ATTACHMENT 15

Technical Rationale and Supporting Documentation for a Proposed Water Quality Objective for Dissolved Oxygen in South San Diego Bay

Prepared for

San Diego Gas and Electric Company
101 Ash Street
San Diego, California 92112-4150

Prepared by

Applied Science Associates
291 County Route 62
New Hampton, New York 10958

February 1998

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February 27, 1998

FILE NO. SFH 400.330.263

Mr. John Robertus
California Regional Water Quality Control Board
San Diego Region
9771 Clairemont Mesa Blvd., Suite A
San Diego, Ca 92124-1331

Subject: **Proposed Basin Plan Amendment for a Dissolved Oxygen Water Quality Objective in South San Diego Bay**

Dear Mr. Robertus:

As required by, and in satisfaction of, Reporting Requirement F.18 of Order No. 96-05, NPDES Permit No. CA0001368, San Diego Gas & Electric Company hereby submits a proposed Basin Plan Amendment for a water quality objective for dissolved oxygen in south San Diego Bay (see the enclosed report). This submittal was developed by Applied Sciences Associates, and is based on a thorough review of the physiography, hydrology and aquatic habitats of south San Diego Bay, including an analysis of the factors influencing dissolved oxygen concentrations, and the designated beneficial uses of San Diego Bay. Supporting documentation for the proposed water quality objective is provided in the report.

Please do not hesitate to call myself (619-498-5212) or Fred Jacobsen (619-696-2511), if you have any questions concerning the enclosed report. We look forward to participating in the Basin Plan amendment process, along with other interested members of the public.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Scott N. Peterson
Acting Power Plant Manager

Enclosure

cc: EPA, Region IX

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EXECUTIVE SUMMARY

The Water Quality Control Plan for the San Diego Basin (Basin Plan) does not currently contain a water quality objective for dissolved oxygen in San Diego Bay. Recognizing the need for an appropriate water quality objective for dissolved oxygen in this area, the Regional Water Quality Control Board for the San Diego Region (RWQCB) has required San Diego Gas and Electric Company (SDG&E) to prepare the following:

> *As soon as possible, but no later than March 1, 1998, the discharger shall submit a proposed Basin Plan amendment, including adequate supporting documentation, for water quality objectives for dissolved oxygen in south San Diego Bay.* [Reporting Requirement F.18 of Order 96-05].

This document provides the technical rationale and required supporting documentation for SDG&E's proposed water quality objective for dissolved oxygen. This proposed objective was developed to provide for the protection of beneficial uses, as defined in the Basin Plan, in South San Diego Bay, from potential adverse effects of inadequate dissolved oxygen concentrations resulting from other than naturally-occurring events.

The South San Diego Bay Ecological Sub-Region encompasses that portion of San Diego Bay extending from the Sweetwater River channel to the extreme southern end of the Bay. Most of this section of the Bay is relatively shallow (< 5 ft MLLW), with maximum depths of approximately 20 ft (MLLW) in the limited dredged channel areas. Tidal currents in this area are limited, resulting in only minimal flushing by ocean waters, and the bottom is principally comprised of mud. The extensive intertidal habitats in this area are largely open mudflats, and much of the shallow subtidal habitat is covered either by an extensive mat of algae, and detrital materials, or by eelgrass beds. South San Diego Bay supports a majority of the Bay's habitats that remain unaltered by historic dredging and filling activities.

Available information demonstrates that the dissolved oxygen dynamics in South San Diego Bay are complex and concentrations of oxygen can be highly variable over a 24-hour period, a pattern not dissimilar to other productive bays and estuaries. Actual concentrations observed at any moment in time reflect the combined effects of factors which input oxygen to the water and factors which remove oxygen from the water. In South San Diego Bay, plants (phytoplankton, macroalgae, and eelgrass) are the overwhelmingly dominant factor controlling dissolved oxygen. During the day, plant photosynthetic activity adds oxygen to the water, resulting in increased oxygen concentrations. At night, respiration removes oxygen from the water, decreasing oxygen concentrations. These productions and consumptions of oxygen result in the wide diel swings in dissolved oxygen observed in South San Diego Bay. During the day, dissolved oxygen concentrations often reach supersaturated conditions, whereas during the night concentrations can drop well below saturation levels. Recent monitoring of dissolved oxygen concentrations in South San Diego Bay revealed concentrations less than 5 mg/l up to 38 percent of the time, depending upon location, principally due to the respiration of plants.

Both numeric and narrative water quality objectives were considered for dissolved oxygen in South San Diego Bay as part of this effort. A detailed review was conducted of numeric water quality objectives for dissolved oxygen from other areas. However none of these numeric objectives is based on species representative of Southern California bays and estuaries or account for the complex natural dynamics of dissolved oxygen levels observed in South San Diego Bay and similar enclosed bays and estuaries. Further, at the present time, there is inadequate information to develop a scientifically sound numeric criterion based on oxygen tolerance for species inhabiting Southern California bays and estuaries.

Accordingly, the following narrative water quality objective for South San Diego Bay is proposed:

> *The dissolved oxygen concentrations of South San Diego Bay shall not be depressed to levels that adversely affect beneficial uses as a result of controllable water quality factors.*

By definition, this water quality objective is protective of the beneficial uses of South San Diego Bay from the potential adverse effects of low dissolved oxygen resulting from other than naturally occurring events. Analysis of available information demonstrates that all designated beneficial uses of the Bay are being protected and hence, this proposed water quality objective for dissolved oxygen is currently being achieved.

1. INTRODUCTION

Oxygen is vital to most organisms. Unlike in the terrestrial environment, oxygen can often be an important limiting factor in the aquatic environment. Consequently, the availability of adequate dissolved oxygen is critical for the growth, survival and reproduction of organisms within aquatic ecosystems, such as found in San Diego Bay. It is for this reason that, historically, many of the efforts towards water quality protection and improvement have focused on factors which can act to limit the concentrations of dissolved oxygen within the Bay's waters. Without adequate dissolved oxygen, maintenance of a healthy aquatic ecosystem would be impossible, and the resulting anaerobic conditions could lead to the production of odorous and toxic substances, such as hydrogen sulfide.

The Water Quality Control Plan for the San Diego Basin (Basin Plan) is the primary vehicle through which water quality in the Region is managed. As required by both Federal and State regulations, the Basin Plan defines beneficial uses for the Bay and establishes water quality objectives which are designed to reasonably protect these beneficial uses. In accordance with federal regulations, the beneficial uses designated for San Diego Bay, are those uses actually attained in the Bay on or after 28 November 1975. Consequently the beneficial uses for San Diego Bay which are designated in the Plan, reflect the effects of all conditions existing on or before that date.

This Basin Plan currently contains dissolved oxygen objectives for inland surface waters and for ocean waters (the latter by adoption of the dissolved oxygen objectives promulgated in the California Ocean Plan), but does not contain an objective for enclosed bays or estuaries such as San Diego Bay.

Recognizing the need for an appropriate water quality objective for dissolved oxygen in South San Diego Bay, the Regional Water Quality Control Board for the San Diego Region (RWQCB) required San Diego Gas and Electric Company (SDG&E) to conduct the following:

> *As soon as possible, but no later than March 1, 1998, the discharger shall submit a proposed Basin Plan amendment, including adequate supporting documentation, for water quality objectives for dissolved oxygen in south San Diego Bay.* [Reporting Requirement F.18 of Order 96-05]

This Order (NPDES Permit No. CA 0001368) is for the South Bay Power Plant which uses water from South San Diego Bay for cooling purposes.

The South San Diego Bay Ecological Sub-Region is at the extreme southern end of the Bay. This fact, coupled with the Bay's shallow nature, high productivity, and limited tidal flushing, creates a highly variable natural environment. Special consideration of the uniquely transient dissolved oxygen environment is essential for the protection of beneficial uses of these shallow habitats.

This document provides the technical rationale and required supporting documentation for SDG&E's proposed water quality objective for dissolved oxygen. The intent of this proposed objective is to provide for the protection of beneficial uses in South San Diego Bay from potential adverse effects of inadequate dissolved oxygen concentrations resulting from other than naturally-occurring events. The Basin Plan identifies 13 beneficial uses, each of which was achieved as of 28 November 1975 and continues to be achieved today.

A description of the physical characteristics, aquatic habitats, and designated beneficial uses of South San Diego Bay is provided in Chapter 2 of this report. Next, a discussion of the current status and dynamics of dissolved oxygen within South San Diego Bay is presented in Chapter 3. Finally, the proposed water quality objective for dissolved oxygen in South San Diego Bay is presented in Chapter 4. This proposed objective is based on applicable and relevant Federal and State guidance and regulations. A discussion on the current status of conditions within this portion of the Bay relative to this proposed water quality objective is also included.

2. SUMMARY OF SOUTH SAN DIEGO BAY ENVIRONMENT

This section of the report provides a brief summary of the environmental conditions within San Diego Bay with particular emphasis on the southern end of the Bay. This information is used as a foundation for selection of an appropriate water quality standard for dissolved oxygen in South San Diego Bay.

2.1 PRESENT CONDITIONS

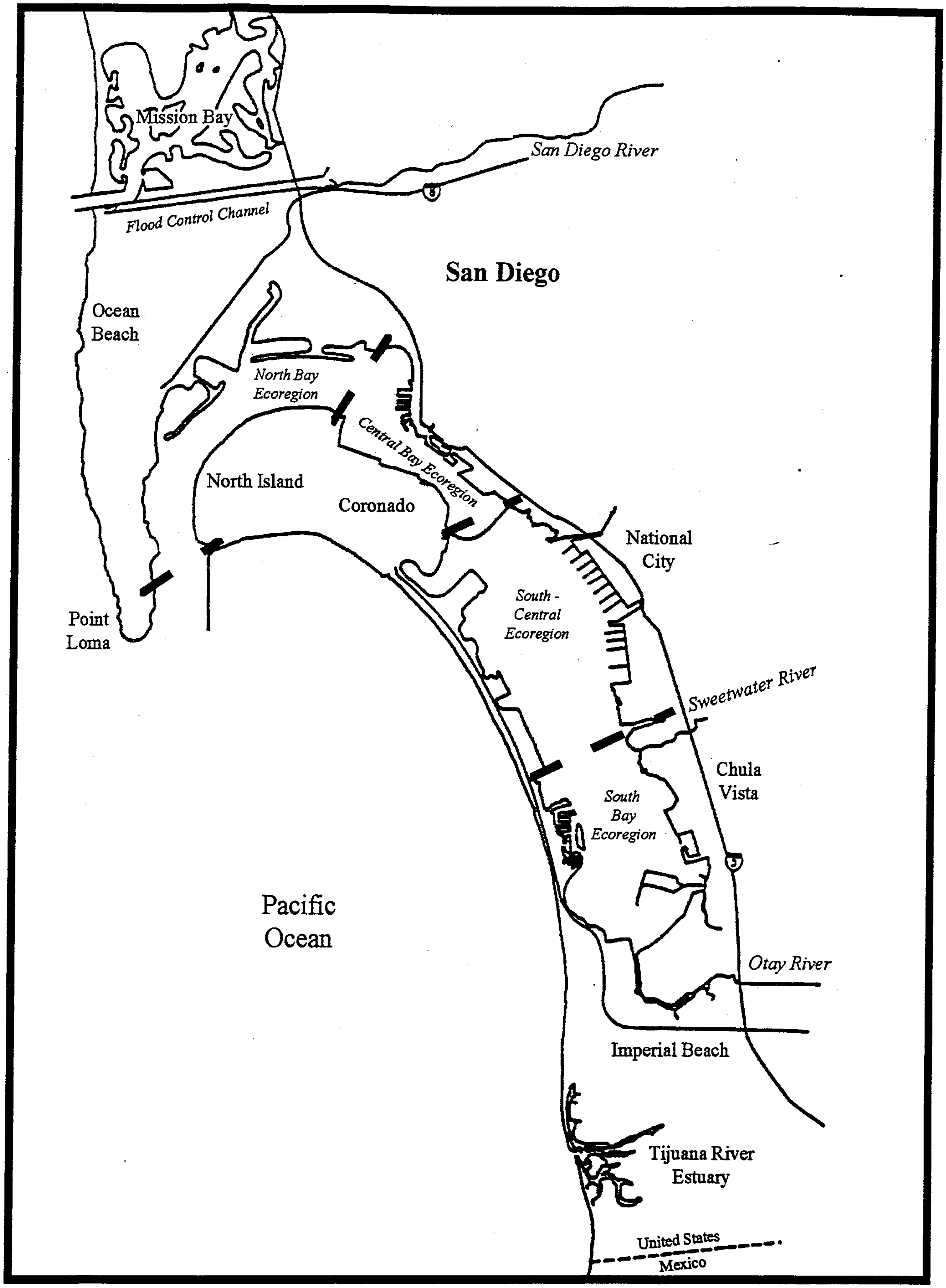
2.1.1 Physiography and Hydrology

San Diego Bay is the largest semi-enclosed marine embayment located along the 900-mi stretch of coast between San Francisco, to the north, and Scammon's Lagoon in central Baja, California, to the south. This natural, crescent-shaped embayment is located approximately 5 mi north of the United States and Mexico international border (Michael Brandman Associates, Inc. 1990). The Bay, which is bounded by the cities of San Diego, Coronado, National City, Chula Vista, and Imperial Beach, is commonly divided into four ecological regions (North, Central, South-Central, and South), each with a unique combination of environmental conditions (Figure 2-1).

San Diego Bay is approximately 14 mi long and ranges between 0.3 and 2.5 mi wide (Michael Brandman Associates, Inc. 1990; SDG&E 1980). Most of the southern portion of the Bay is relatively shallow with depths typically in the range of 0 to 8 ft below mean low low water (MLLW), except in dredged channels (Ford and Chambers 1974; Michael Brandman Associates, Inc. 1990). In North San Diego Bay, water depths generally exceed 30 ft MLLW and may reach 70 ft MLLW near the inlet to the Pacific Ocean. The bottom of the Bay and its margins consists principally of sand, silt, clay, and mud or mudstone. Sands are most common near the inlet to the ocean and along the ocean side of the Bay whereas silts and muds predominate in South San Diego Bay and along the eastern side of the Bay (SDG&E 1980).

There are two daily tidal cycles within the Bay with an average tidal range of 3 to 5 ft, although under tidal extremes ranges can be twice that amplitude. At mean tide level, the surface area of the Bay is estimated at approximately 18 mi^2 and the water volume at slightly more than 60 billion gallons (USACE 1974, in Michael Brandman Associates, Inc. 1990). The tidal prism (volume of water between MHHW and MLLW) in the Bay is approximately 20 billion gallons, or about one-third of the total volume of the Bay.

Water movements within most of the Bay are predominantly a result of tidal action, except during periods of high wind. Current speeds are markedly lower in the southern portion of the Bay ($\leq$ 0.1 m/second) than they are near the inlet to the ocean (0.6 - 0.8 m/second) (SDG&E 1980; Michael Brandman Associates, Inc. 1990) . These tidal currents are principally responsible for the continual flushing of San Diego Bay although, as a result of the reduced current speeds in South San Diego Bay, flushing rates in this area of the



Adapted from: Ford (1994).

Figure 2-1. San Diego Bay and It's Ecological Sub-Regions.

Bay are low (Michael Brandman Associates, Inc. 1990). As a result of the relatively large tidal volume, small-scale local mixing appears to be substantial throughout the Bay.

Owing to its relatively narrow entrance, San Diego Bay is well protected from the intrusion of ocean waves, although local winds generate steep, short waves or chop within the Bay (SDG&E 1980). While rarely exceeding 2-3 ft in height, these wind-generated waves can stir up bottom sediments in shallow areas leading to increased turbidity, especially in the southern areas of the Bay.

As a result of relatively dry climatic conditions, San Diego Bay is rarely subject to the influx of large quantities of freshwater and subsequent dilution of Bay waters. As a result, salinities near the inlet to the Bay are similar to that of the adjacent ocean waters whereas in South San Diego Bay, high evaporation often produces slightly hypersaline conditions. Even during rare storm events, runoff rates are low compared to the tidal transport of seawater and, thus, resulting effects on salinity within the Bay tend to be localized and, at most, transient.

SDG&E's South Bay Power Plant is located at the extreme southeastern corner of the Bay and uses water from South San Diego Bay for cooling purposes. The plant began commercial operation in 1960 with the last unit being completed in 1971. The plant is, thus, considered part of the existing environmental conditions within the Bay for the purposes of assessing impacts on beneficial uses. SDG&E's permit specifically finds that:

> *Since all the existing units of the South Bay Power Plant were in commercial operation before that date [28 November 1975], it is reasonable to conclude that the beneficial uses (and characteristics of the beneficial uses) of San Diego Bay actually attained on and after that date coexisted with the South Bay Power Plant discharge.* [Finding No. 25.]

This plant has a maximum cooling water flow of 601 million gallons per day. Cooling water is withdrawn through a common intake basin and returned to the Bay through a discharge cooling channel. This discharge channel is separated from the intake channel by an earthen dike. Operation of the plant's cooling water system increases water circulation within the far reaches of the Bay.

2.1.2 Aquatic Habitats

Four general categories of aquatic habitat exist within San Diego Bay, vegetated and unvegetated subtidal, intertidal sand and mudflats, intertidal saltmarshes, and salt ponds, which form an overall north-to-south habitat gradient within the Bay. Each of these habitat categories is discussed in detail by Ford (1994) and is briefly summarized below. As discussed in the subsequent subsection, the aquatic habitats within the Bay reflect the considerable habitat altering activities by humans, especially within the past century.

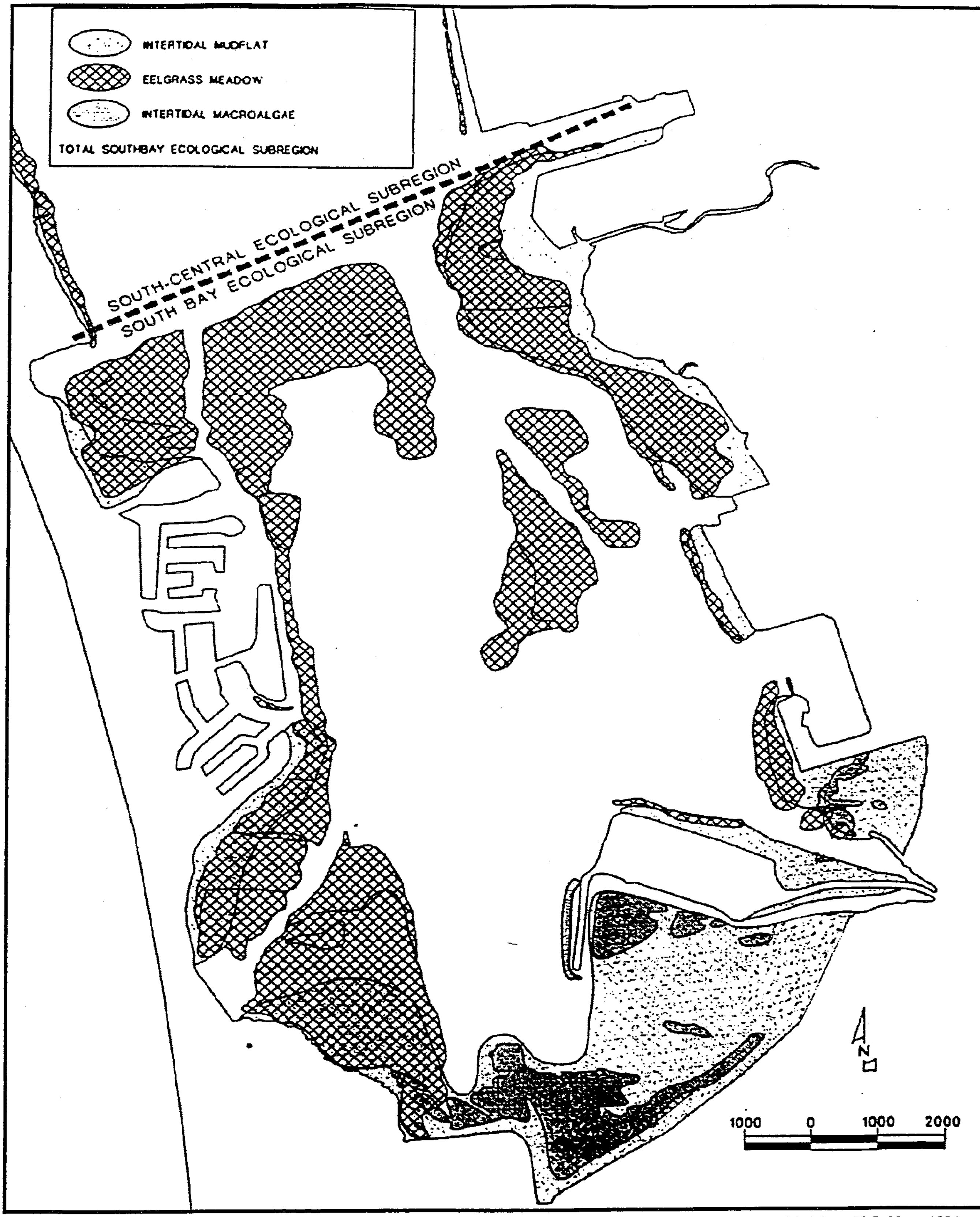
There are slightly more than 10,000 acres of subtidal habitat within San Diego Bay at present. This represents more than 82 percent of the total available aquatic habitat (i.e., subtidal plus intertidal) in the Bay. More than 80 percent of this subtidal habitat is greater than 6 ft deep (MLLW) and predominantly found within dredged areas and naturally deeper areas of the north and central areas of the Bay. Most of the shallow subtidal habitat is found within South San Diego Bay.

Intertidal sand and mudflats presently comprise approximately 766 acres, almost all of which occur within South San Diego Bay. These habitats are exposed to air during some portion of the tidal cycle. Tidal saltmarshes are also found within intertidal areas. At present, approximately 250 acres of the once extensive saltmarsh habitat remain within San Diego Bay, almost all of which is associated with the Sweetwater River-Paradise Creek complex in South San Diego Bay.

Saltponds are a man-made aquatic habitat created by diking the once expansive intertidal mudflats of South San Diego Bay. These ponds currently total 1,252 acres and are used for the solar evaporation of seawater to produce salt and minerals. While providing important bird habitat for the region, these ponds are isolated from normal water exchange with the Bay.

South San Diego Bay presently contains the majority of unaltered natural habitats remaining within the Bay. Most of this section of the Bay is relatively shallow (< 5 ft MLLW), with maximum depths of approximately 20 ft (MLLW) in the limited dredged channel areas (Figure 2-2). Much of the shallow subtidal habitat in South San Diego Bay is covered by an extensive mat of algae and detrital materials. Although varying seasonally and across years, this mat can exceed 1 ft thick during summer in some areas. Red and green algae, along with associated bryozoan colonies, typically comprise this plant mat which, in turn, provides habitat and food for a variety of benthic invertebrate animals and fish.

Another important habitat within shallow subtidal and lower intertidal areas of South San Diego Bay are the eelgrass beds. Eelgrass is a seed-bearing vascular plant inhabiting shallow, sheltered substrates. Of the 1,260 acres of eelgrass mapped in the Bay (U.S. Navy 1994), nearly 60 percent occur within South San Diego Bay. These plants are rooted in surface sediments and derive nutrients through root hairs. In South San Diego Bay, eelgrass is limited to water depths of 3 - 6 ft below MLLW, or less, owing to the high wind-induced turbidity in this portion of the Bay. These eelgrass beds provide important habitat for a variety of invertebrate and fish species in this portion of the Bay and further help to stabilize sediments against resuspension. Eelgrass is a significant contributor to overall primary productivity and assists in supporting the detritus-based food web in the South San Diego Bay ecosystem.



modified from U.S. Navy 1994

Figure 2-2. Aquatic habitats within South San Diego Bay

Salt marshes are also found within intertidal areas of South San Diego Bay, the largest of which is the Sweetwater Marsh. These saltmarshes are dominated by salt-tolerant vascular plants such as cordgrass, glasswort, beach lotus, and yerba buena. These saltmarshes form a complex of high and low marshes together with associated tidal creeks.

The remaining intertidal areas within South San Diego Bay are mudflats which are common in the most southern portion of this area. These mudflats are exposed to air and sunlight on a regular basis at low tides. These mudflats provide important feeding habitat to a variety of shorebirds and waterfowl.

2.1.3 Aquatic Communities

The biological community within San Diego Bay is comprised of a dynamic mix of marine species, which utilize the Bay as spawning, nursery, or feeding habitat, and other species which spend their entire life cycle within the shallow, protected waters of the Bay. The actual composition of this community varies throughout the year, following the natural seasonal cycles of the individual species, and spatially as a result of differences in habitat characteristics within the Bay. For example, as just discussed, there is a gradient in physical habitat conditions within the Bay from deeper, sandy bottom habitat in the north end of the Bay near the connection with the ocean to shallow, predominantly mud bottom habitat in the southern portion of the Bay. Similarly, as discussed in the previous subsection, the generally less variable, clear, cooler and low nutrient levels of waters in the north Bay near the connection to the ocean gradually transition to a more variable environment. Higher average temperatures, with more significant daily and seasonal variability, are associated with the combined influences of solar radiation and cooling water discharge. Similarly, turbidity, salinities, and nutrient concentrations are also elevated on average and less stable due to reduced tidal flushing, non-point surface runoff from the Basin, and roiling action of wind-driven waves on the mud flats. As a result of this gradient in physical and chemical environmental conditions, the assemblage of species comprising biological communities within the Bay also exhibits considerable spatial variability. The community in the northern part of the Bay is dominated by species typical of nearshore ocean habitats (e.g., northern anchovy, surfperches, and jack mackerel), whereas the community in the southern portion of the Bay is comprised of species best typifying the more variable, and generally warmer, more turbid, and higher salinity waters characteristic of that habitat (e.g., striped mullet, slough anchovy, round stingray, and California killifish).

Studies on the biological communities within South San Diego Bay reveal a healthy, fully functioning ecosystem. The benthic macroinvertebrate community within this portion of the Bay appears stable and similar to that observed in other back bays along the California coast (EA 1995). The clams, crustaceans, and polychaete worms, which are numerically dominant, provide an important food resource for fish and birds inhabiting the area. Similarly, the fish community is also similar to that observed in other back bays along the California coast (Michael Brandman Associates, Inc. 1990; Ford 1994). In addition to fish and invertebrates, South San Diego Bay serves as important habitat for a variety of shorebirds and waterfowl (Michael Brandman Associates, Inc. 1990). Many of these birds are fall migrants from northern breeding grounds that winter in this section of the Bay. While in residence, these birds feed on the abundant invertebrates and small fish found in the shallows of South San Diego Bay. Finally, South San Diego Bay provides year-round habitat to green turtles, which are federally listed as a threatened species. These turtles are able to survive in the area as a result of the warm water from the South Bay Power Plant which keeps winter water temperatures within a tolerable range for these species. These turtles feed on the eelgrass, other seagrasses, and macro-algae in this portion of the Bay.

2.2 HISTORICAL ENVIRONMENTAL PERTURBATIONS

2.2.1 Habitat Alterations

San Diego Bay has been subject to considerable habitat alterations since the mid-1800's, principally through dredging and filling. These alterations, which are discussed in detail by Michael Brandman Associates (1990), are summarized below.

Large-scale alterations of the Bay began when the San Diego River was permanently diverted from the Bay and development began along the shoreline and on piers out into the Bay in the late 19th century. In the early 20th century, the human population in the area began to increase rapidly and with it came extensive shoreline development. From the 1920's to 1960's there was considerable filling and dredging of the Bay, especially in the northern and central areas. As a result, once extensive mudflats and saltmarshes in these areas were filled for airfields, ship terminals, shipyards, and highways. There was also considerable alteration of subtidal habitat through dredging during this interval. Subsequently, filling of intertidal areas has been substantially reduced, although periodic maintenance dredging of selected areas of the Bay continues.

As a result of man's activities there has been an overall loss of aquatic habitat in San Diego Bay of more than 30 percent. In addition, a dramatic shift has occurred in habitat composition from a system dominated by intertidal and shallow subtidal habitat in its natural state to one dominated by deeper subtidal habitat. This shift is especially prevalent in the northern and central areas of the Bay where little of the former intertidal and shallow subtidal habitat remains. It is likely that dredging and development of the shoreline areas resulted in substantial alteration of the hydrologic characteristics of the Bay and likely reduced overall biotic productivity of the Bay especially in the northern and central areas. Species typical of shallow warm bays were substantially displaced by species with less specific affinities.

South San Diego Bay was less affected by these development activities than elsewhere in the Bay. Recently, considerable efforts have been expended towards protection and enhancement of the remaining natural habitats within this section of the Bay. The principal areas of filling in this section of the Bay are associated with the Chula Vista Marina and the creation of the Chula Vista Wildlife Island. Recent dredging activities in this area are principally associated with entrance channels to marinas and the intake channel to the South Bay Power Plant. The most significant habitat alteration in South San Diego Bay was the creation of more than 1,250 acres of salt ponds at the extreme southern end of the Bay. These evaporation ponds were largely created in the early 1900's by diking of saltmarsh and intertidal habitats. This process effectively isolated these areas from the Bay's ecosystem and is likely to have further moderated the environmental variability in salinity, temperature, and dissolved oxygen normally seen in large shallow embayments.

2.2.2 Water Quality

Recent summaries of the history of water pollution in San Diego Bay provide a view of the temporal pattern of pollutant loadings to the Bay from municipal sewage and food processing industry (Michael Brandman Associates 1990; Ford 1994). The use of San Diego Bay as a receptor of waste materials increased dramatically with the increase in population growth, beginning in the early 1900s. Municipal sewage and industrial wastes were discharged into the Bay in untreated form, and began to cause serious problems in water quality by the mid-1930s. By 1941, the number of untreated sewage systems and outfalls that discharged directly into San Diego Bay had increased to at least 15 (CRWQCB 1952).

Although various measures were taken, beginning in the mid-1940s, to provide primary treatment and disinfection of the primary waste discharges to San Diego Bay, obvious and serious degradation in water quality continued up to 1963. At this time, 56 million gallons per day of domestic waste was being discharged into the Bay. High bacterial counts had caused the State Board of Health and the San Diego County Department of Public Health to declare much of the Bay contaminated and to post quarantine and warning signs. Persistent phytoplankton blooms caused by the heavy loadings of nutrients made the waters in much of the Bay highly turbid and discolored to various shades of green and red. Sludge deposits several feet thick covered the bottom of the Bay along more than 25,000 ft of the eastern shoreline.

These heavily polluted conditions caused an oxygen demand, or consumption rate, that exceeded the natural oxygen replacement, or generation rate, resulting in widespread and severe reduction in dissolved oxygen levels in the Bay. Studies conducted during the 1950s indicate that these depressed dissolved oxygen levels, and other conditions created by the heavy pollutant loadings, were inadequate to support the natural community of marine life. Detailed studies of the flora and fauna of San Diego Bay during this period of severe water quality degradation (1930's-1963) were limited in number, in part because the pollution effects were so obvious. However, the available information shows that the species composition and biomass of benthic invertebrates and fish were very low in comparison to unpolluted bay communities, and to communities present in San Diego Bay both before and after this period (Newman 1958; CRWQCB 1952; Ford 1994).
The diversion of all domestic sewage effluents from the Bay to a new ocean outfall between August 1963 and February 1964 abruptly reversed the long period of water

quality degradation in San Diego Bay. The reversal continued in subsequent years as the Regional Water Quality Control Board for the San Diego Region (Regional Board) regulated discharges from the remaining pollution sources through the National Pollution Discharge Elimination System (NPDES) and State water quality programs. The last of the significant industrial discharges was diverted from the Bay in 1969, and nearly all of the Navy discharges were eliminated by the early 1970s (U.S. Navy Civil Engineering Laboratory 1972; CRWQCB 1985).

Water quality conditions in the Bay improved dramatically following removal of the major pollution discharges. Water clarity improved and dissolved oxygen increased to levels sufficient to support a natural marine community typical of such enclosed back-bay areas (Ford 1994). In response to the improved water quality, a wide variety of marine organisms repopulated San Diego Bay and, in fact, almost all of the original species described from the Bay in the late 1800s have now become re-established (Ford 1994). The pollution control successes in San Diego Bay have returned the Bay's dissolved oxygen dynamics to the control of natural environmental factors.

2.3 BENEFICIAL USES OF SAN DIEGO BAY

Beneficial uses are a cornerstone for the protection of the quality of the Nation's waters. Beneficial uses have their foundation in Section 303 of the federal Clean Water Act and in California's Porter-Cologne Water Quality Control Act. In California, these beneficial uses of surface and ground waters are designated by the State and Regional Board (CRWQCB 1994) as follows:

> *Beneficial uses of the waters of the state that may be protected against quality degradation include, but are not necessarily limited to, domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves.*

In 1979, the State Board adopted a uniform list and description of beneficial uses to be applied throughout the State. Two types of beneficial uses have been defined-- existing and potential. As defined by federal regulation, existing beneficial uses are those which have actually been attained since 28 November 1975. Potential beneficial uses are those which are achievable under reasonable water quality control, as determined by a "use attainability" analysis. All beneficial uses currently designated for the Bay are deemed to be existing in San Diego Bay and apply to all areas of the Bay including tidal sections of tributary streams and rivers. There are currently no potential beneficial uses identified for the Bay.

The 13 beneficial uses designated for San Diego Bay are defined in the Basin Plan (CRWQCB 1994) as follows:

- **Industrial Service Supply (IND)** - Includes uses of water for industrial activities that do not depend primarily on water quality including, but not limited to mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil-well re-pressurization.

- **Navigation (NAV)** - Includes uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

- **Contact Water Recreation (REC-1)** - Includes uses of the water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These include, but are not limited to, swimming, wading, water-skiing, skin and SCUBA diving, surfing, white water activities, fishing, or use of natural hot springs.

- **Non-contact Water Recreation (REC-2)** - Includes uses of the water for recreational activities involving proximity to water, but not normally involving body contact to water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

- **Commercial and Sport Fishing (COMM)** - Includes the uses of water for commercial or recreational collection of fish, shellfish, or other organisms including but not limited to, uses involving organisms intended for human consumption or bait purposes.

- **Preservation of Biological Habitats of Special Significance (BIOL)** - Includes uses of water that support designated areas or habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance (ASBS), where the preservation of natural resources requires special protection.

- **Estuarine Habitat (EST)** - Includes uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

- **Wildlife Habitat (WILD)** - Includes uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food resources.

- **Rare, Threatened, or Endangered Species (RARE)** - Includes uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered.

- **Marine Habitat (MAR)** - Includes uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).

- **Migration of Aquatic Organisms (MIGR)** - Includes uses of the water that support habitats necessary for migration, acclimatization between fresh and salt water, or the temporary activities by aquatic organisms, such as anadromous fish.

- **Shellfish Harvesting (SHELL)** - Includes uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sport purposes.

- **Spawning, Reproduction, and/or Early Development (SPWN)** - Includes uses of water that support high quality habitats suitable for reproduction, early development and sustenance of marine fish and/or cold water freshwater fish.

It is these 13 beneficial uses which any water quality objective for South San Diego Bay must protect. Beneficial uses of most relevance to the issue of dissolved oxygen are those involving the biotic communities of the Bay which includes the last 9 uses on the list above.

It is important to remember that not all portions of a waterbody are anticipated to achieve beneficial uses in exactly the same way. It is generally recognized that certain portions of San Diego Bay are more intensively developed in providing beneficial uses such as NAV, REC-1, REC-2, COMM, BIOL, etc. In fact, these beneficial uses are affected by various Federal, State, and local regulations and policies on Bay uses. Similarly, a wide variety of temporally and spatially distinct environments provide a composite of biological communities and uses which define many of the distinct biologically-defined, beneficial uses including EST, WILD, RARE, MAR, SHELL, MIGR and SPWN. Studies to characterize the Bay environments have revealed distinct aquatic habitats which define the Bays diverse biological communities (Allen 1996, Ogden 1996). All of these biological communities, while frequently differing in composition, diversity, and abundance of individual species, play a role in meeting the overall beneficial uses that define the Bay.

3. DYNAMICS OF DISSOLVED OXYGEN IN SOUTH SAN DIEGO BAY

This section provides an overview of the dynamics of dissolved oxygen in South San Diego Bay and resulting spatial and temporal patterns in dissolved oxygen concentrations. An understanding of these natural dynamics is important to the development of a scientifically sound water quality objective for dissolved oxygen in South San Diego Bay.

3.1 FACTORS INFLUENCING DISSOLVED OXYGEN CONCENTRATIONS IN WATER

Oxygen is essential to the metabolism of all aquatic organisms that respire aerobically. The concentration of oxygen dissolved in natural waters is determined through a balance of processes which add oxygen to the water or remove oxygen from it. As a result of these processes, the amounts of oxygen dissolved in water, and thus available to organisms, are quite variable from time to time and place to place. The actual quantity of oxygen that water can hold under the most favorable conditions is relatively low in comparison to that continuously available in the atmosphere. Because of the physical limit of oxygen solubility in water and the natural fluctuations in dissolved oxygen levels that occur, oxygen is frequently a limiting factor for aquatic life. Species comprising natural aquatic communities have adapted to the varying availability of oxygen in the waters they inhabit, and their behavior and distribution is, at least in part, a consequence of this adaptation.

The mechanisms that control dissolved oxygen concentrations are, therefore, important in relation to oxygen availability for utilization by an individual organism, as well as in relation to the overall oxygen regime required for maintaining natural biological communities. The oxygen supply in water comes chiefly from two sources: by diffusion from the air and as a product of photosynthesis by aquatic plants. Oxygen diffuses into water only very slowly, except when helped along by wind and water movements, while photosynthetic production of oxygen is primarily dependent on the biomass of plant material, available light, and temperature of the water. The sources of dissolved oxygen from the atmosphere and from photosynthetic inputs and the hydromechanical redistribution of oxygen by water flows are counterbalanced by metabolic consumption (i.e., biological oxygen demand), and to a lesser extent by chemical oxidation reactions (i.e., chemical oxidation demand). Dissolved oxygen is consumed by respiration in all multicellular animals and plants, as well as in aerobic single-celled organisms. However, the largest oxygen demand in natural waterbodies is generally associated with microbial decomposition of dead organic matter and respiration by aquatic plants, including single cell phytoplankton and multicellular algae and vascular plants.

The upper limit on dissolved oxygen concentration on a long-term basis is determined by the saturation level, or maximum solubility of oxygen in water at a given temperature, salinity and pressure. At sea level, the oxygen solubility decreases with increasing temperature of the water, and to a lesser extent, with increasing salinity. For example, the saturation levels for dissolved oxygen in seawater decrease from about 10 mg/L at 40°F to

6.6 mg/L at 80°F, while in freshwater dissolved oxygen levels would be approximately 1-3 mg/L higher. At times, high inputs of oxygen from photosynthesis or rapid temperature elevations may cause dissolved oxygen concentrations in natural waters to exceed theoretical saturation levels, a condition called supersaturation. Supersaturated conditions are typically transient and the physical processes of diffusion and aeration tend to return concentrations toward equilibrium saturation levels.

3.2 FACTORS AFFECTING DISSOLVED OXYGEN CONCENTRATIONS IN SOUTH SAN DIEGO BAY

Concentrations of dissolved oxygen in South San Diego Bay result from a balancing of inputs and outputs from the water column. A variety of factors have been identified which tend to add oxygen or remove oxygen from the water (Figure 3-1). As discussed in this section, it is the interaction of these factors which determines the actual concentrations of dissolved oxygen in this section of the Bay at any moment in time.

The primary physical mechanisms expected to add oxygen to South San Diego Bay waters are inflow from the ocean during tidal exchanges, wind-induced aeration, and possibly inflow from rainfall and runoff, the major sources being the Otay and Sweetwater River drainages. The extensive beds of eelgrass and benthic algae in South San Diego Bay undoubtedly serve as major photosynthetic sources of oxygen, along with more transient phytoplankton.

Runoff from rainstorms may also deplete oxygen in South San Diego Bay by dilution, if the inflowing waters contain lower dissolved oxygen levels than the Bay waters. Also, runoff may introduce organic loads that deplete oxygen as a result of their biological and chemical oxygen demands, and wind-induced turbulence may resuspend sediments with oxygen demand. In addition, oxygen may be depleted by off-gassing caused by rapid temperature increases in the Bay. For example, the warming of shallow areas of South San Diego Bay could reduce oxygen solubility and lead to potential off-gassing of oxygen under supersaturated conditions. Finally, respiration by plants and animals will remove oxygen from the water. Respiratory consumption by eelgrass and micro- and macro-algae, and detrital decomposition, are likely to be dominant factors controlling oxygen consumption in South San Diego Bay.

Because of the relatively low rates of tidal flushing, oceanic input of oxygen is not expected to dominate the oxygen dynamics of South San Diego Bay as it typically might in more open bays with higher rates of tidal exchange. Because of the relatively infrequent occurrence of major riverine inputs to South San Diego Bay, the inflow of freshwater is also not likely to dominate the system except on an episodic basis. During such inputs, dissolved oxygen may be driven down by high organic loading, or may rise as a result of decreased salinity and consequent increased oxygen solubility. A more balanced influence of all the factors listed in Figure 3-1 likely occurs, with significant swings in dissolved

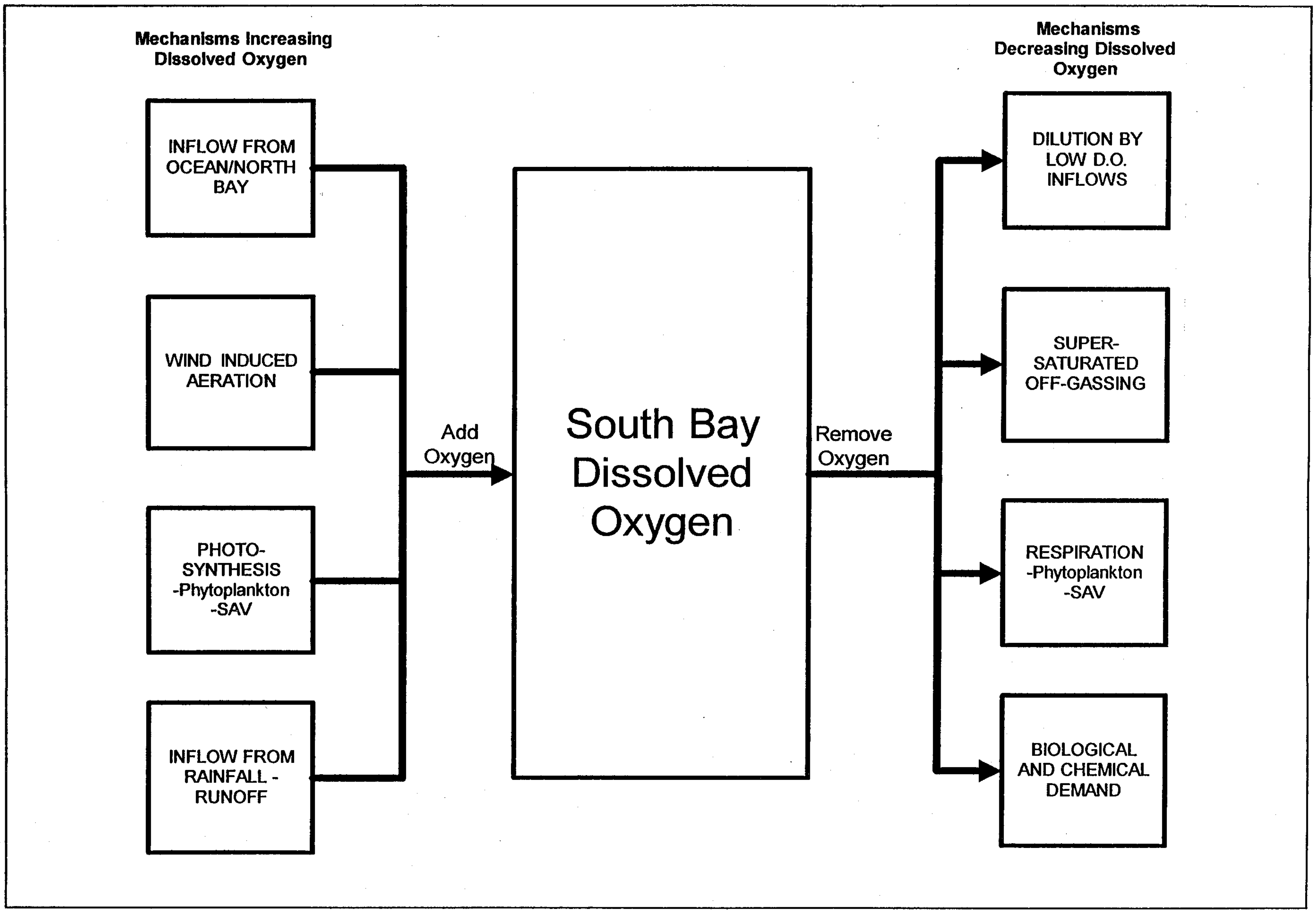


Figure 3-1. Factors Potentially Affecting Dissolved Oxygen Concentrations within South San Diego Bay

oxygen levels possibly resulting from meteorology, tidal stage, and especially diel and seasonal cycles in the relative magnitudes of photosynthesis and respiration.

3.3 OBSERVED DISSOLVED OXYGEN DYNAMICS IN SOUTH SAN DIEGO BAY

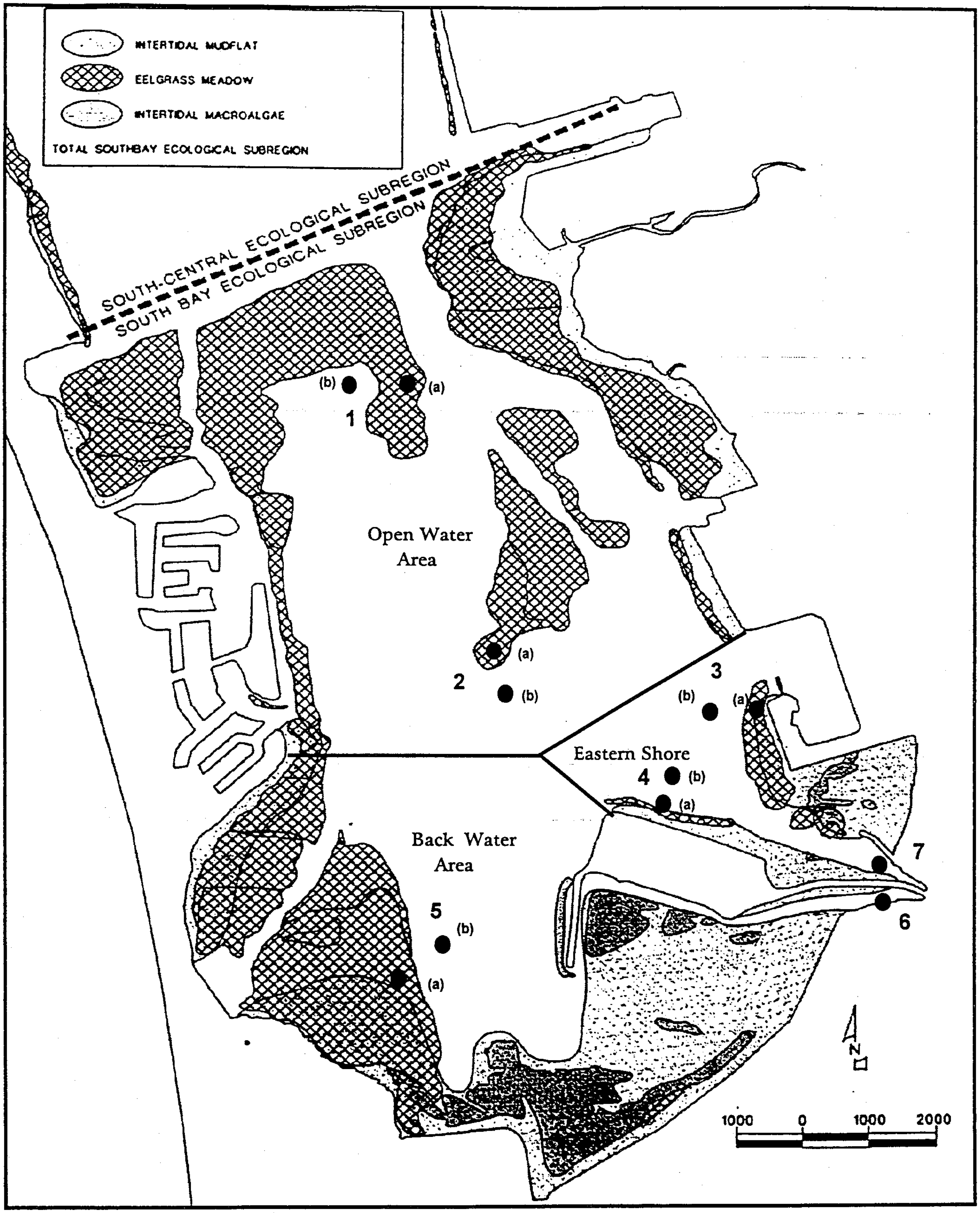
Despite the importance of adequate dissolved oxygen for a healthy ecosystem, historical information relative to the spatial and temporal patterns in dissolved oxygen concentrations in South San Diego Bay is limited. Synoptic water quality surveys conducted annually at 11 stations throughout the southern portion of the Bay during daylight hours in August from 1970 through 1994 revealed little spatial pattern in oxygen concentrations throughout the area surveyed and no differences with depth (EA 1995). This pattern is consistent with the high degree of local wind- and tide-induced mixing believed to occur in this area of the Bay.

A short-term continuous monitoring program conducted at four stations located throughout the Bay over a 13-day period in late May and early June 1996 revealed a strong diel (day/night) pattern throughout much of the Bay, including South San Diego Bay and little difference between South, South-Central, and Central Bay eco-region stations (EA 1996). Only in North San Diego Bay at the station nearest the ocean was a strong tidal influence on dissolved oxygen concentrations evident. At this station, highest dissolved oxygen concentrations were consistently observed during flood tide as a result of the presence of well-oxygenated oceanic waters in this section of the Bay. In South, South-Central and Central San Diego Bay, dissolved oxygen concentrations were often well above saturation in late afternoon, most likely as a result of photosynthetic activity but fell well below saturation levels during early morning hours as oxygen was consumed by respiration.

As a result of limited information to describe spatial and temporal patterns in South San Diego Bay, SDG&E conducted a more extensive continuous monitoring program for dissolved oxygen at the 12 stations located throughout this portion of the Bay (Figure 3-2). This monitoring program was conducted as part of an ongoing eelgrass study and provided data[1] for the period 27 June through 22 December 1997. This dissolved oxygen monitoring was specifically designed to describe the natural dynamics of physical water quality parameters in South San Diego Bay, to assist in the development of an appropriate water quality objective for dissolved oxygen, and to provide information on the environmental factors controlling eelgrass distribution and abundance.

In order to summarize this dissolved oxygen data, the monitoring stations were combined into three groups, the open-water group, the eastern-shore group, and the back-water group. Classification into a particular group was based on physical location in the bay and ambient water circulation patterns. Stations in the open-water group (1A, 1B, 2A, and

[1] Data validation protocols used in the evaluation of this data are described in Appendix A.



modified from U.S. Navy 1994

Figure 3-2. Sampling locations used for an intensive dissolved oxygen survey of South San Diego Bay, 27 June - 22 December, 1997.

2B) are located in the middle of South San Diego Bay and are exposed to water from Central San Diego Bay each tide. The eastern-shore group, composed of Stations 3A, 3B, 4A, 4B, and 7, is closer to land than the open water group and under the influence of net water flow into the power plant cooling water intake. The back-water group (Stations 5A, 5B, and 6), although also close to land, is located near the southern tip of the Bay, in an area of reduced water circulation which is under the direct influence of the power plant thermal discharge. As only limited data were collected during June, analysis were limited to the interval 1 July through 22 December to facilitate graphing.

Overall, hourly dissolved oxygen concentrations in South San Diego Bay during this study period ranged from 2.9 to 8.9 mg/L at the open water stations, from 2.8 to 9.4 mg/L at the eastern-shore stations, and from 1.7 to 8.6 mg/L at the back-water stations. Approximately 2 percent of the hourly measurements were less than 4 mg/L at the open water stations while 20 percent were less than 5 mg/L. At the eastern-shore stations, almost 3 percent and more than 26 percent were less than 4 and 5 mg/L respectively, while at the backwater stations almost 10 percent and 38 percent were less than 4 and 5 mg/L, respectively. Daily means averaged 5.7 mg/L (4.3 - 7.8 mg/L) at the open water stations, 5.6 mg/L (4.3 - 7.4 mg/L) at eastern-shore, and 5.4 mg/L (3.9 - 7.1 mg/L) at the backwater stations. As expected, daily means in all areas were lowest in August and September when water temperatures reduced the saturation capacity of the water and natural respiration demands were highest. Mean dissolved oxygen concentrations were substantially higher in December when conditions were cooler and natural respiration demands were lower (Figure 3-3).

While there were not substantial differences in mean dissolved oxygen concentration across the three areas, there were clear differences in the magnitude of diel (day/night) changes (Figure 3-4). The mean diel range was smallest at the open water stations (1.0 mg/L), greater at the eastern-shore (1.3 mg/L), and greatest at the back-water stations (1.8 mg/L). In fact at the back-water stations, dissolved oxygen concentrations averaged less than 5 mg/L during the early morning hours across the entire 6-month study period. This diel swing in dissolved oxygen concentrations observed throughout South San Diego Bay is likely a result of photosynthetic activity and respiration of eelgrass, benthic algae, and phytoplankton and is similar to the diel pattern observed in other comparable systems. Slightly more than 1 percent of the hourly readings at the open water stations, and 3 percent of the hourly readings at the eastern-shore and backwater stations, were greater than saturation levels. This frequency of supersaturated conditions is considerably lower than observed during the earlier (May - June 1996) sampling event, when up to 30 percent of the observed dissolved oxygen concentrations were greater than saturation levels. Again, these conditions are likely reflective of the presence of higher seasonal photosynthetic activity during the prior spring period.

The results of this analysis demonstrates that dissolved oxygen concentrations less than 5 mg/L, a value frequently used as a numeric objective for dissolved oxygen, are common throughout South San Diego Bay (up to 38 percent of hourly values in the backwater

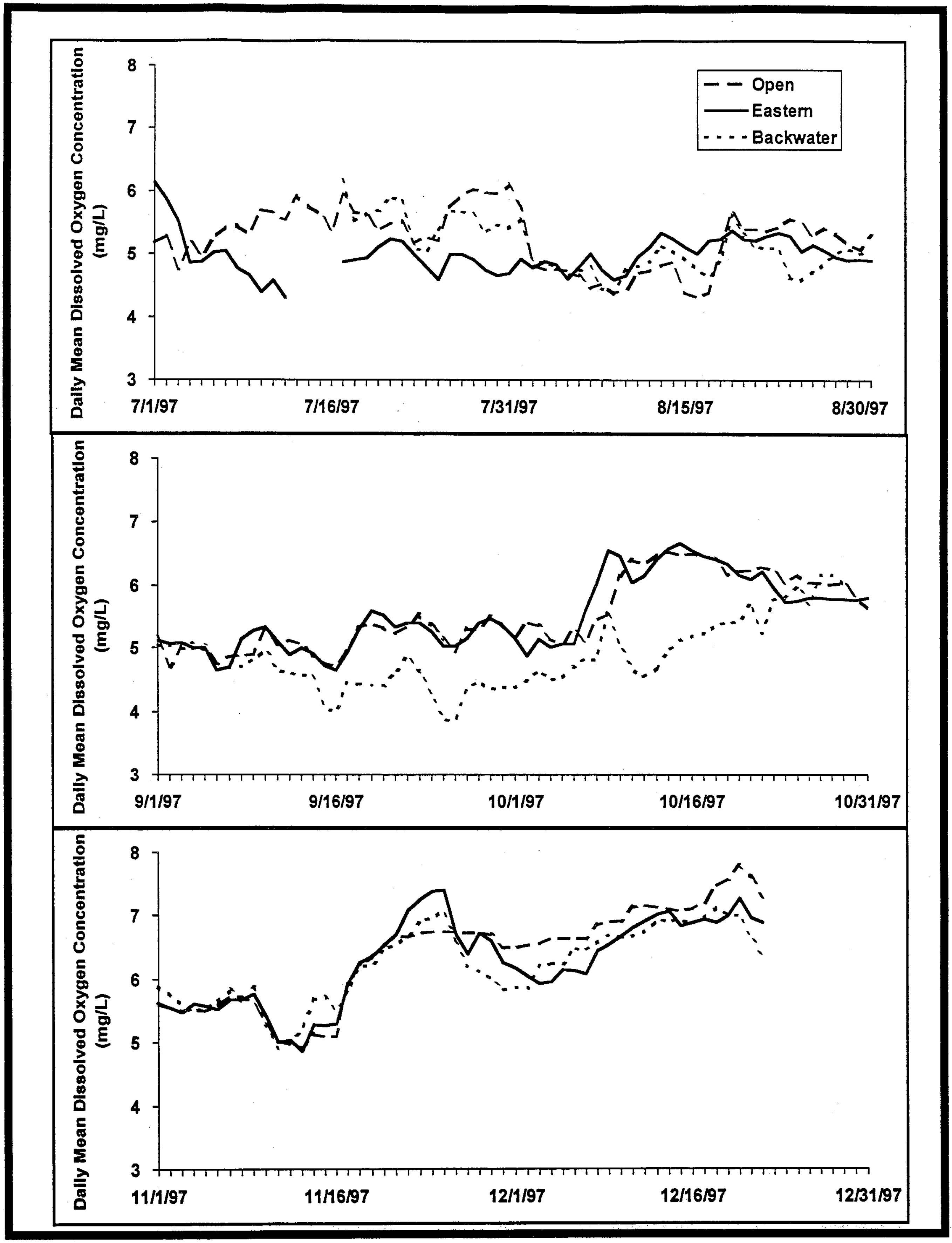


Figure 3-3. Daily mean dissolved oxygen concentrations observed in three areas of South San Diego Bay, 1 July - 22 December, 1997.

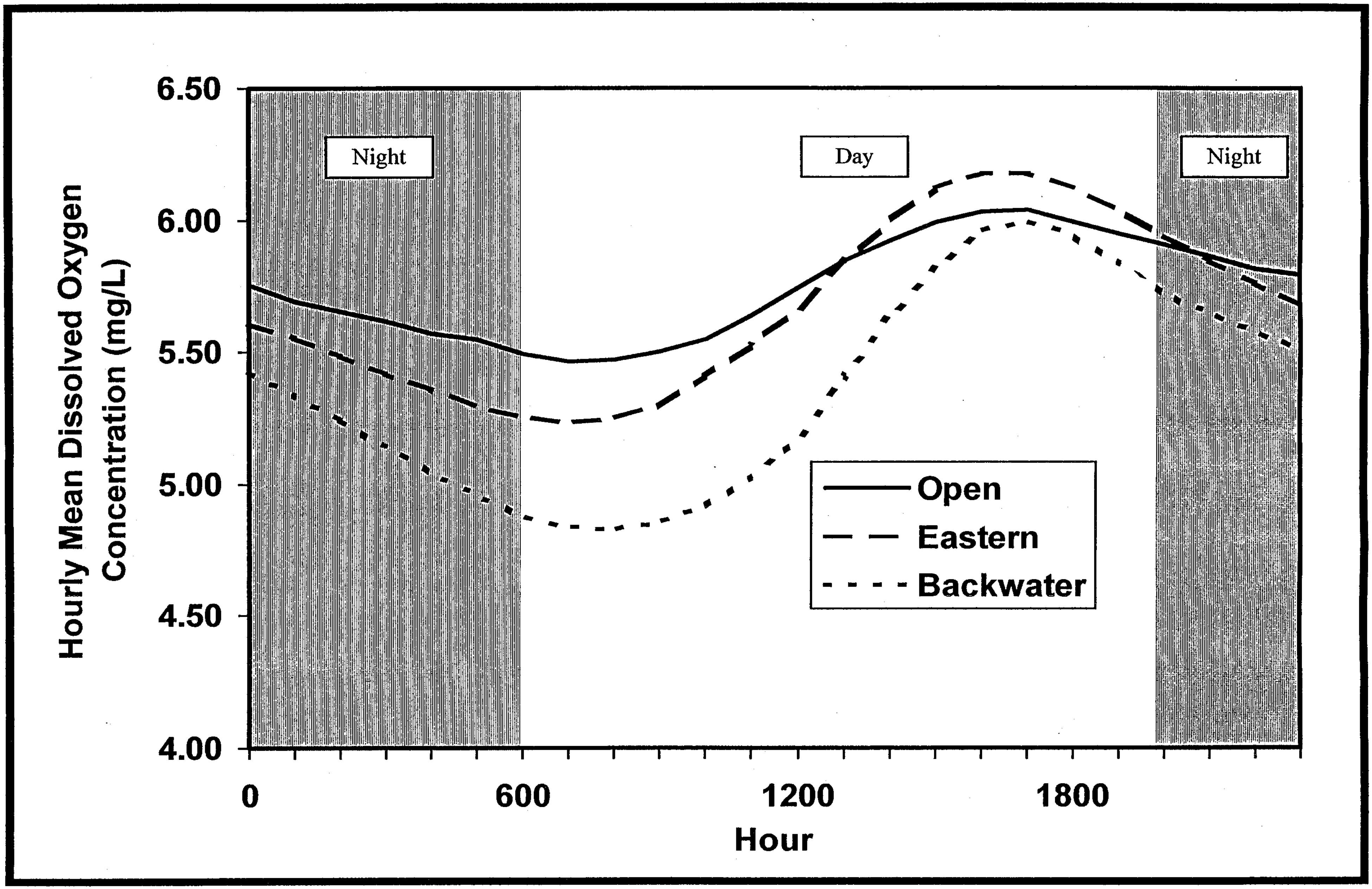


Figure 3-4. Overall mean dissolved oxygen concentrations by hour observed in three areas within South San Diego Bay, 1 July - 22 December, 1997

area). Such relatively low values are found on an hourly and even daily average basis. The diel patterns observed also demonstrate that the dynamics of dissolved oxygen in this area of the Bay are largely under the influence of photosynthesis/respiration of algae and eelgrass which are naturally abundant in the area. These dissolved oxygen patterns contrast considerably from that expected in more open water areas (e.g., ocean) where more limited photosynthetic activity and increased mixing would result in concentrations closer to saturation levels and exhibiting considerably less short-term variability. These patterns also differ substantially from those expected with freshwater systems where dissolved oxygen saturation levels are substantially higher.

The biological communities presently found in South San Diego Bay are a result of the effects of a variety of biotic and abiotic factors including the highly variable, and often low, dissolved oxygen concentrations in the area. Compared to other areas of the Bay, members of this community either have lower oxygen requirements or use behavioral mechanisms (e.g., day/night movements, reduced activity, alternate metabolic processes, etc.) to persist in spite of the naturally-occurring low oxygen levels which exist there. As a result, these species have a competitive advantage over other similar species which inhabit more highly oxygenated ocean waters. Rather than the ecosystem being a reduced subset of the ecosystem present in northern areas of the Bay, South San Diego Bay contains some unique biological communities that are less well represented, or absent altogether, from the northern portions of the Bay. Long-term studies of the benthic infauna of the area have illustrated that the communities are well developed, stable, and relatively diverse (EA 1995, Merkel & Associates 1997). Fish communities observed in South San Diego Bay contain a comparable number of species as observed in Central and South-Central eco-regions during recent studies, but also include some species that are unique to the southern end of the Bay (Allen 1996). Biomass of fish collected was also comparable to that of other stations including the northern part of the Bay.

4. PROPOSED WATER QUALITY OBJECTIVE FOR DISSOLVED OXYGEN

4.1 BACKGROUND

Water Quality Objectives are defined in the California Water Code Section 1305(h) as follows:

> *The limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.*

The basis for the establishment of water quality objectives is contained in Section 303 of the Clean Water Act (CWA) which requires states to adopt water quality objectives (called water quality criteria) for the protection of designated uses of surface waters. These criteria must be based on sound scientific rationale and must be protective of the most sensitive use(s) (40 CFR 131.11). Following this federal requirement, the California Water Code, Division 7 (Porter-Cologne Act) provides that each of the Regional Water Quality Control Boards establish water quality objectives for the surface and ground waters of the State which, in the opinion of the Regional Board, are necessary for the reasonable protection of beneficial uses. In establishing such water quality objectives, the Regional Board should consider, but not be limited to, the following factors:

- Past, present, and probable future beneficial uses of water;
- Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto;
- Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area;
- Economic considerations;
- The need for developing housing within the region; and
- The need to develop and use recycled water.

The EPA defines two types of water quality objectives (criteria): numeric and narrative. Numeric criteria are values expressed as levels, constituent concentrations, toxicity units, or numbers deemed necessary to protect designated (beneficial) uses (U.S. EPA 1996). Under Section 304(a) of the CWA, EPA is required to develop national numeric objectives (criteria) which can be used as a guide for development of state objectives. To date, EPA's focus in this area has been toxics, especially those defined as "priority pollutants" under Section 303(c)(2)(B) of the CWA. Narrative criteria are statements that describe the desired water quality goal. Narrative criteria can be used as the basis for limiting specific pollutants where the State has no numeric criteria or as a supplement to existing numeric criteria.

Federal regulations (40 CFR 131) provide three options for setting water quality objectives. These are: (1) adopt the national criteria established by the U.S. Environmental Protection Agency (EPA) pursuant to Section 304(a) of the Clean Water Act, (2) modify EPA's national criteria to reflect site-specific criteria, or (3) use other scientifically defensible methods. For dissolved oxygen, there presently exists no national standard which would be directly applicable to South San Diego Bay. The EPA has had a standard for the Nation's freshwaters since 1986 but no national standard for any saltwater area is presently available. A new standard for the saltwaters of the Virginian Province along the Atlantic coast is under development and a proposed standard should be released for public comment within the next year or so (U.S. EPA 1998). However, due to regionally specific data being used to establish this standard, it is not likely to be directly applicable to Pacific coastal waters.

The reason for the long delay in the development of a saltwater standard (i.e., more than 10 years since the freshwater standard) can be attributed to the paucity of dissolved oxygen tolerance data for marine species. This is especially true for species likely to be found in southern California waters. It appears unlikely that a national dissolved oxygen standard which is appropriate to apply to saltwaters of southern California will be proposed anytime in the near future. Further, owing to the substantially different environmental conditions naturally occurring in South San Diego Bay compared to the open marine waters along the coast (e.g., hypersalinity, limited circulation, and extensive shallows with high photosynthetic activity within this section of the Bay), it is likely that any saltwater criteria developed for southern California coastal waters would need to be modified to account for these site-specific conditions before it could be applied to South San Diego Bay.

Since there is presently: (1) no federal marine water quality objective for dissolved oxygen (and, therefore, no opportunity to develop a site-specific dissolved oxygen water quality objective based upon a national criterion), and (2) no direction or guidance from the EPA with regard to methods which should be used to establish an appropriate dissolved oxygen objective, the water quality objective for South San Diego Bay proposed in this document was developed in accordance with the third EPA (40 CFR 131) option identified above—the use of other scientifically defensible methods.

4.2 REVIEW OF EXISTING WATER QUALITY OBJECTIVES FOR DISSOLVED OXYGEN

One possible approach to development of an objective for dissolved oxygen would be to look elsewhere to determine if an appropriate objective exists which could be adopted for South San Diego Bay. For example, the RWQCB adopted within the Basin Plan a numeric objective for dissolved oxygen for ocean waters of the Region by incorporation of the State's Ocean Plan. This objective states:

The dissolved oxygen concentration in ocean waters shall not at any time be depressed more than 10 percent from that which occurs naturally, as the result of the discharge of oxygen demanding waste materials.

While no scientific rationale for this objective was provided, its form implicitly acknowledges that dissolved oxygen concentrations can and do vary such that a fixed standard is not appropriate. However, this objective was developed for well mixed ocean waters where dissolved oxygen levels are spatially uniform and typically near saturation levels. In South San Diego Bay, natural spatial and temporal variability in dissolved oxygen levels make definition of appropriate ambient conditions for comparison practicably impossible. Further, the biological importance of any reduction in dissolved oxygen, either fixed or relative, is dependent upon the level of existing oxygen concentrations. For example, a 10 percent reduction in dissolved oxygen concentrations may be biologically meaningful at lower concentrations but of no biological consequence when ambient concentrations are higher. Changes between lower and higher oxygen concentrations are common and often occur within a 24-hour period and, thus, such an objective could only be partially protective of the biological communities. It is for these reasons that the Ocean Plan objective for dissolved oxygen is not appropriate for South San Diego Bay.

In the Basin Plan, the RWQCB also adopted a numeric water quality objective for dissolved oxygen for inland surface waters of the Region including tributaries to San Diego Bay. This objective states:

Dissolved oxygen levels shall not be less than 5.0 mg/l in inland surface waters with designated MAR or WARM beneficial uses or less than 6.0 mg/l in the waters with designated COLD beneficial uses. The annual mean dissolved oxygen concentration shall not be less than 7 mg/l more than 10 % of the time.

While the scientific rationale for this objective remains unclear, it is likely that the 5.0 mg/L objective with MAR or WARM beneficial uses was based on the EPA's National Freshwater Criteria for warmwater fish species (U.S. EPA 1986). As the freshwater fish species upon which this standard is based can not exist in South San Diego Bay, it does not appear that this criteria would be applicable or relevant. Further, the analysis of ongoing dissolved oxygen surveys presented in the previous section clearly demonstrate that this objective is frequently exceeded, even though the biological community is consistent with that expected for this type of habitat.

A brief review of numeric water quality objectives for dissolved oxygen in other California Regions and in other states with similar climatic conditions revealed that 5 mg/L is a commonly used objective. As with the WARM and MAR beneficial uses for the San Diego Region, no scientific rationale is offered for any of these numeric objectives although they also appear to be based on EPA's National Freshwater Criteria for warmwater fish species (U.S. EPA 1986). However instead of insisting on strict adherence to this freshwater standard, several of the other states acknowledge that natural processes, such as found in South San Diego Bay, can result in dissolved oxygen concentrations in selected areas which are less than the numeric criteria. Such situations are addressed on a case-by-case basis. Further on this point, the EPA's freshwater criteria document for dissolved oxygen (U.S. EPA 1986) offers the following:

> *Natural-occurring dissolved oxygen concentrations may occasionally fall below target criteria levels due to a combination of low flow, high temperature, and natural oxygen demand. These naturally-occurring conditions represent a normal situation in which the productivity of fish or other aquatic organisms may not be the maximum possible under ideal circumstances, but which represent the maximum productivity under the particular set of natural conditions. Under these circumstances the numerical criteria should be considered unattainable, but naturally-occurring conditions which fail to meet criteria should not be interpreted as violations of criteria. Although further reductions in dissolved oxygen may be inadvisable, effects of any reductions should be compared to natural ambient conditions and not to ideal conditions.*

The situation discussed in the above quotation appears to reflect that presently occurring in South San Diego Bay.

One approach used to address the complexities of dissolved oxygen in areas similar to San Diego Bay has been through the use of a narrative objective. For example, California Region 8 (Santa Ana River Basin) incorporates the following narrative water quality objective for dissolved oxygen in bays and estuaries in the current Basin Plan (1995):

> *The dissolved oxygen of enclosed bays and estuaries shall not be depressed to levels that adversely affect beneficial uses as a result of controllable water quality factors.*

This narrative objective was incorporated as part of the 1995 revision to the Basin Plan. The original (1975) Basin Plan had a water quality objective of 5.0 mg/L, identical to that of other regions.

4.3 PROPOSED WATER QUALITY OBJECTIVE FOR DISSOLVED OXYGEN IN SOUTH SAN DIEGO BAY

Based on a careful review and assessment of all relevant scientific information, regulatory guidance, and federal and state practice, it appears that a narrative water quality objective is most appropriate for dissolved oxygen in South San Diego Bay. This conclusion is based on the following facts:

1. There is no national criterion for dissolved oxygen that is applicable to saltwaters of Southern California, nor is there likely to be one in the near future.

2. Any national criterion which would be developed is likely to be designed for open, well-mixed systems and, therefore, would potentially require substantial modification to be applicable to waters of South San Diego Bay.

3. There is a paucity of relevant scientific data on oxygen tolerance upon which to base a numeric dissolved oxygen objective for the waters of South San Diego Bay.

4. Numeric criteria developed at the regional level in California and at the State level elsewhere cannot be met in South San Diego Bay as a result of conditions which existed on or after 28 November 1975.

5. The biological community existing in South San Diego Bay reflects the current environmental conditions which includes the often low, and highly variable dissolved oxygen conditions.

6. Beneficial uses of South San Diego Bay are being protected.

7. A narrative water quality objective for dissolved oxygen in enclosed bays and estuaries is currently incorporated in the Water Quality Control Plan for the Santa Ana River Basin (Region 8) and would appear appropriate for South San Diego Bay as well.

The proposed narrative water quality objective for South San Diego Bay is:

> *The dissolved oxygen concentrations of South San Diego Bay shall not be depressed to levels that adversely affect beneficial uses as a result of controllable water quality factors.*

As used in this objective, "adversely affect" is defined as the demonstrable reduction or threat of reduction in the value of a beneficial use in San Diego Bay, "controllable" is defined consistent with Porter-Cologne which requires a careful balancing of environmental and economic considerations, and "water quality factors" is defined to include oxygen consuming pollutants, as well as pollutants which affect the rate of oxygen consumption.

4.4 ACHIEVEMENT OF THE PROPOSED WATER QUALITY OBJECTIVE

The warm, productive shallow waters of South San Diego Bay provide a unique aspect to the overall diversity and productivity of San Diego Bay. The current status of beneficial uses that exist in the South San Diego Bay are outlined as follows:

Industrial Service Supply (IND) - The waters of South San Diego Bay are the only waters of the Bay presently in use for IND beneficial uses. This use is associated with the use of bay water as cooling water for the South Bay Power Plant.

Navigation (NAV) - All waters of San Diego Bay are open to navigational uses. Limited navigation occurs in South San Diego Bay. This is predominantly associated with access to the existing Chula Vista Marina, South Bay boat yard, and recreational, research, and commercial fishing access. Much greater navigational use occurs in the northern and central portions of San Diego Bay.

Contact Water Recreation (REC-1) - Water contact recreation occurs along the eastern shoreline of South San Diego Bay where Port District Parks have been developed to promote this use. In general, the promoted uses have been fishing, swimming, and wading. Other uses of this portion of the Bay include water skiing, jet skiing, and wind surfing. These uses have, however been discouraged by the presence of a 5 mph speed limit in the area, imposed both as a safety measure and to protect the abundant avian population and green turtles.

Non-contact Water Recreation (REC-2) - Non-contact uses of the South San Diego Bay exist along shoreline access areas of both the east and western sides of the Bay. These include access to structured educational facilities such as the Chula Vista Nature Interpretive Center as well as less formal recreational areas such as the Biological Study Area of the far southern end of the Bay, Port District Parks, and the Silver Strand State Park on the western side of the South San Diego Bay. Additionally, kayaking also occurs in this portion of the Bay.

Commercial and Sport Fishing (COMM) - The striped mullet is the only marine species that is commercially harvested from San Diego Bay. The warm waters of the far South San Diego Bay provide the only areas of the Bay conducive to providing commercial yields of this species. Sportfishing in the South San Diego Bay is generally limited to a small informal fishery dominated by local residents and a minor subsistence fishery dominated by the area's ethnic community.

Preservation of Biological Habitats of Special Significance (BIOL) - The only portion of South San Diego Bay presently designated as a habitat of special significance is the Sweetwater River Marsh National Wildlife Refuge (NWR). This area is dependent upon tidal exchange of waters of the Bay. The Sweetwater Marsh is recognized as one of the region's most significant wetland resources and its biologic values were key to the acquisition and designation of this area as a NWR. The San Diego Bay Biological Study Area in the far southern portion of the Bay could also be considered a habitat of special significance as a designated area of protection for sensitive resources. The U.S. Fish and Wildlife Service is presently considering an NWR overlay for the larger South San Diego Bay. The overlay would make the area a part of the San Diego Bay NWR (USFWS 1998). The existing ecological resources of South San Diego Bay are cited as the conservation interests in the region.

Estuarine Habitat (EST) - Estuarine habitat in South San Diego Bay is limited by the natural paucity of freshwater flows and the historic damming of the Sweetwater and Otay rivers. Year-round flows of predominantly urban sources occur from the Sweetwater River and nearly perennial flows occur from the Telegraph Creek drainage. Even during winter months, flows from freshwater drainages which would define the estuarine boundary between the saltwater bay and freshwater is pulsed and only ephemeral brackish water conditions extend much beyond the mouths of the Bay's creeks and rivers. Estuarine habitats are generally restricted to the upper ends of tidal influence within the individual creeks. These areas support a flora and fauna reflective of the highly dynamic salinities and sediment conditions which exist at this freshwater and saltwater interface.

Wildlife Habitat (WILD) - Important wildlife habitat dependent upon the waters of South San Diego Bay are limited both by the marine nature of the waters and the highly urbanized setting of the Bay itself. The only significant link to wildlife to the South San Diego Bay's waters is found with avian populations. San Diego Bay is a vital link in the Pacific Flyway. Hundreds of thousands of migrating shorebirds, nesting seabirds, and wintering waterfowl depend upon the southern portion of the Bay (USFWS 1998).

Rare, Threatened, or Endangered Species (RARE) - South San Diego Bay provides the only U.S. Pacific Coast habitat of the federally-threatened green turtles. This turtle is dependent upon the warm waters of South San Diego Bay in order to persist in the Bay through winter months. Within South San Diego Bay environments, other rare, threatened, and endangered species include the light-footed clapper rail, Belding's savannah sparrow, salt marsh bird's beak. This area offers the only habitat for these species in San Diego Bay. Also of less restricted occurrence are California brown pelican, western snowy plover, California least tern, peregrine falcon, and, rarely, the southern bald eagle.

Marine Habitat (MAR) - Marine habitat protection has been demonstrated through on-going and historic fish community studies (Ford 1994, Allen 1996, Merkel 1997) and a long-term benthic infauna data base (EA 1995). The marine resources of South San Diego Bay have been previously reviewed in these documents and others and have been noted as supporting a productive and stable fauna and flora. Vegetated marine habitats are well represented in South San Diego Bay and are considered to be indicative of the health of the marine system.

Migration of Aquatic Organisms (MIGR) - Migratory patterns of aquatic organisms in southern California's coastal waters are inherently limited. Lack of dependable flows of oxygen rich, cool waters within coastal streams limits the potential for establishment of anadromous fish runs and no potential for such runs exists within San Diego Bay. Striped mullet is a resident bay species which migrates to offshore locations for spawning and the adults return to the Bay once the breeding is complete. Similarly, green turtles migrate out of the Bay for breeding.

Shellfish Harvesting (SHELL) - Shellfish harvesting in South San Diego Bay is limited to a small ethnic subsistence fishery. While shellfish are suitable for consumption, overfishing, lack of accessible intertidal areas, and a perception of poor bay water quality has limited the harvest of these resources. A significant sport bait harvest of ghost shrimp once existed at the mouth of the Sweetwater River and along the Chula Vista Bayfront, but the designation of this area as a National Wildlife Refuge and enforcement of game laws has all but terminated this harvest. Continued minor harvests occur along the shoreline. Shellfish resources consisting of jacknife clams are abundant within the sandier substrates at the mouths of the Sweetwater River on the "D" Street Fill, as well as at the mouths of the Otay River, Telegraph Creek, and Palomar Drain.

Spawning, Reproduction, and/or Early Development (SPWN) - The South San Diego Bay ecoregion is an important area for the early development of a number of species. This is exemplified by the catch of over 40,000 young of the year slough anchovy during the October 1997 fish sampling in the South Bay Power Plant discharge channel (Merkel & Associates 1997), which is comparable to the highest catches of northern anchovy in North San Diego Bay during July 1995 (Allen 1996). Also indicative of the area's achievement of this use is the presence of juvenile striped mullet within the South Bay Power Plant discharge channel in January 1998 in numbers higher than anywhere else in the Bay (Merkel & Associates, in prep.). Other juvenile fish captured in South San Diego Bay on a regular basis include topsmelt, California halibut, diamond turbot, round stingray, halfbeak, among others.

The long-term history of the south bay environment has been one of improving conditions since the early 1960's when sewage discharges to the Bay were terminated. The bay has continuously achieved or exceeded those beneficial use conditions present on or after 28 November 1975. The shallow warm waters of the southern portion of the Bay add a unique dimension to San Diego Bay's aquatic environment by favoring species adapted to such shallow productive bays. These areas are preferentially occupied by a host of fish species that are residents of the cool tropics and warm temperate environments. Important aspects of the South San Diego Bay environment include its role as a nursery area for important forage fish and commercial species. Areas of South San Diego Bay, including the discharge channel of the South Bay Power Plant, play an important role in the juvenile life stages of a number of species and provide a seasonal refuge from the cold for other species.

This analysis demonstrates that all existing beneficial uses of San Diego Bay are being protected in the southern end of the Bay. Consequently, it can be concluded that existing dissolved oxygen conditions are sufficient and that the water quality objective for dissolved oxygen in South San Diego Bay proposed in this document is being achieved.

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Appendix A. Dissolved Oxygen Data Collection Program - Data Validation Summary

Merkel & Associates, Inc.
February 1998

General Field Methods

Merkel and Associates, Inc. (M&A) collected dissolved oxygen data using Hydrolab Datasonde 4® water quality probes deployed over the bay bottom in south San Diego Bay in a sampling array which includes both a latitudinal and axial coverage of the South Bay.

Each Hydrolab® Datasonde 4 water quality dissolved oxygen probe collected data every 20 minutes and stored in an internal datalogger. Equipment maintenance was performed frequently due to limited data storage capacity and battery life, as well as due to the tremendous sedimentation and biological fouling rates in the study area. At each servicing the unit was removed from the water, data downloaded from the unit onto a laptop computer, and the unit was then fully inspected and serviced. Pre-deployment and post-collection calibrations were done on the unit to verify data values being logged. The downloaded data was reviewed to detect any problems with the unit. If working properly, each probe was then thoroughly cleaned and recalibrated with known standards, and then returned to the water equipped with a new logging file and new batteries. The completion of regular and frequent maintenance decreased the potential for data loss and further minimized instrument fouling and subsequent measurement drift or decay.

An affirmative action checklist approach was taken during the servicing of the monitoring equipment. This approach made use of a pre-printed servicing form that requires an entry for each step of the sequential procedure for data recovery, calibration, and redeployment of instruments. This has proven very useful in controlling data losses in the field and ensuring accuracy from the monitoring equipment. The specific instruments, service history, calibration data, and any problems were also kept as a part of the project records.

Data Validation Protocols

Data from deployed instruments can contain a substantial amount of spurious information. This includes data taken by the instruments prior to their being put into the water, data from probes that collect drifting algae or debris and provide blatantly erroneous readings, and data which shows erratic response or decay without apparent cause. In order to make use of the data sets, it is essential to use only the valid data from the instruments. Because the units are deployed for anywhere from one to two weeks at a time, the data collected can be corrupted, lost, or can return erroneous values which do not reflect true environmental conditions. Some losses may be of a short or intermediate duration (*e.g.* algal fouling of probes, signal decay from sediment loading or biotic activities), while other problems may eliminate data for an entire station for the one to two week monitoring interval (*e.g.* power failures, unit flooding, errors in logging file set-up).

To ensure that data being evaluated are reflective of true conditions, it is necessary to trim the data records to remove spurious data prior to conducting analyses. To accomplish this it is important that a standard set of protocols be used to ensure that the remaining data portrays a true and accurate representation of the monitored environment. The rules employed to clip data include:

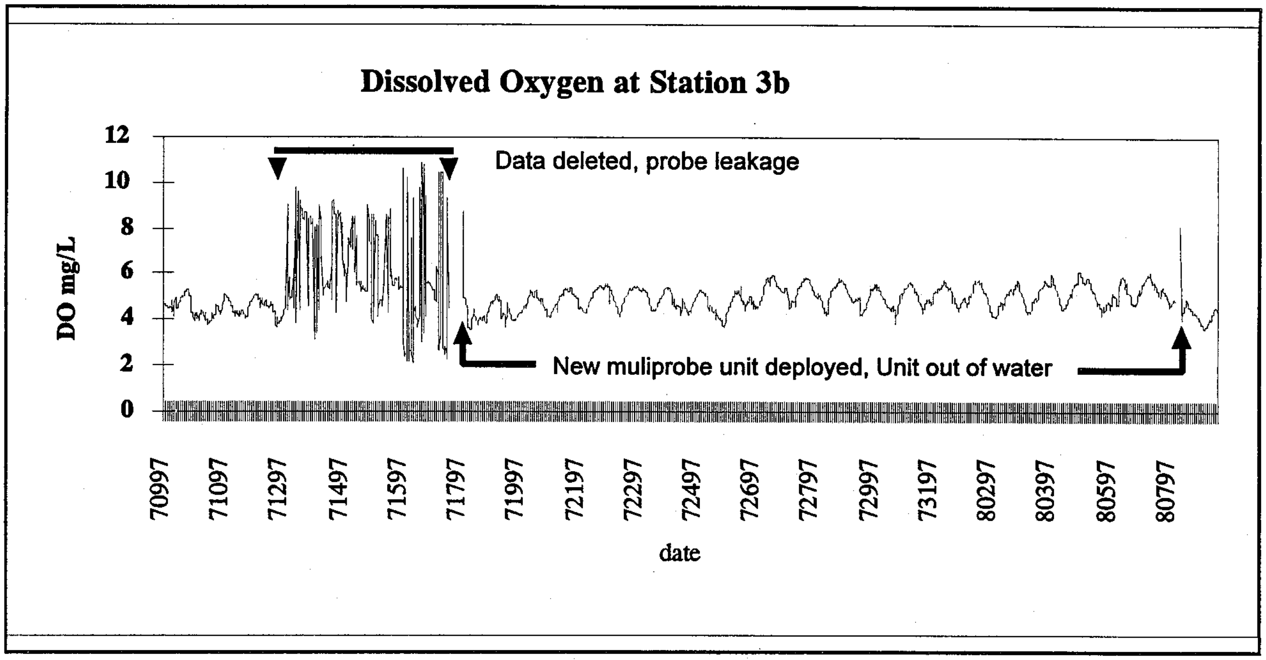
1) No data is to be used which precedes deployment of instruments or which is collected within the period immediately following deployment;
2) No data is to be used which is either out of sensor range or is either the preceding or following data point around a sensor range violation;
3) No data is to be used where the sample interval to sample interval change exceeds that reasonably expected in the specific parameter, unless a station pair reflects similar changes, or a specific causative agent is known (flood event, etc.);
4) No data is to be used where instrument diagnostic reports indicate sensor or calibration failures;
5) No data is to be used where human error or instrument failures resulted in no data being collected for the time period (*i.e.* null values will not be used in developing trendlines or means);
6) No data is to be used from that portion of a record in which data trends and patterns suggest that units were under the influence of abnormal conditions or were not functioning properly. Data trimming for these purposes should also be backed by observed instrument problems or conditions from field log notes where possible (*e.g.* sensors in mud, stirrer tip lost, flooding of sensors, animals in or on sensors).

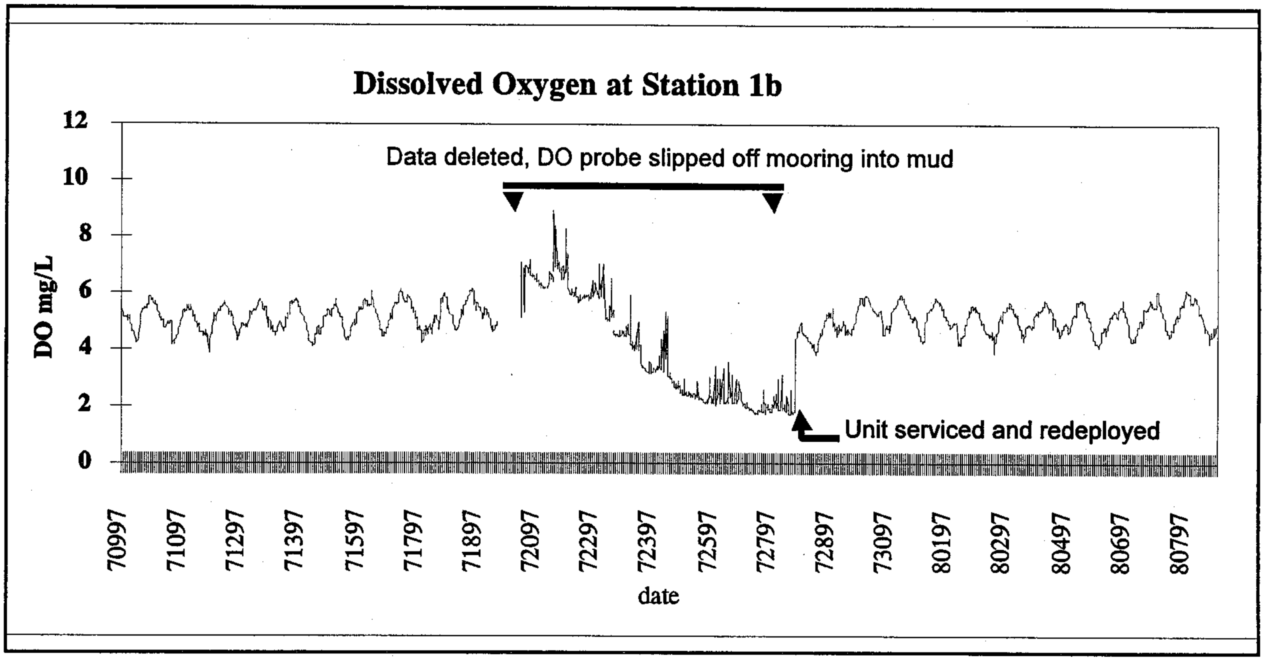
Dissolved oxygen data was clipped out if it fell clearly outside of ranges observed at a particular station and the rate of change exceeded that which could be explained by environmental changes, was atypically erratic suggesting a problem with the unit, or was collected before or after the unit was deployed in the water. There are both technical and environmental factors that may contribute to the collection of poor quality data. Poor battery contact has been a problem resulting in intermittent power losses (and therefore data losses) during the monitoring period. This resulted in no data collection for a period of time. This has been generally addressed by changing the batteries at each servicing, and most recently by applying conductive grease to battery ends and changing equipment contact springs. The probes have had occasional leakage problems that lead to corrosion of the electrical connections and shorting across electronic sockets and pins. This causes an erratic response in the meter and can result in deteriorating curves. Dissolved oxygen is measured across a gas permeable membrane which occasionally is damaged, fouled, or heavily "slimed" by mucous of marine animals while deployed. This generally results in the collection of no usable data from that point on as the permeability of the membrane is compromised and dissolved oxygen readings tend to noticeably decline and the amplitude of diel curves dampens significantly. A flow of water across that membrane is normally maintained by a stirring probe next to the dissolved oxygen probe. This both provides fresh flow and also serves to limit fouling of the membrane. The spinning tip of that stirrer is attached by a screw that often has corroded allowing the tip to spin off. The loss of the stirrer results in a recognizable decline in the measured DO and a dampening of the diel swings. The data collected when this happens is also unacceptable.

There are many environmental concerns that also regularly affect the quality of the collected data. The monitoring sites in the South Bay are subject to very high rates of biological fouling and sedimentation which can impact sensor accuracy. During periods of rapid biotic growth, a film can develop on the membrane of the DO probe causing the data values to drop over the logging period. Single erratic data points are occasionally collected that may be due to the passage of an invertebrate or algae over the membrane or temporary fouling of the stirrer. Algae has been observed wrapped around the stirrer tip which either causes the tip to not spin or causes it to draw excess electrical current while trying to spin, draining the batteries prematurely in the process. There has also been a problem with some anthropogenic impacts in which units have been snagged in fish nets and otherwise knocked off moorings into the mud. When this happens, dissolved oxygen readings decline in a precipitous and chronic manner indicative of a slow submergence of the probes into the mud.

In rare occasions, a single or a few readings may spike well above the ambient readings from the meter. This is preliminarily believed to be associated with the trapping of gas bubbles on the membrane or the settling of rapidly photosynthesizing macroalgae or eelgrass blades on the membrane during a reading. While the exact cause of these readings is unknown, these high spikes were also deleted.

Examples of some common DO data edits are included below.





Most of the inaccurate data have been from repeated situations that are easily recognized and addressed by data removal. Remaining records provide adequate information for analyses.