heat loss/gain through the pipeline).

ISSUES

Several basic issues are associated with the discharge of water from the Salton Sea into other water bodies. These include: (1) possible environmental effects of hypersaline water discharged into oceanic water environments; (2) introduction of viable exotic organisms into the area of discharge; (3) introduction of possible hazardous wastes that may be present in discharge waters; and (4) nutrient loading of the receiving waters. Each of these is addressed in this evaluation.

EVALUATIONS

Hypersaline Discharges

Discharges from the pipeline will involve water that has a salinity of approximately 51ppt (i.e., projected salinity of the Sea in 2015, assuming no appreciable reduction in inflows to the Sea) (USBR, 1999). Salinity of the receiving waters will range seasonally from 37ppt to 39ppt for the upper Gulf (Lavin et al., 1998) and will be approximately 35ppt for the Pacific Ocean sites. Because of the hypersaline nature of the Sea, any discharges to the Gulf of California or the Pacific Ocean have the potential to negatively affect the biotic environment of the receiving waters. The following information provides a synopsis of physical processes at play in the upper Gulf and nearshore waters off the coast of southern California that could affect the dispersion or dilution of the hypersaline discharge from the Sea.

Background. The upper Gulf is a relatively shallow (<30meters depth), triangular-shaped, tidal area located at the head or northernmost part of the Gulf of California. It has been characterized by Lavin et al. (1998), as an inverse estuary because of its high evaporation rate and paucity of freshwater input from rainwater and the Colorado River. Hydrographic data suggests that the area is vertically well mixed throughout the year, primarily because of strong tidal influences and vertical convection. Salinity levels gradually increase toward the head of the Gulf, as do water densities. The pressure gradients thus formed lead to water-mass formation and gravity currents ($\sim 0.1 ms^{-1}$) that result in a residual cyclonic circulation pattern within the upper Gulf.

The main physical oceanographic factors that influence temperature structure and mixing in shallow nearshore areas of the Pacific Ocean along the southern California coast are primarily seasonal water density stratification (caused by water temperature variations), seasonal wind regimes, and major oceanic anomalies such as El Nino and La Nina conditions. Several times during the year, changes in surface water temperatures result in the formation of convection currents that produce thorough mixing of relatively warm nearshore waters. Oceanic circulation several miles off the coast of southern California is influenced by colder, southerly moving waters of the California Current system.

The following case studies of outfalls within marine environments were evaluated to provide guidance regarding probable outcomes associated with discharges of water from the Salton Sea. Each case study evaluates the effects of discharge and dispersion of a concentrated effluent stream of wastewater to an oceanic environment and describes its relative effects on the biota.

Case Study No. 1. The Southwest Florida Water Management District and University of South Florida jointly investigated the effects on marine benthic communities from the discharge of desalination brines, or concentrates, from an operating sea water reverse osmosis (RO) facility (Hammond et al., 1998). The objective of the study was to provide the evidence necessary to adequately predict effects from the concentrate discharged in areas such as west-central Florida.

Initial laboratory tests were conducted to determine if discharges from a sea water RO facility could meet Florida water quality standards. The initial test results, using a bench-scale RO unit and acute and chronic toxicity bioassays on standard marine organisms (i.e., inland silversides, *Menidia beryllina*, and mysid shrimp, *Mysidopsis bahia*), showed that by blending the RO concentrate with three parts sea water, the discharge could not only meet the state water quality standards, but also test organisms did not show any observable effects with respect to growth, reproduction, or survival.

To further document possible discharge impacts under actual field conditions, the investigators next studied the structure and health of the benthic communities within the discharge zone of an operating sea water RO facility at Antigua in the Caribbean Sea. The Antigua RO plant is located in a shallow (less than 30 feet deep), largely protected and relatively calm harbor with a total surface area of about three square miles.

The Antigua RO plant has a production capacity of 1.32 million gallons of fresh water per day and about 1.8 million gallons of concentrate per day. The concentrate, which has a salinity of 57ppt, is discharged via a channel outfall into the harbor. Background salinity within the harbor was measured at 35ppt. As part of the investigation, a new 12-inch diameter pipe was constructed to divert the discharged brine to a study area approximately 20 meters offshore and about 26 meters east of the RO plant discharge channel. Prior to diverting the discharged brine, biological, water quality, and other related data were collected from the study area along six 10-meter long radial transects spaced at 60-degree intervals from the discharge outfall (ground zero). Two additional surveys along the radial transects were conducted three months and six months after the initial diversion of the brine.

The water quality sampling results from these later surveys suggest that temperature (which is higher in the discharge) and pH (which is lower in the discharge) returned to background levels within 2 to 6 meters from ground zero (e.g., surveys detected only 39ppt salinity within 2 meters of ground zero). Elevated salinity levels, which are the best "tracer" of the spatial influence of the plume, were found up to ten meters and beyond for those transects that extended into deeper water from ground zero. The brine discharge seemed to dissipate mostly as a density-driven plume.

Next, the structure and health of the nearshore, or littoral, communities within the study area were evaluated with respect to impacts caused by the discharge plume. The communities included expansive areas of sea grasses and macroalgae, benthic microalgae, benthic foraminifera, and typical tropical reef invertebrates or macrofauna and fish. The benthic communities were of particular interest because they are immobile and cannot escape the effects of materials discharged into their surroundings, thereby making them potentially sensitive indicators of ecological impacts from such things as brine discharges.

In general, the surveys showed no detectable toxic effects of the discharge plume on seagrass (*Thalassia testudinum*) density, biomass, or production. However, the survey at month three showed a positive, but weak correlation between the intensity of the plume (measured as change in salinity vs. background) in the abundance of the alga *Dictyota dichotoma*. Interestingly, algal abundance for the survey at month six showed no significant differences from densities recorded prior to the start of the study and no effect on algal productivity or biomass. It seems probable that the elevated algal abundances found at month three were from higher nutrient inflows to the study area caused by episodic events associated with back flushing, detergent discharges, and/or storm water runoff from the RO plant complex and not from chronic effects associated with the discharge. In addition, the discharge plume apparently had no observable effect on the grazing rate or feeding behavior of a major seagrass consumer, the bucktooth parrotfish (*Sparisoma radians*).

The surveys also showed that the discharge of high salinity effluent had no detectable effect on the biomass (i.e., chlorophyll concentration) or abundance of the benthic microalgal community in the study area. In fact, the biomass increased and remained elevated during the study period and there were no significant differences in average chlorophyll concentrations for samples taken within three meters and at greater than three meters from ground zero.

Benthic foraminifera, because of their relative sensitivity to environmental change and predicable responses to salinity stress, were considered key indicators of the effects of desalination effluents on nearshore benthic communities. However, the surveys revealed no significant differences in the foraminiferal assemblages between transects or with distance from the outfall, thus indicating that salinity stress was not a factor affecting the relative abundance (or ratio) between key genera.

No evidence of stress or mortality in the macrofaunal assemblage was observed within the study area; in fact, two species of coral (soft coral, *Pseudoterogorgia acerosa*, and hard coral, *Porites asteroides*) were found seemingly unaffected within one meter of the point of discharge throughout the study and two mobile species, the queen conch, *Strombus gigas*, and the cushion starfish, *Oreaster reticulatus*, were observed within two meters of the discharge point. The elevated salinities also did not limit the ability of organisms to colonize available substrates, even within the area of maximum salinity. In addition, no obvious or statistically significant effects of the saline discharge were observed on the macro-epifauna or pelagic fish.

In conclusion, this study showed no obvious effects of the concentrate on the benthic or pelagic biological communities present in the discharge zone of the RO plant if the concentrate is blended with sea water at a ratio of 1:1 or 2:1. A rapidly dissipating density-driven plume was evident in the study area, but no significant difference in aquatic productivity or relative abundance of micro- and macroalgae or changes in the foraminiferal populations and macrofaunal assemblage were noted between the time the project began and after brine effluents had been continuously discharged for six months. These findings were also consistent with the conclusions of Smith (1995) and others who have studied the effects of a discharge plume from sea water desalination plants elsewhere in the Caribbean and the Middle East.

<u>Case Study No. 2</u>. For the last 35 years, the San Diego Metropolitan Wastewater Department has been monitoring the environmental effects of discharging nearly 195 million gallons per day of primary-treated effluent from the Point Loma Wastewater Treatment Plant to the Pacific Ocean off the coast of San Diego. The Point Loma Ocean Outfall was initially constructed as a 108-inch diameter concrete pipe that extended 2.5 miles offshore, ultimately discharging at a depth of about 220 feet. To avoid contamination of an important nearshore kelp bed zone, the outfall was extended in 1993 to 4.5 miles offshore and a depth of about 320 feet, making it one of the longest and deepest ocean outfalls in the world. A Y-shaped diffuser pipe further extends about 2,500 feet from the end of the west-facing outfall in a northerly and southerly direction to better disperse treated wastewater.

In December 1998, the Metropolitan Wastewater Department completed the South Bay Ocean Outfall, which currently discharges primary-treated effluent from the new International Wastewater Treatment Plant and, in the future, from the planned South Bay Water Reclamation Plant and South Bay Wastewater Treatment Plant to the Pacific Ocean near Imperial Beach. The South Bay Ocean Outfall, which has a capacity of about 174 million gallons per day, uses a 144-inch diameter pipe that extends approximately 3.5 miles offshore. The outfall consists of a drop shaft structure, a 2.5-mile long tunnel and pipeline section, a riser assembly, and an about 1.5-mile long seabed pipeline and diffuser system.

The Metropolitan Wastewater Department has established one of the largest and most comprehensive ocean monitoring programs in the United States to study the effects of its regional treatment processes on the marine environment. The objectives of the program are to: (1) identify potential health concerns associated with the recreational uses of nearshore waters along the San Diego coastline, (2) document the temporal and spatial changes to the marine environment and ensure its protection, (3) differentiate between natural changes to marine ecosystems and those that may be caused by sewage discharge, and, finally, (4) measure compliance with state and federal regulations.

As part of the ocean monitoring program, numerous monitoring stations have been established, using a GPS tracking system, to monitor the biological and physical components of the ocean environment. The monitoring area encompasses nearly 120 square miles from Del Mar, California, to Punta Bandera, Mexico, and seaward approximately 10 miles to depths of 600 feet. Each week, several thousand samples of the water and wastewater column, ocean sediments, and marine biota are collected and analyzed for compliance with state and federal water quality parameters at various depths (e.g., pH, clarity, temperature, DO, coliforms, heavy metals, nutrients, and other organic loading), possible sediment contaminants, and signs of effluent toxicity. In addition, annual aerial surveys of the kelp bed canopy, ranging from southern Orange County to the US/Mexico border, are conducted to determine temporal and spatial changes to the kelp bed caused by the operation of the outfalls.

After nearly 35 years of monitoring, there have been no detectable environmental problems associated with the effluent discharge from the Point Loma Ocean Outfall (except for elevated coliform levels). Not enough information is available to adequately evaluate the environmental effects of the effluent discharge from the South Bay Ocean Outfall.

Case Study No. 3. Parsons Engineering Science recently conducted a phased oceanographic study off the coast of Lima, Peru, to determine the extent of wastewater contamination from the discharge of domestic and industrial wastes via three coastal rivers (Meiorin et al., 1997). The objective of the investigation was to evaluate several wastewater disposal scenarios to determine which would reduce the nearshore pollution to acceptable levels. Phase one of the study entailed documenting environmental baseline conditions of the receiving waters within Miraflores Bay, off the coast of metropolitan Lima. Phase two involved the development of three-dimensional outfall models to help simulate different project scenarios. Lastly, phase three of the study compared the baseline conditions and model results to provide a better understanding of the expected long-term changes in the ocean environment.

To characterize the existing environmental conditions, data on the physical and biological attributes and extent of contamination of waters within Miraflores Bay were collected during phase one. Two extensive oceanographic surveys of the approximately 500-square-kilometer project impact area (50 km of shoreline and out to 10 km offshore) were conducted. The surveys of the nearshore waters showed strong evidence of wastewater pollution, with beach and other shoreline areas having total coliform concentrations exceeding 10^6MPN/100ml, while offshore areas near the middle of the bay showed concentrations of up to 2.5 x 10^4MPN/100ml. In addition, microbial pathogens, such as *Salmonella* and *Vibrio*, as well as several parasites and elevated metal concentrations were found in fish inhabiting the bay. Biological oxygen demand (BOD) was much higher than normal sea water levels, which is characteristic of waters with high external inputs of organic matter and often produces hypoxia in the water column and anoxic conditions in the bottom sediments. Typical pH values near the river outlets were as high as 10.27, levels which are generally very stressful to marine life. The high nutrient content of the waste effluent frequently spurred algal blooms within the bay despite poor water transparency caused by unusually high concentrations of suspended solids (50 percent higher than those of typical sea water). As would be expected, these inhospitable conditions combined to significantly reduce overall marine productivity within the bay.

The next phase of the study included development of detailed hydrodynamic and water quality models simulating offshore current patterns, water quality profiles, and potential plume dispersion patterns that could be expected from the four ocean outfall scenarios evaluated. The four scenarios, or situations, evaluated were: (1) existing conditions (i.e., the discharge of untreated or partially treated sewage to the ocean via existing coastal rivers or shoreline pipes), (2) primary treatment of all sewage and discharge through two outfalls, (3) primary treatment of all sewage but discharge (of about one-third of the treated wastewater) through only one outfall (with the remainder discharged via existing coastal rivers or shoreline pipes), and (4) varying levels of treatment of wastewater and discharge through two outfalls. Model runs were conducted for each situation, simulating both summer and winter hydrodynamic conditions, at three different ocean depths (surface, mid-water, and bottom). The runs used 11 separate physical-chemical and biological parameters (i.e., BOD_5, DO, Total N, NH_3, NO_3, NO_4, Total P, PO_4, algae, coliforms, and other tracers). In all, 264 different model runs, comprising 66 representations of each scenario, were produced, depicting the probable transport, mixing, and chemical interactions that would occur within the bay.

Phase three of the investigation compared the results of the modeling runs to the existing baseline environmental conditions to determine frequency of compliance with water quality standards among the four scenarios. The results indicated that Scenarios 2 and 4 comply with the water quality standards and would, therefore, be the most suitable alternatives for safe use of beaches and nearshore waters for recreational activities and other public uses. Scenario 3 showed some improvement over baseline conditions (Scenario 1), but standards for nutrients (NH_4), tracer, DO, and coliforms were still exceeded. Comparisons of the modeling results indicate that the greatest improvement in nearshore water quality was achieved with the use of an outfall rather than with increased treatment. Specifically, the outfall must be long enough to carry the discharge to a point in the ocean where it will not significantly harm the environment. The initial dilution (ratio of discharge to receiving water) is critical with regard to toxicity and must be considered, with other oceanographic parameters, such as eddy diffusivity, density structure (i.e., salinity, temperature, etc.), marine topography, and marine geology, to determine the potential dispersion of effluents and possible environmental consequences.

Analysis. According to direct hydrographic measurements from Argote et al. (1995), the shallow (<~ 50m depth) coastal areas of the upper Gulf exhibit a strong tidal influence that, along with vertical convection currents and seasonally wind-induced turbulence, results in a thorough mixing of the nearshore waters. As an example, the tidal range at San Felipe ranges from less than 1m to almost 6m with a maximum current speed of $0.5ms^{-1}$ (Lavin et al., 1998).

A direct measure of how well a water column is mixed is the difference in temperature between the surface and the bottom (ΔT). Argote et al. measured the distribution of ΔT in the upper Gulf; results showed that a complete vertically mixed coastal area ($\Delta T = 0$), from Puertecitos on the Baja peninsula to Point Lobos on the mainland coast, extended to approximately the 30m isobath in September and to about 60m in December.

Alvarez-Borrego (1983) described the surface salinities in the shallow coastal areas of the upper Gulf as increasing to the northwest, with a seasonal maximum (39ppt) in May-September and minimum (37ppt) in December-February. Surface densities also increased to the northwest with greater winter (December-February) densities than summer. In addition, a slight density stratification was evident throughout the year in most of the upper Gulf, but not enough to cause inversions. Lavin noted that the coldest, saltiest, and densest water in the upper Gulf was generally found in the shallow, gently sloping, extended shelf adjacent to the Baja peninsula. Hydrographic data suggest that the slightly denser bottom water, originating from the Baja peninsula side, moves gradually (~$0.1 ms^{-1}$) as a near-bottom gravity intrusion as deep as the 30m isobath where surrounding water densities are similar. By comparison, the mainland side of the upper Gulf has a much smaller shelf that rapidly drops off to deeper water.

Based on this information, a hypersaline discharge from the Salton Sea would likely move at a relatively slow density gradient into deeper regions (>~ 50m depth) of the upper Gulf. Although shallower areas of the upper Gulf are generally well mixed, the discharge plume would not be expected to dissipate rapidly given its relatively high density and temperature profile compared to ambient conditions.

Hydrographic conditions along the southern California coast are dominated by seasonal wind regimes and variations in surface water temperature that result in water column stratification and, in nearshore areas, the formation of convection currents that cause the thorough vertical mixing of littoral waters. Like conditions in the upper Gulf, convective vertical circulation or thermohaline circulation of the water column is typically density driven caused by thermal and salinity changes. As surface water temperatures along the coast decrease, the waters become increasingly dense and sink, gradually flowing southward at depth along the continental shelf. This process results in the creation of water layers based on the physical characteristics of the water itself (e.g., salinity, temperature, and density). These homogeneous water layers or gradients are typically slow to dissipate and mix with adjacent waters.

Similar to the situation in the upper Gulf, a discharge from the Salton Sea into southern California coastal waters near Oceanside would likely create a distinct water gradient or plume because of its high salinity, temperature, and density differential compared to ambient water quality near the discharge point. Furthermore, this plume could persist well beyond (~ 5-10m) the immediate discharge location. However, given the case studies above and the relatively small volume of water discharged from the Sea compared to the volume and mixing potential of ocean water, any plume or gradient so generated would also likely dissipate rapidly beyond 10m from the discharge point.

<u>Conclusions</u>. The ocean is often the ultimate sink for waste products. However, the ability of the ocean to assimilate wastes often depends upon physical oceanographic factors such as wind, wave, swell, littoral currents, variable currents, density gradients, upwelling, etc., as well as conventional physical, chemical, and biological characteristics of the oceanic environment. Because these factors and characteristics differ markedly between the upper Gulf of California and the coast of southern California, each location's ability to dilute and rapidly disperse hypersaline discharges from the Salton Sea will differ. An analysis of the current circulation patterns for the upper Gulf and southern California coast would be required to accurately predict the degree of initial dilution and dispersion that can be achieved at each of the proposed outfall sites.

However, based on the case studies evaluated plus the physical characteristics of the upper Gulf as compared to the southern California coast, it is clear that mixing forces in an open ocean setting would achieve a higher level of initial dilution and dispersion of hypersaline discharges from the Salton Sea. Consequently, possible adverse effects on the local benthic and pelagic communities near the discharge sites would likely be less for discharges off the coast of Oceanside.

Introduction of Exotic Organisms

The discharge of water from the Salton Sea could potentially introduce exotic organisms into the upper Gulf of California or to waters along the southern California coast. Many of these organisms may have the capacity to colonize the receiving waters, thus radically transforming these marine communities by out competing, killing, or infecting native species and by eventually dominating the ecosystem or affecting its health and productivity.

Background. The Salton Sea is known to be a highly productive, biologically rich ecosystem with a complex community structure. Because of elevated salinities, accelerated eutrophication, and dramatic temperature and water quality fluctuations, many of the marine organisms of the Sea have become highly adaptive. Photosynthetic algae are the major phytoplanktonic component of the Sea. Some of the more abundant algal species found in the Sea, like various dinoflagellates and the raphidophyte *Chattonella* cf. *marina* (which may be responsible for the Sea's "green tides" frequently observed in summer months), are known to produce neurotoxins that can be extremely injurious to fish. In general, diatoms and dinoflagellates co-dominate in the plankton biomass with the superimposition of an abundance of *Chattonella* in the warmer months (Dexter et al., 1998).

The Sea also has an abundance of various zooplankton species, dominated by the rotifers *Brachionus plicatilis* and *Synchaeta* sp., the copepod *Cyclops dimorphus*, planktonic larvae of the barnacle *Balanus* and the marine polychaete worm *Neanthes succinea*, and an assemblage of ciliate protozoans. Other common nektonic invertebrate organisms include brineshrimp (*Artemia franciscana*) and water boatmen (*Trichocorixa reticulata*), which are commonly found swimming at the surface of the water in protected embayments and isolated pools along the shore, where salinity is usually higher than in the main body of the Sea..

Several benthic invertebrate species are known to play an important role in the Salton Sea food chain. These include the amphipod *Gammarus mucronatus*, which has been shown to be an important food source of eared grebes and is presumably available to other bird species that feed in shallow waters; *Neanthes succinea*, whose free swimming larvae stage is the key linking the Sea's detrital food chain to fish and birds (Dexter et al., 1998); and *Balanus*, whose naupliar larvae is a food source for the gulf croaker *Bairdiella icistius*.

The Salton Sea fish community had its beginnings in 1929 with the introduction of about 25 marine species that were mainly taken from the Gulf of California near San Felipe. Of the species planted, only orangemouth corvina (*Cynoscion xanthulus*), bairdiella (*Bairdiella icistius*), and sargo (*Anisotremus davidsoni*) became established and flourished in the Sea. Later, in the early 1960s, tilapia (*Oreochromis* spp.) were accidentally introduced into the Sea and quickly became the dominant fish species in the Sea and the most important prey for the increasing numbers of piscivorous birds (Costa-Pierce, 1998). Several less abundant species of fish are also known to inhabit the Sea and its associated freshwater rivers and inlets, including the endangered desert pupfish (*Cyprinodon macularius*), the only fish species endemic to the Salton Sink.

Analysis. The northern part of the upper Gulf of California is considered among the most productive marine regions in the entire world. Its fertility mainly results from its hydrodynamic properties, characterized by strong surface and tidal currents (> 3m/sec) and extremely shallow zones, which promote extensive vertical mixing and upwelling of the nutrient-laden bottom waters (Alvarez-Borrego, 1983). The waters of the upper Gulf exhibit variable levels of productivity, with the west side of the upper Gulf being the more biologically productive zone and exhibiting greater biotic diversity (Thomson, 1969).

Walker (1960) identified 22 species of fish endemic to the upper Gulf that inhabit waters of moderate depth (5 – 100m), including the totoaba (*Totoaba macdonaldi*), the only marine fish in the world considered in danger of extinction. In addition, three species of endemic grunion are also found in relatively shallow waters of the upper Gulf. At least ten species of marine mammals have been recorded in the Gulf of California, including the endangered vaquita (*Phocoena sinus*), the only cetacean species endemic to Mexico, whose range is seemingly restricted to the extreme northern Gulf of California corresponding with waters of the Biosphere Reserve.

Besides being an important reproduction and nursery area for many other species, the upper Gulf is also important for its commercial fishery consisting of shrimp, shark, sardine, and other species that form the economic backbone for the entire upper Gulf region.

Conclusions.

Introduction of Hazardous Wastes

Background.

Analysis.

Conclusions.

Nutrient Loading

Background.

Analysis.

Conclusions.

GENERAL COMMENTS AND CONCLUSIONS

FIGURES

Figure 1 – Proposed Pipeline Routes to the Gulf of California and the Pacific Ocean.

Figure 2 – Potential Pump-out Routes: Salton Sea to the Gulf of California

Figure 3 – Potential Pump-out Routes: Salton Sea to the Pacific Ocean

References

Alvarez-Borrego, S., 1983. Gulf of California. In: Ketchum, B.H. (Ed), Estuaries and Enclosed Seas. Elsevier Scientific Publishing Company. Chapter 17 (1-23), pp. 427-449.

Argote, M.L., A. Amador, M.F. Lavin, J.R. Hunter, 1995. Tidal Dissipation and Stratification in the Gulf of California. Journal of Geophysical Research, Vol. 100, No. C8, pp. 16, 103-16, 118.

California Coastal Commission. Seawater Desalination in California. Chapter 3: Potential Environmental Impacts/Coastal Act Issues. October 1993, pp. 1-14.

CICTUS, et al., 1994. Management Program for the Biosphere Reserve of the Upper Gulf of California and the Colorado River Delta. The Center for Scientific and Technological Research. University of Sonora. June 1994, pp. 1-59.

Costa-Pierce, B., 1998. Final Synthesis Document – Fish and Fisheries of the Salton Sea. Institute of Marine Science, University of Southern Mississippi.

Dexter, D.M., M.A. Tiffany, K. Reifel, and S.H. Hurlbert, 1998. A Synthesis of Our Knowledge of the Biological Limnology of the Salton Sea. Center for Inland Waters and Department of Biology, San Diego State University.

Duxbury, A.C., 1971. The Earth and its Oceans. Addison-Wesley Publishing Company. Chapter 6 (1-18), pp. 114-121.

Foster, M.S., and D.R. Schiel, 1985. The Ecology of Giant Kelp Forests in California: A Community Profile. U.S. Fish and Wildlife Service Biological Report 85. 152pp.

FWQA, 1970. Salton Sea, California. Water Quality and Ecological Management Considerations. U.S. Department of the Interior, Federal Water Quality Administration, Pacific Southwest Region.

Hammond, M.A., N.J. Blake, C.W. Dye, and D.A. Tomasko, 1998. Effects of Seawater Reverse Osmosis Concentrate on Marine Benthic Communities. In: Proceedings of the American Desalting Association, "*The Desalting Revolution.*" August 1998, pp. 3-14.

Holdren, C.G., 1999. Literature Review: Chemical and Physical Analyses of the Salton Sea, California. U.S. Department of the Interior, Bureau of Reclamation, Denver. Unpublished information.

Horn, M.H., and L.G. Allen, 1978. A Distribution Analysis of California Coastal Marine Fishes. Journal of Biogeography 5: 23-42.

Lavin, M.F., V.M. Godinez, and L.G. Alvarez, 1998. Inverse-estuarine Features of the Upper Gulf of California. Estuarine, Coastal and Shell Science (1998) 47, pp. 769-795, Report No. ec980387.

Meiorin, L., 1995. Marine Wastewater Disposal – Presentation to the XI Peruvian Congress of Sanitary and Environmental Engineering, 30 October – 03 November 1995, Cusco, Peru. November 1995, pp. 1-8.

Meiorin, L. and R.N. Pissani, 1997. Environmental Evaluation of Treatment/Discharge Alternatives for the City of Lima, Peru. Parsons Engineering Science, Inc. La Jolla, California.

San Diego Metropolitan Wastewater Department. Annual Reports on Ocean Monitoring Program for Point Loma Ocean Outfall.

San Diego Metropolitan Wastewater Department. Web pages: Point Loma Wastewater Treatment Plant and South Bay Ocean Outfall, from: http://www.sannet.gov/mwwd//general/facilities.html, and Ocean Monitoring Program, from http://www.sannet.gov/mwwd/community/oceanmon.html.

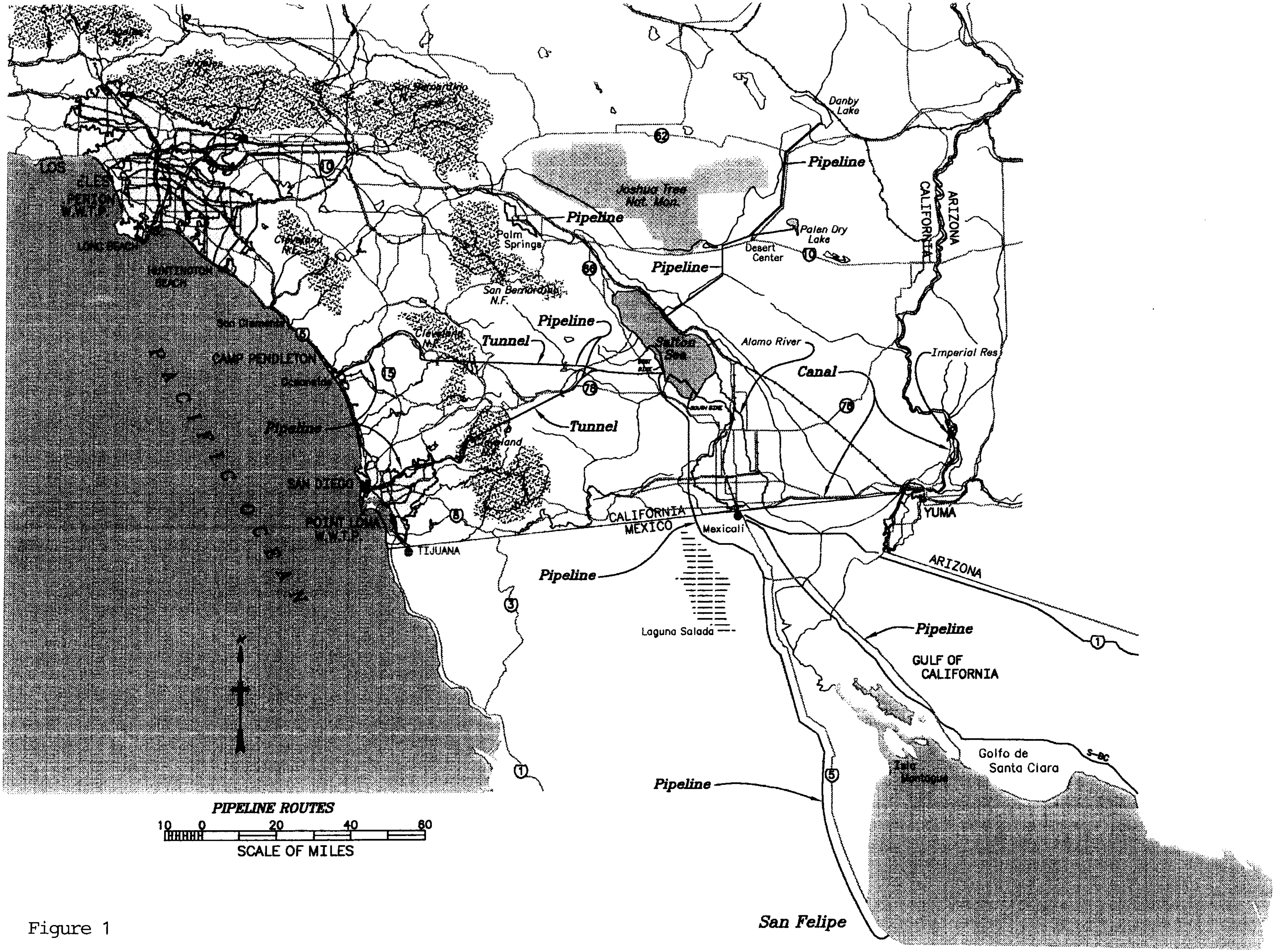
Smith, S.R., 1995. Final report on the marine environmental impact of the Watlington Water Works reverse osmosis plant. Bermuda Biological Station for Research, Inc. Ferry Reach, Bermuda.

Southern California Edision Company, 1998. Annual Marine Environmental Analysis and Interpretation; Report on 1997 Data. San Onofre Nuclear Generating Station.

Thomson, R.W., 1969. Tidal currents and general circulation. In: Environmental impact of brine effluents on Gulf of California. U.S. Report Insurance and Development Program Report No. 387.

USBR, 1999. Potential Export Options to the Gulf of California. U.S. Department of the Interior, Bureau of Reclamation, Lower Colorado Region. Unpublished data.

Walker, B.W., 1960. The distribution and affinities of the marine fish fauna of the Gulf of California. In Symposium: The biogeography of Baja California and adjacent Seas. Part II. Marine Biotas. Syst. Zool. 9(3):123-133



LOS
ANGELES
PERION
W.W.T.P.
LONG BEACH
HUNTINGTON
BEACH
San Clemente
CAMP PENDLETON
Oceanside
Pipeline
SAN DIEGO
POINT LOMA
W.W.T.P.
TIJUANA
Cleveland
N.F.
Palm
Springs
San Bernardino
N.F.
Joshua Tree
Nat. Mon.
Pipeline
Pipeline
Pipeline
Tunnel
Tunnel
Salton
Sea
Alamo River
Canal
Danby
Lake
Palen Dry
Lake
Desert
Center
CALIFORNIA
ARIZONA
Imperial Res
YUMA
CALIFORNIA
MEXICO
Mexicali
Pipeline
Laguna Salada
ARIZONA
Pipeline
GULF OF
CALIFORNIA
Golfo de
Santa Clara
Pipeline
San Felipe
PIPELINE ROUTES
10 0 20 40 60
SCALE OF MILES

Figure 1