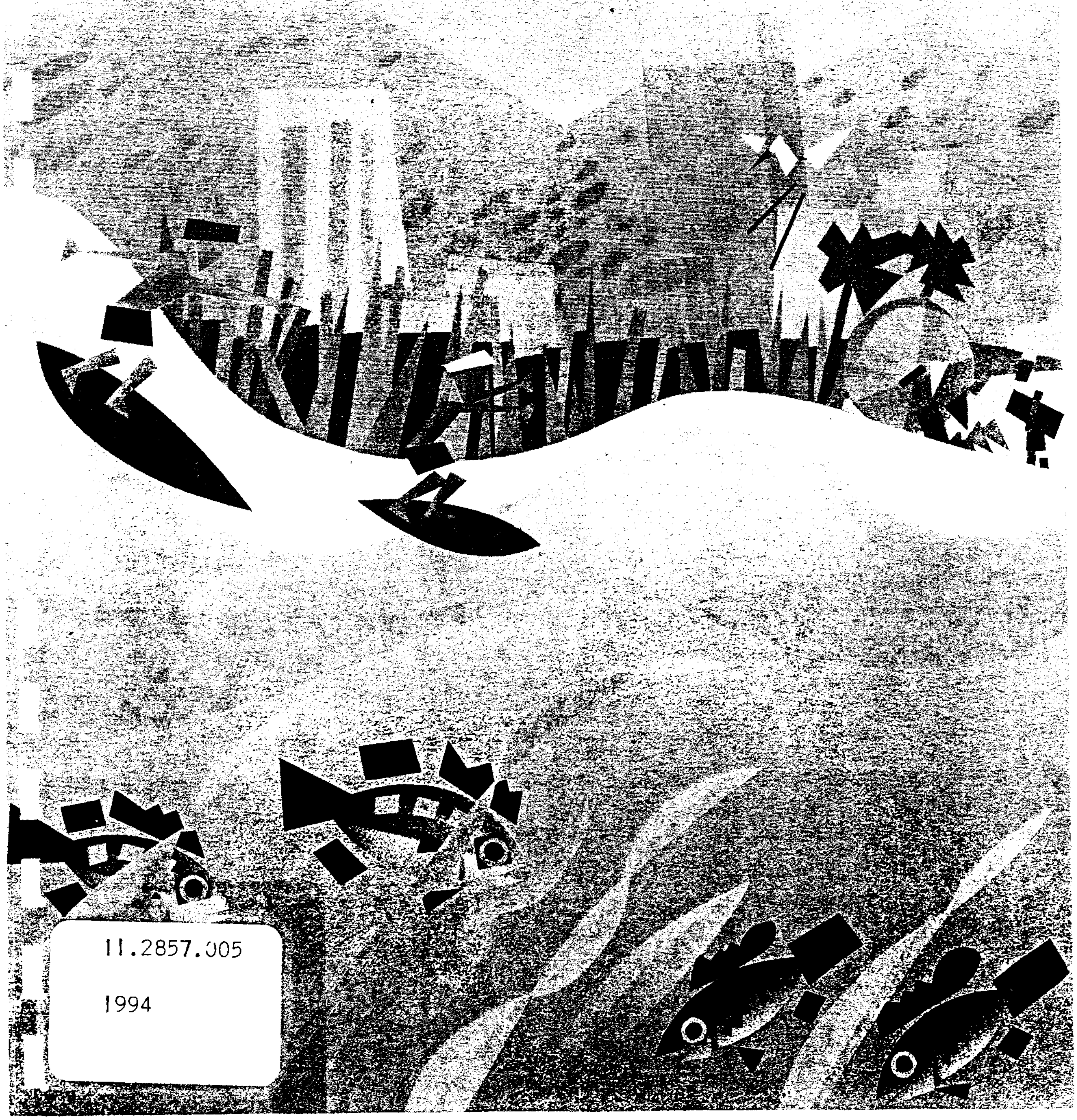
STATE OF THE BAY 1993



Characterization Study of the Santa Monica Bay Restoration Plan

STATE OF THE BAY 1993

January 1994

Santa Monica Bay Restoration Project
101 Centre Plaza Drive
Monterey Park, CA 91754
(213) 266-7516

CREDITS

MBC Applied Environmental Sciences - Report Authors

Project Managers:

Dr. M. James Allen
Thomas J. Kauwling

Project Coordinator:

Marnie Pavlick

Marine Scientists:

Stephen Gruber
Donald Johnston
Michael Mancuso
Leslie MacNair
Robert Moore
Carol Paquette
Janalyn Sanders
Dr. William Stockton

Technical Support Staff:
Phyllis Barton
Diana Budris
Mark Fanizza
Sarah McFadden
Carol Mitchell
Kathryn Mitchell
Kathleen O'Brien
Marnie Pavlick
Paula Simon
David Vilas

Applied Management & Planning Group

Dr. Cheryl Stecher
Christine Bogdanovich

Santa Monica Bay Restoration Staff

Catherine Tyrrell, Director
Dr. Rainer Hoenicke, Contract Manager
Audrey Whisiker, Desktop Publishing

SANTA MONICA BAY RESTORATION PROJECT
TECHNICAL ADVISORY COMMITTEE MEMBERS AND AD-HOC MEMBERS

M. James Allen
Southern California Coastal Water Research Project

Chuck Cleeves
Topanga Las-Virgenes Resource Conservation District

John Dorsey
Hyperion Treatment Plant

Jacqi Gamble
Tapia Water Reclamation Facility

Malcolm Gordon
University of California, Los Angeles Department of Biology

Robert S. Grove
Southern California Edison Co.

Michael J. Lyons
Regional Water Quality Control Board

Alan Mearns (TAC Vice Chair)
National Oceanographic and Atmospheric Administration

Paul J. Papanek
LA County Department of Health Services Toxics Epidemiology Program

Daniel Smith
State Department of Health Services Environmental Epidemiology and Toxicology Section

Michael Sowby
Department of Fish and Game

Gary Strathearn
Sierra Club

Craig J. Wilson, (TAC Chair)
State Water Resources Control Board

Sue Yoder
USC Sea Grant

Tareah Hendricks

Gerald Greene

Pat Baird
California State University, Long Beach

Jeffrey N. Cross
Southern California Coastal Water Research Project

Terry Fleming
U.S. Environmental Protection Agency

Mark Gold
Heal the Bay

Paul Gregory
CA Department of Fish and Game

Melinda Bartlett
Department of Environmental Affairs

David Young
U.S. Environmental Protection Agency Hatfield Marine Science Center

Phil Oshida
U.S. Environmental Protection Agency Wetlands Section

Gerald A. Pollock
Office of Environmental Health Hazardous Assessment

Robert W. Smith
EcoAnalysis, Inc.

Michael K. Stenstrom
University of California, Los Angeles Department of Civil Engineering

Jan Stull
Los Angeles County Sanitation Districts

Stephanie Wilson
U.S. Environmental Protection Agency

Charles McGee
Orange County Sanitation Districts

John Mitchell

Scott Johnson

RESOLUTION

SANTA MONICA BAY RESTORATION PROJECT
TECHNICAL ADVISORY COMMITTEE

WHEREAS, under the Cooperative Agreement between EPA and the State, the SMBRP is required to develop a characterization report for Santa Monica Bay as part of the Comprehensive Conservation Management Plan (CCMP),

WHEREAS, this committee and the SMBRP Management Committee adopted the State of the Bay report as the preliminary characterization report in June 1992,

WHEREAS, the SMBRP initiated a contract to prepare the final Santa Monica Bay Characterization Study report by updating the State of the Bay report with new scientific information,

WHEREAS, members of this committee as well as outside experts have carefully reviewed and helped revise the draft of the final Santa Monica Bay Characterization Study report,

WHEREAS, this committee finds that the final Santa Monica Bay Characterization Study report as received on this date has accurately presented the information regarding the Bay's history, status, and trends, and can be used as a credible scientific reference for management decision making,

BE IT RESOLVED THAT, the final characterization report be approved and be submitted to the Management Committee for approval,

BE IT FURTHER RESOLVED THAT, this committee recommends that the characterization report be periodically updated during the implementation of the Santa Monica Bay CCMP.

Craig J. Wilson, Chair

CONTENTS

Page

CHAPTER 3-1: THE BIOLOGICAL SETTING

Page

CHAPTER 4-1: THE HUMAN POPULATION

CHAPTER 5-1: POINT SOURCES OF CONTAMINATION

Page

CHAPTER 6-1: NONPOINT SOURCES OF CONTAMINATION

Page

Page

Page

CHAPTER 13-1: SUMMARY, STATUS AND TRENDS

LIST OF FIGURES

Page

Page

Page

LIST OF TABLES

LIST OF APPENDICES

1 INTRODUCTION

CHAPTER 1
INTRODUCTION

Santa Monica Bay is an open embayment on the central part of the southern California coast which lies seaward of Los Angeles County (Figure 1-1). The Bay is bordered offshore by Santa Monica Basin, on each end by rocky headlands (Point Dume and the Palos Verdes Peninsula), and onshore by the Los Angeles Coastal Plain and Santa Monica Mountains.

Five hundred years ago the shores of Santa Monica Bay and the Palos Verdes Peninsula were probably inhabited by less than 10,000 native American Indians. These natives used the natural resources of the Bay for a variety of purposes, but there were so few of them that any impacts on the environment were probably not perceptible. From the time of European contact to the twentieth century human impacts on the environment remained relatively minor: much of the area remained undeveloped or was used for ranching. However, during the twentieth century the area became a major population and industrial center which increasingly imposed itself on the natural environment of the area.

Today, Santa Monica Bay is a valuable natural resource that contributes to the local economy and enhances the quality of life for those who work or live in the area or visit it. The Bay supports a commercial party boat fishing industry and offers recreational fishing from piers, beaches and private boats. Approximately 500,000 tourists and local residents visit the beaches annually to surf, swim, and pursue the many recreational activities. This influx of visitors bolsters the local economy and constitutes an important source of revenue. Greater Los Angeles is the second largest metropolitan area in the United States, and is home to about 15 million people, nearly 6% the population of the United States (Hoffman 1992). This population uses the Bay not only for recreation, but also for domestic and industrial waste disposal. Multiple uses of a single resource inevitably lead to conflicts of interest and opinion.

PUBLIC CONCERN FOR THE BAY AND WATERSHED

Although concern for the condition of Santa Monica Bay and its watershed has increased dramatically during the last 25 years, solutions to some multiple-use conflicts were enacted long ago. For example, prior to 1884 raw sewage was discharged across the beach near the present Hyperion Treatment Plant and in the following decades nearshore discharges also contaminated the beaches with oil, grease, other floatables, and enteric bacteria. However, as the population and volume of discharge grew, sewage treatment was improved and discharge outfalls were moved further offshore into deeper water, so recreational use of the shore would not be affected. In 1935 the California Department of Fish and Game recognized the value of Santa Monica Bay for sport fishing and prohibited commercial fishing (by most methods) throughout the Bay. Public concern for the condition of Santa Monica Bay grew gradually after World War II and received a major impetus when the Federal Clean Water Act was established in 1972. The heightened awareness of the impacts of pollution which accompanied this legislation has resulted in public pressure to restore the natural state of the Bay.

In 1987, the Southern California Association of Governments (SCAG -Appendix A lists all acronyms used in this report) established the Santa Monica Bay Steering Committee and Santa Monica Bay Scientific Review Committee, and conducted public workshops at which issues and concerns about the Bay were aired. SCAG initiated one study to evaluate the state

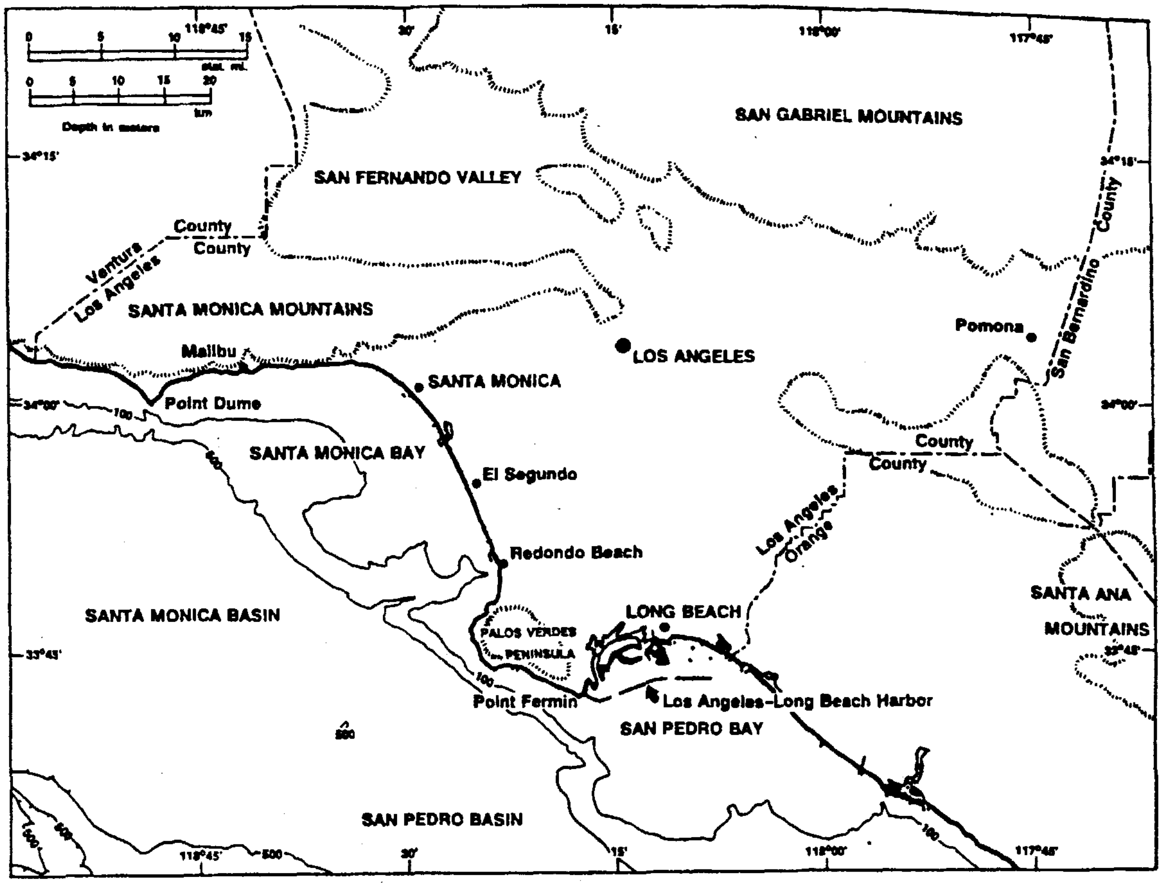


Figure 1-1. Santa Monica Bay and the greater Los Angeles Basin.

of Santa Monica Bay and another to guide the management of resources and problems in the Bay and its watershed. The studies were followed by the preparation of two State-of-the-Bay reports: Assessment of Conditions and Pollution Impacts (MBC 1988) and Management Framework (SCAG 1988). The information, findings, and recommendations of the two reports were publicized at a "State-of-the-Bay" conference in November 1988.

THE NATIONAL ESTUARY PROGRAM

The National Estuary Program (NEP) was established by U.S. Congress in the Water Quality Act of 1987 and is administered by the United States Environmental Protection Agency (EPA). The purpose of the NEP is to create a conservation and management plan which will protect and enhance water quality in specific bodies of water (USEPA,OMEP 1987). In 1988, California Governor Deukmejian nominated Santa Monica Bay to be included in the NEP and in July 1988 the Bay became one of 21 bodies of water nationwide to be granted this status (Table 1-1).

SANTA MONICA BAY RESTORATION PROJECT

Under sponsorship by EPA, State Water Resources Control Board (SWRCB), and State Environmental Affairs Agency (SEAA), the Santa Monica Bay Restoration Project (SMBRP) was established and mandated to meet the goals outlined by the NEP. A Management Conference was established to overview the activities of the Project and is being conducted by a Management Committee composed of representatives of 54 organizations, including Santa Monica Bay area Congressional and State legislative representatives, cities bordering Santa Monica Bay, Los Angeles County, regulatory and resource agencies, major dischargers, environmental and industry groups, and public interest groups. A

STATE	BODY OF WATER
WEST COAST	
California	San Francisco Bay
California	Santa Monica Bay
Oregon	Tillamook Bay
Washington	Puget Sound
GULF OF MEXICO	
Florida	Indian River Lagoon
Florida	Sarasota Bay
Florida	Tampa Bay
Louisiana Estuarine Complex	Barataria-Terrebonne
Texas	Corpus Christi Bay
Texas	Galveston Bay
EAST COAST	
Delaware	Delaware Inland Bays
Maine	Casco Bay
Massachusetts	Buzzard's Bay
Massachusetts	Massachusetts Bays
New Jersey, Pennsylvania, Delaware	Delaware Bay
New York	Peconic Bay
New York, Connecticut	Long Island Sound
New York/New Jersey	New York/New Jersey Harbor
North Carolina	Albemarie-Pamlico Sound
Rhode Island	Narragansett Bay
ATLANTIC OCEAN	
Puerto Rico	San Juan Bay

Table 1-1. Bodies of water included in the National Estuary Program

Technical Advisory Committee (TAC) provides scientific and technical expertise to the Management Committee while a Public Advisory Committee (PAC) advises those affected by the Management Committee's recommendations and actions.

COMPREHENSIVE CONSERVATION & MANAGEMENT PLAN

The goal of the SMBRP is to develop a Comprehensive Conservation and Management Plan (CCMP) for the Bay which includes the following goals:

- To restore the beneficial uses of Santa Monica Bay and to protect present and future beneficial uses of the Bay. Beneficial uses include active and passive recreation, sport fishing, shellfish harvesting, and protection of marine habitat, including habitats for rare and endangered species and for fish spawning.

- To improve or eliminate discharges to the Bay that may adversely affect biloically sensitive sites, including wetlands, or important swimming and fishing areas.

- To improve water quality to a point where local marine species are not degraded and human health is not threatened.

To accomplish these goals, the SMBRP concentrates is in the process of building a consensus among all user groups; identifying the major environmental problems in Santa Monica Bay; and preparing a plan that can be implemented to protect the Bay and its resources.

PURPOSE AND OBJECTIVES OF THE STUDY

In 1990, the SMBRP adopted the "State of the Bay: Assessment of Conditions and Pollution Impacts" report (MBC 1988) as its preliminary characterization report. Since then the SMBRP has developed an outline of the CCMP, drafted Action Plan Elements to be addressed in detail in the Plan (Table 1-2), and has commissioned several studies to fill data gaps identified in the State of the Bay report. Meanwhile, the need to document present conditions in the Bay was recognized. In April 1992, MBC Applied Environmental Sciences was contracted to update the State of the Bay report.

ACTION PLAN	DISCUSSION CHAPTERS
I. REDUCE SOURCES OF POLLUTION	
A. Mass Emission Policy	5,6
B. Pollution Prevention Program	5,6
C. Comprehensive Stormwater/Urban Runoff Management Program	3,7
D. Municipal and Industrial Discharge	5
E. Prevention and Response to Oil and Hazardous Materials Spills	6
F. Remediate Contaminated Sediments	9
II. PROTECT THE PUBLIC FROM HEALTH RISKS ASSOCIATED WITH SWIMMING AND CONSUMING SEAFOOD FROM THE BAY	
A. Ensure that Bay Seafood is Safe to Consume	12
B. Reduce Human Health Risks Associated with Swimming in Bay Waters	11
III. RESTORE, PROTECT AND MANAGE HABITATS AND WATERSHEDS	
A. Marine Ecosystem	3,8,9,10
B. Wetlands	3,8
C. Beaches and Intertidal Zones	3,8
D. Watersheds	3,6

Table 1-2. Draft Action Plan Elements of the Comprehensive Conservation and Management Plan for Santa Monica Bay.

The objectives of the present study are to update the State of the Bay Report and to provide a final characterization report for the Santa Monica Bay Restoration Project, emphasizing the tentative Action Plan Elements identified. The general aims of the update, like those of the original study, are to assess historic and present levels of pollution and to evaluate the impacts of that pollution in the study area. Specific goals include the following:

- to document what is and is not known about the condition of the Bay and its watershed, with an emphasis on the effects of pollution on human health and the marine environment.
- to determine inconsistencies in the literature regarding the condition and effects of pollution in the Bay and its watershed.
- to summarize the reviewed literature and evaluate conclusions from major documents and reports.

- to identify areas where additional research is needed to resolve inconsistent findings or to clarify appropriate clean-up measures; and,

- to prepare recommendations based upon this information.

STUDY APPROACH

The basic study approach was to collect, compile, review, summarize, and evaluate new information (collected between 1988 and 1992) relevant to the issues of concern. No field collections or measurements were made and few original analyses were performed. The original working bibliography of more than 1,000 citations was reviewed, leading to the identification of additional pertinent studies. Some of the information in this report was derived from published studies, but most of the recent data were collected from unpublished reports and personal communications from knowledgeable persons. Unpublished data from local agencies were integrated into existing figures and tables. However, the large number of studies and the quantity of data which have been generated precluded the inclusion of all information; only the more important references are actually cited.

HUMAN USES OF THE BAY

The developed area adjacent to Santa Monica Bay is important to Southern California for its social, economic, and environmental resources. The Bay forms the western-most edge of much of the Los Angeles metropolitan area and is simultaneously a marine environment and a densely populated urban area. The kinds of human uses that occur at the interface between the Pacific Ocean and Los Angeles have varied over time, including:

- Recreation, Tourism, and Aesthetic Enjoyment

- Sport and Commercial Fishing

- Coastal Development

- Industrial Uses

These uses constantly compete with each other for the limited amount of land and water, resulting in the current patchwork of open space as well as commercial, residential, and industrial development. Some uses are mutually exclusive, others can coexist. Recreation, tourist facilities, and aesthetic features (views and mild climate) have a symbiotic relationship in which the elements reinforce one another; in contrast, some shipping and industrial uses are incompatible with fishing and recreational uses.

The following inventory of human uses in and adjacent to Santa Monica Bay emphasizes the social, environmental, and economic significance of these activities. When possible, the economic value is described. Coastal Santa Monica Bay includes the eleven incorporated cities adjacent to the Bay plus the communities of Playa del Rey, Westchester, Venice, Pacific Palisades (City of Los Angeles), and Marina del Rey (County of Los Angeles) (Figure 1-2). The eleven incorporated cities are El Segundo, Hermosa Beach, Manhattan Beach, Malibu, Palos Verdes Estates, Rancho Palos Verdes, Redondo Beach, Rolling Hills, Rolling Hills Estates, Santa Monica, and Torrance. Malibu was incorporated in April 1991 and has a population of about 15,000. Major factors behind incorporation were the local residents' desire for low-growth policies and to block construction of a new county sewer system.

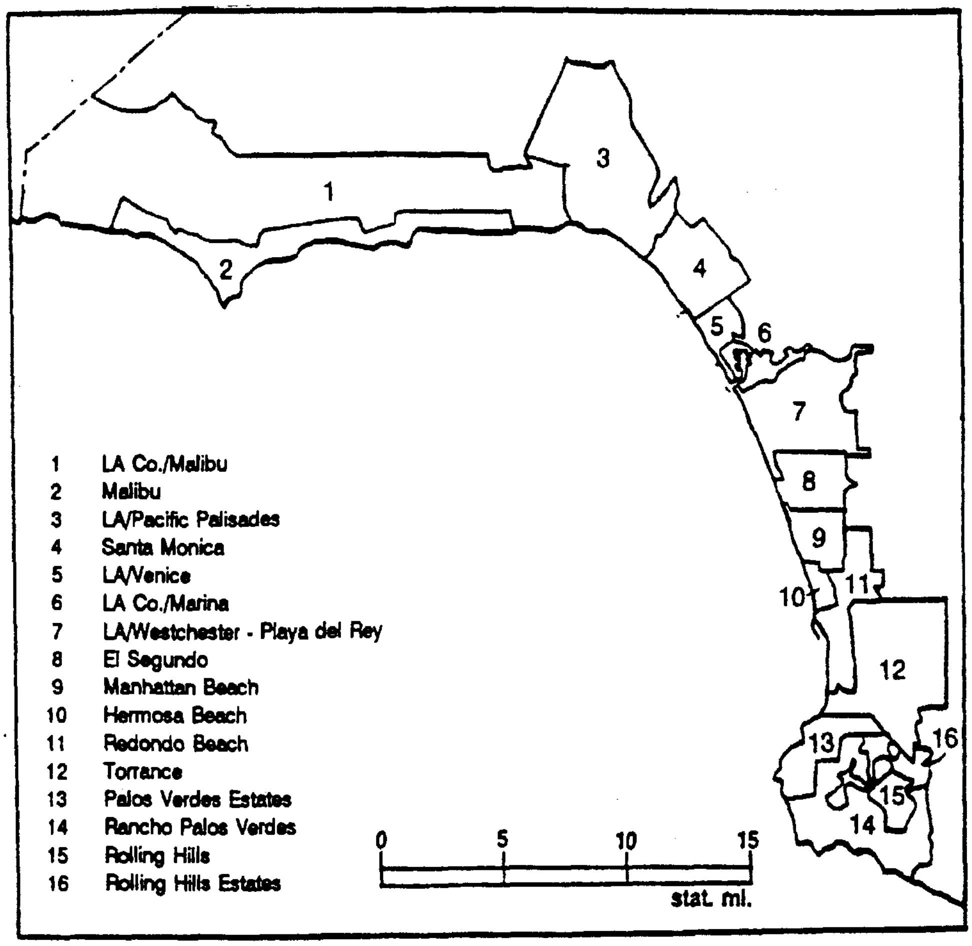


Figure 1-2. Local coastal jurisdictions in the Santa Monica Bay study area, 1992 (modified from MBC 1988).

RECREATIONAL, TOURIST, AND AESTHETIC USES

Recreation features and activities can be natural or developed, commercially or non-commercially operated. Examples of the four possible combinations abound throughout the Bay area.

NATURAL OPEN SPACE

Undeveloped natural recreation areas are scarce along the predominantly urban coastline; pristine wildlife conditions no longer exist in the study area. Yet significant natural resources remain. The Ballona wetlands (between Marina del Rey and Playa del Rey at the mouth of Ballona Creek) is a surviving wetlands that contributes to recreation, tourism, and aesthetic enjoyment. Urban development has impacted the marsh in recent decades, but efforts to reestablish and enhance 151 acres of degraded wetlands habitat are being advanced (MBC 1988). Some relatively undisturbed marsh and riparian habitat is also found in the Malibu Creek drainage and the Santa Monica mountains offer a wide range of natural habitats, especially inland of the Malibu and Carillo coasts.

DEVELOPED BEACH FACILITIES

The many miles of bathing beaches between Torrance and Point Dume almost define Santa Monica Bay for many persons. The 22 public beaches along the shore provided more than 46 million person-days of recreation in 1991. Activities include sunbathing, swimming, boating, and surfing as well as access to the nearshore waters for skin- and SCUBA-diving. Most of these beaches are at least partially developed, offering parking, restrooms, concessions, and rental equipment. The natural state of most of them is supplemented with imported sand and/or landscaping. The busiest beach in the County is the three-mile long Santa Monica Beach. Other developed natural recreation facilities include the beach bike path, which extends from Santa Monica to Redondo Beach, and several bluff-top parks overlooking the Bay.

Recreational use of Los Angeles County beaches increased sharply until the early 1980s, attendance peaking in 1983 at 79 million visitors. While the region's population and visitors to the area have increased steadily since then, beach attendance has decreased 56% since 1983 (Figure 1-3) (LAC,DBH 1987, 1992). Although changes in the weather account for annual fluctuations, the dramatic decline may indicate basic changes in recreational conditions at the beaches. In particular is public fear of water pollution, congestion, and lack of parking. For example, despite warm temperatures, beach attendance declined in late October and November 1987 following two sewage spills into the Bay from the Hyperion Treatment Plant (HTP) when some beaches were closed for up to seven days (LAC,DBH 1987). In 1991, beaches were closed on five occasions due to spills or overflows, and in 1992 beaches were closed at least eight times, including several days following contamination flowing from the storm drains created from the civil unrest in the spring of 1992.

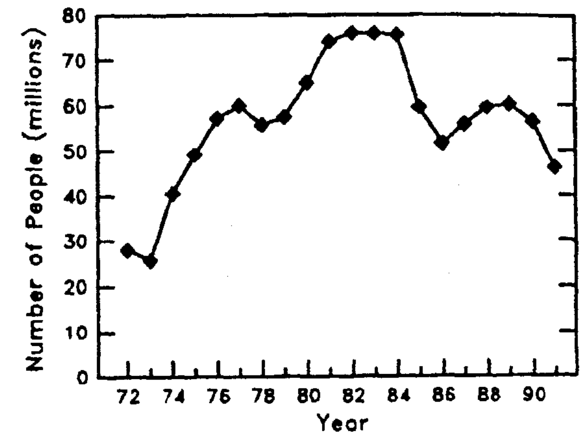


Figure 1-3. Beach attendance along Santa Monica Bay, 1972-1991 (LAC,DBH unpubl. data).

COMMERCIAL

Commercial recreation opportunities range from bicycle and roller skate rentals, and "fun zone" arcades, to restaurants, bars, and art galleries. Most of these establishments capitalize on the pedestrian traffic attracted to the beach and some areas have evolved into recreation attractions of their own: Main Street and Santa Monica Pier in Santa Monica; Fisherman's Village in Marina del Rey; and King Harbor in Redondo Beach.

Tourist facilities and activities are abundant around Santa Monica Bay. Hotels, motels, apartments by the week, restaurants, shops, and conference facilities all cater to day visitors and out-of-town visitors. While neither the local economy nor the beach environment alone would attract tourism, in combination they create a powerful magnet for visitors. In addition, Los Angeles International Airport (LAX) is situated directly on Santa Monica Bay and it funnels a large percentage of its 48 million annual passengers into the Santa Monica Bay area for at least a portion of their stay.

Tourist services and attractions are not distributed evenly in the Bay area. Hotel development is centered around LAX, although small numbers of guest rooms and conference facilities are available in Santa Monica, Marina del Rey, El Segundo, Manhattan Beach, and Redondo Beach. An average of 9,372 guest rooms are available daily in the Santa Monica-LAX area, 10.4% of Los Angeles County's total (Pannell Kerr Forster 1992). The Santa Monica market has performed well despite the recession and is expected to remain strong even after the addition of two high-end hotel properties that are being added and will diversify the supply.

Demand in the LAX market has declined in recent years due to reductions in domestic and international tourism and in corporate travel. In addition, 700 new rooms were added to the market in 1991. Hotel supply in Los Angeles County outpaced demand by moderate levels: between 1986 and 1990 the daily average number of rooms available increased by 5%. Growth in new hotel rooms during the 1990s is expected to be at a slower rate than in the late 1980s due to the slow economy, cutbacks in corporate and leisure travel, escalating land prices and a more difficult development climate (Pannell Kerr Forster, 1992). There are few parcels of land left in the coastal area which are large enough to accommodate hotel-conference complexes (LAVCB 1988, pers. comm.).

Tourism is a powerful economic factor in the Bay area. Complete visitor data are not available for most jurisdictions, but a profile of Santa Monica's experience indicates the magnitude of visitor contributions to the local and regional economy. Santa Monica reports 2.5 million visitors annually, 64% of them day visitors. On average, day visitors spend $25 per day; overnight visitors staying in hotels spend $81 per day and constitute 15% of the city's visitor volume. Visitors who lodge with friends and relatives spend approximately $30 per day and make up about 20% of the total. In 1986, these visitors added $232 million and more than 3,000 jobs to Santa Monica's economy and the city received $4.2 million in tax revenues generated by tourist expenditures. In total, Santa Monica garnered approximately 6.8% of the state's $3.4 billion tourist income (MBC 1987).

NONCOMMERCIAL

The aesthetic features (especially marine) and favorable climate of Santa Monica Bay enjoy a worldwide reputation. These resources are an amalgam of natural and man-made features which have been achieved through merging of coastal themes with urban development.

The Santa Monica Bay shore offers numerous opportunities to appreciate physical beauty: broad beaches, boardwalks, and piers; vistas of Palos Verdes Peninsula, Malibu, and Santa Catalina Island; and a variety of public and private facilities and spaces. Local jurisdictions review proposed development plans in order to preserve and enhance existing aesthetic resources and scenic areas.

Aesthetic resources make an intangible but important contribution to the local economy. They tend to boost tourism and recreation and are closely tied to specific businesses such as television and motion picture filming, two staples of the regional economy.

SPORT AND COMMERCIAL FISHING

Fishing is one of the most fundamental human uses of the Bay and includes commercial passenger fishing vessels (party boats), pier fishing, private boat fishing, scientific collecting, and limited commercial fishing. While sport fishing is allowed throughout the Bay, commercial fishing has been prohibited in about 62% of Santa Monica Bay proper to protect local fish populations, which could be depleted by a combination of both commercial and sport fishing. Commercial fishing for white croaker off Palos Verdes has been banned since early 1990 due to white croaker contamination problems (Velez 1993, pers. comm.). Purse seining, gillnetting, and traps are prohibited in parts of the Bay east of a line between Malibu Point and Palos Verdes Point.

Commercial fishing activity in the rest of the Bay centers around gillnetting for California halibut west of Malibu and south of Palos Verdes Point, and purse seining for northern anchovy in the outer portions of the Bay (MBC 1985). Under Assembly Bill 2315, experimental gear permits are issued for round haul net fishing for live bait (Velez 1993, pers. comm.) throughout all the Bay. Commercial catches from Santa Monica Bay are negligible. Limited commercial marine life collections are made for scientific and educational specimens and unauthorized commercial fishing and poaching may occur to some extent, although its magnitude is not known.

Although statistics are not available for Santa Monica Bay alone, 5.5 million sport fishing trips were made in Southern California in 1989. It is estimated that 11% of those trips involved beach fishing, 22% involved pier fishing, 30% involved commercial passenger fishing vessels (CPFVs), and 37% involved private fishing boats (NMFS 1991). The sport fishery catch from Santa Monica Bay is monitored by the California Department of Fish and Game (CDFG). In 1987 the sport fishery catch (79,197 anglers) was dominated by Pacific bonito, chub (Pacific) mackerel, and barred sand bass (CDFG,MRD, unpub. data). In 1991-1992, the sport fishery of the Bay was dominated by chub mackerel, barred sand bass, and kelp bass (MBC, in prep.).

The sport fishery catch has some economic value as food, but fees paid to charter operators and other onshore expenditures have a much greater impact on the local economy. Expenditures on saltwater fishing in Southern California totalled $536.3 million in 1989, 16% of which was on licenses and gear, 23% on boat related expenses, and 61% on trip-related expenses. Los Angeles County residents accounted for 37% of that total. About 465,000 of the 6.1 million households in Southern California coastal counties included at least one member who went sportfishing in 1989.

Los Angeles residents spend an average of $27.13 per fishing trip on tackle, food, lodging, boat fuel, boat fees, and gasoline. Shore anglers spend an average of $27.44 per fishing trip and party boat anglers spend an average of $72.76 per fishing trip. The average expenditures noted above, if applied to the totals counted by CDFG, would account for a total contribution to the local economy by sport anglers in Santa Monica Bay in excess of $3.6 million.

Recreational fishing facilities in the Bay area include piers at Malibu, Santa Monica, Venice, Manhattan Beach, Hermosa Beach, and Redondo Beach and a fishing barge off Redondo Beach. There are small craft harbors at Marina del Rey and at King Harbor in Redondo Beach. Fourteen artificial reefs designed to enhance marine life and improve sport fishing opportunities have been installed offshore at Malibu, Paradise Cove, Santa Monica, Marina del Rey, Manhattan Beach, Hermosa Beach, and Redondo Beach since 1958 and nine of these remain (Lewis and McKee 1989). Commercial passenger fishing vessels (party boats) can be taken at Malibu, Marina del Rey, and Redondo Beach. Party boats from Los Angeles and Long Beach Harbors also fish in the area.

COASTAL DEVELOPMENT IN THE SANTA MONICA BAY AREA

Development of the Santa Monica Bay area is extensive: of the 67.6 mi^2 of land adjacent to the Bay (for which data exist) about 55% are devoted to residential uses; 14% commercial uses; 11% industrial uses; and 3% to transportation corridors (Table 1-3) (SCAG 1992a). Although 17% of the area are vacant, few sizable vacant parcels remain, the Hughes Playa Vista property is the largest.

Like the rest of the region, the Santa Monica Bay area is under pressure for living and working space; several regional employers in the area have fueled competition for the limited supply of coastal land. Density in areas adjacent to the Bay has increased in response to the demand for housing and business locations with coastal amenities.

For the most part land-use is regulated by the individual jurisdictions bordering the Bay and are specified in each cities' General Plan. The California Coastal Commission also regulates development in the Coastal Zone through Local Coastal Plans which are formulated by the jurisdictions in accordance with Commission policies and planning principles.

Jurisdictions	Area (mi²)					
	Commercial	Industrial	Residential	T/C	Vacant	Total
El Segundo	0.82	2.88	1.14	0.15	0.54	5.53
Hermosa Beach	0.23	0.01	0.62	0.07	0.15	1.08
LA/Venice	na	na	na	na	na	na
LA/LAX Westchester	na	na	na	na	na	na
LA/Pacific Palisades	na	na	na	na	na	na
LA/Malibu	na	na	na	na	na	na
LA/Playa Del Rey	na	na	na	na	na	na
LA/Marina Del Rey	na	na	na	na	na	na
Manhattan Beach	0.66	0.14	2.64	0.10	0.34	3.89
Palos Verdes Estates	0.20	0.00	3.08	0.07	1.38	4.73
Rancho Palos Verdes	0.51	0.06	7.22	0.18	5.34	13.31
Redondo Beach	1.14	0.35	3.08	0.16	0.37	5.09
Rolling Hills	0.04	0.00	1.94	0.01	1.05	3.04
Rolling Hills Estates	0.40	0.21	1.91	0.30	0.61	3.43
Santa Monica	1.70	0.51	4.76	0.42	0.42	7.81
Torrance	3.85	3.20	10.51	0.86	1.26	19.68
Total Area	9.55	7.36	36.90	2.33	11.45	67.59
Total Percent	14.1	10.9	54.6	3.4	16.9	

Table 1-3. Major land uses of local coastal jurisdictions within the Santa Monica Bay area, 1992.

Coastal development itself is a major economic activity. The assessed valuation of property in jurisdictions around Santa Monica Bay ranged from $296 to $7,618 million in 1987 (Table 1-4) (LAC,AC 1988) and the full-market value of residential, commercial, and industrial properties in the area exceeded $30 billion. This figure does not include the value of publicly-held or otherwise tax exempt property such as libraries, schools and colleges, and parks and recreation facilities, nor does it include City and County of Los Angeles Plan areas, for which statistics were unavailable. Nevertheless, this indicator of private investment accounts for 9.7% of the Los Angeles County total.

In addition to its ultimate assessed value, development contributes to local and regional economics during construction. Construction jobs and expenditures are a major segment of the southern California economy. Coastal development also supports the local economy through property taxes and development fees, which are used in part to fund recreation and open-space amenities that encourage still other economic benefits, primarily tourism.

The predominant human use in the Santa Monica Bay area is residential (Table 1-3). The Bay's recreation and air quality resources make it one of the most desirable sectors of the region in which to live: housing unit vacancies fall well below the County's 4% average in all but a few of the Bay jurisdictions. Except for the Palos Verdes Peninsula, the average household size is also below the Los Angeles County average, indicating a trend toward smaller, denser housing units (LAC,DRP 1987). The Bay area's housing stock is 7% of the Los Angeles County total (Table 1-5) (SCAG 1992b) and it houses 7% of the County's population, underlining the small household size along the coastal area. Torrance, Santa Monica, and Redondo Beach have the greatest number of housing units (Table 1-5) (SCAG 1992b). Between 1987 and 1992, the number of housing units increased 450% in Playa del Rey; the next highest rates of increase were Marina del Rey with 16% and Rancho Palos Verdes with 7% (Table 1-5). Pacific Palisades, Westchester, and Venice had fewer housing units in 1992 than in 1987, with decreases of 66, 58, and 20%, respectively.

Commercial and industrial land uses in the Santa Monica area contribute to the regional economy in terms of employment. In 1980, commercial and industrial land users in the Bay area provided 18% of the five-county region's jobs on only 4% of its land. These figures include inland portions of West Los Angeles, but exclude major job centers such as UCLA, Westwood, and Century City. Jobs within the Bay area are diffused throughout the 16 jurisdictions, although there are major concentrations in Santa Monica, South Bay, and at LAX. While the absolute numbers of jobs have changed since 1980, the general patterns have been reinforced through additional land development and employment growth.

Jurisdictions	Valuation ($ in millions)
El Segundo	4,724
Hermosa Beach	1,002
LA/Venice	na
LA/LAX Westchester	na
LA/Pacific Palisades	na
LA/Malibu	na
LA/Playa Del Rey	na
LA/Marina Del Rey	na
Manhattan Beach	2,533
Palos Verdes Estates	1,284
Rancho Palos Verdes	2,571
Redondo Beach	3,690
Rolling Hills	296
Rolling Hills Estates	767
Santa Monica	5,863
Torrance	7,618
Total	30,348

Table 1-4. Assessed values of development within jurisdictions of the coastal Santa Monica Bay area, 1987.

Commercial and industrial land uses in the area support 17% of the region's retail jobs, 16% of financial jobs, 22% of business sector employment, 23% of service and entertainment jobs, 16% of professional workers, and 15% of public administration positions. The area also accommodates 20% of the region's manufacturing workers, 23% of transportation employment, and 18% of wholesale employment. This impact is augmented by the goods and services produced by the workers, which have regional, national, and international significance (Gordon 1988, pers. comm.).

Marine development in the Bay area includes piers, artificial reefs, and breakwaters. Commercial and industrial activities which depend on a coastal location are clustered in and around the small craft harbors and piers. Boat building and maintenance, fishing, and tourist facilities are coastal dependent commercial and industrial activities. However, electric power generating stations and an oil refinery must also be included as coastal-dependent, the former for cooling water and the latter for tanker access.

Secondary economic impacts from the Bay area's commercial and industrial activities emanate to the rest of the Los Angeles region. Employees from outside areas spend most of their income elsewhere, thus boosting sales and tax revenues there. Goods and services produced in the Bay area are often sold or consumed in other sectors of the region.

With the exception of the Playa Vista land holding, which is being planned for mixed-use development, the study area is at or near build-out. Future coastal development is limited by the lack of available vacant land. Future growth, along with its primary and secondary economic benefits, will be restricted to scattered infill development, recycling, and redevelopment activities. Thus, significant expansion of the Bay area's economic position in the region is likely to result in a denser pattern of human activities and development.

Infrastructure constraints - the willingness of local jurisdictions to work together to fund and construct new streets, parking, and sewage treatment capacities - will also limit future growth. Downzoning and other growth-curtailing planning and policy actions are now being considered in several local jurisdictions. Some of these proposals affect residential growth only, others address commercial growth, and some would impact all development. The outcome of these deliberations may freeze the present land use pattern and thus limit the area's current contribution to the regional economy.

Jurisdictions	Units 1987	Units 1992	Percent Difference
El Segundo	6,951	7,231	4.0
Hermosa Beach	10,012	9,743	-2.7
LA/Venice	20,530	16,354	-20.3
LA/LAX Westchester	19,236	8,098	-57.9
LA/Pacific Palisades	9,776	3,291	-66.3
LA/Malibu	7,371	7,570	2.7
LA/Playa Del Rey	1,496	8,235	450.5
LA/Marina Del Rey	4,756	5,513	15.9
Manhattan Beach	14,882	14,826	-0.4
Palos Verdes Estates	5,023	5,144	2.4
Rancho Palos Verdes	14,580	15,565	6.8
Redondo Beach	28,826	28,591	-0.8
Rolling Hills	664	676	1.8
Rolling Hills Estates	2,767	2,924	5.7
Santa Monica	47,843	47,976	0.3
Torrance	52,288	55,370	5.9
Total Coastal Units	247,001	237,107	-4.0
Total Los Angeles County Units	3,023,573	3,206,500	6.1
Percent of Total County	8.2	7.4	-0.8

Table 1-5. Housing stock in the coastal Santa Monica area, 1987 and 1992.

INDUSTRIAL USES OF THE BAY AREA

Industrial land use is found in all but two Bay area jurisdictions. El Segundo, Torrance, and Westchester-LAX-Playa del Rey contain industrial centers of 1,500 acres or more, while Santa Monica, Redondo Beach, and Manhattan Beach contain industrial centers of 250 to 500 acres (LAC 1987). Industrial uses also affect the marine environment directly through wastewater discharges and use of the ocean for transport.

The industrial/municipal activities that most impact the Bay are power generation, oil refining, and waste disposal. Most of the industrial facilities of concern are located nearshore, between Marina del Rey and Redondo Beach: the Los Angeles Department of Water and Power's Scattergood Generating Station; Southern California Edison's (SCE) El Segundo and Redondo Generating Stations; the Chevron USA's El Segundo Refinery; and the City of Los Angeles Hyperion Treatment Plant (HTP).

Los Angeles International Airport (LAX) is an industrial facility and aerospace-related manufacturing center which is located on the Bay but provide essential regional services; the airport relies upon its proximity to the Bay for safe flight paths exiting the airport.

The three power generation facilities use Bay water for condenser cooling and disposal of a small amount of treated effluent. Together, these plants circulate up to 238 billion gallons of seawater per day. Southern California Edison's plants generated $625.5 million worth of electrical energy sales to the region in 1987 (SCE,SGD 1988).

Chevron USA uses Santa Monica Bay to transport crude oil and refined petroleum products to and from its El Segundo Refinery. Small coastal lightening tankers load and off-load at the refinery using a three-berth offshore facility which connect the marine terminal to the refinery with subsea pipelines (Chevron USA 1988, pers. comm.). Small amounts of treated effluent are also discharged.

HTP discharges treated municipal wastewater at a distance of five miles from shore, relying on ocean water to dilute the effluent to safe levels. HTP disposes of a mixture of secondary- and primary-treated wastewater via a 5-mi long outfall pipe into the Bay. The 5-mi outfall discharges 60% secondary and 40% primary treated effluent. A 1-mi outfall is used for emergency purposes, to discharge chlorinated secondary treated effluent. A 7-mi outfall was used for sludge disposal until November 1987.

The Los Angeles County Sanitation Districts' Joint Water Pollution Control Plant (JWPCP) discharges approximately 325 mgd of treated municipal wastewater onto the Palos Verdes Shelf. The JWPCP disposes of a mixture of 60% secondary- and 40% advanced primary-treated wastewater through two outfalls, 90- and 120-in. diameter, with a 72-in. diameter outfall for emergency backup. JWPCP is the central solids processing facility for five upstream water reclamation plants located in Los Angeles County; these plants provide primary, secondary, and tertiary treatment for 150 mgd wastewater (Stull 1993, pers. comm.).

Each of these industrial/municipal uses impacts the economy in two ways. Each generates employment and goods for the local economy and each also provides a regional service with a high replacement value. Replacement costs for SCE's electrical generating stations at Redondo and El Segundo illustrate the magnitude of the economic value that major industrial uses for the study area and the region. Based on 1987 totals for capital investment, operations and maintenance expenses (including payroll and repairs), fuel expenditures, property taxes, and electricity sales, SCE estimates the power replacement value of its El Segundo station at $918,000,000, and for its Redondo station at $1,442,000,000 (SCE,SGD 1988).

HTP also represents a substantial replacement value, although no estimates are available. Some facilities might not be able to replace the loss of a Bay location or resource, at any cost. For example, loss of its marine terminal pipelines across the Bay could force Chevron to relocate to an area without transportation constraints.

Future impacts of industrial facilities on regional economics will depend on the amount of expansion and updating that occurs. LAX is the hub of a regional airport system, which is expected to grow to 65 million passengers annually by the year 2000 (CLA,DA 1992). HTP is being expanded and upgraded at present and is expected to remain the linchpin of Los Angeles' wastewater treatment system, whether or not additional capacity is added elsewhere. However, as additional land is unavailable, any expansions can only occur with more intensive use of existing land holdings and water resources, or through eminent domain.

Plans for further oil and gas development in and around Santa Monica Bay have changed in recent years. The Department of the Interior Lease Sale No. 95 Offshore Drilling Proposal for Southern California, which would have made areas immediately west of Santa Monica Bay available for oil and gas exploration and development, has been dropped. Lease Sale No. 95 was originally slated for January 1990 but in June of that year President Bush deferred the sale until 1996 and in 1992, a moratorium was placed on offshore drilling and Lease Sale No. 95 was canceled. In addition, Occidental Petroleum's 22 year effort to drill for oil on the company's two acres of coastal property along Pacific Coast Highway ended in 1992. Occidental decided not to pursue the drilling plan any further and transferred ownership of the property to the City of Los Angeles (LA Times 1992).

2

PHYSICAL SETTING

CHAPTER 2
THE PHYSICAL SETTING

Santa Monica Bay is an open embayment on the Southern California coast just west of Los Angeles, with natural boundaries which extend from Point Dume to Palos Verdes Point. For the purposes of this study, the Bay has been defined as extending from the Ventura-Los Angeles County Line (west of Point Dume) to Point Fermin (south of Palos Verdes Point) and offshore to water depths of about 1,650 feet (Figure 2-1).

Santa Monica Bay is a relatively small feature in a larger geographic region [the Southern California Continental Borderland (Emery 1960, SCCWRP 1973)] — the offshore, submerged lands from Point Conception, California to Cape Colnett, Baja California and seaward to the Patton Escarpment. Without the geological connotation, this region is known more commonly as the Southern California Bight, the seaward boundary of which is the California Current.

The study area consists of three regions: Santa Monica Bay itself; its natural watershed; and the wasteshed which drains to it (Figure 2-1). Santa Monica Bay includes the marine waters and seafloor of the area already defined. The watershed is that region of coastal land from which surface waters drain naturally to the Bay. The wasteshed is that area from which municipal wastes are collected before being treated and discharged to the Bay. The surface area of Santa Monica Bay is approximately 266 mi^2 and that of the combined watershed and wasteshed is approximately 1,380 mi^2. Most surface runoff from the wasteshed is carried to Los Angeles' Long Beach Harbor (east of the Palos Verdes Peninsula) but some is carried to the Bay.

The physical characteristics of the Santa Monica Bay ecosystem are determined primarily by the geology, climate, and oceanography of the region. Geological features provide the framework for the system within which climate and oceanography determine many natural environmental cycles.

GEOLOGY

The present configuration of the Southern California Continental Borderland is largely the result of the movement of the Pacific tectonic plate against the North American tectonic plate, the San Andreas fault marking the line of contact between the two. Many local features in the area result from block-faulting, a geological process in which large blocks of the earth's crust are thrown upwards or downwards. Offshore islands and banks represent upthrown blocks whereas basins represent downthrown blocks (Emery 1960). The Santa Monica Mountains were uplifted, then shifted to the West.

Santa Monica Bay is the submerged portion of the Los Angeles Coastal Plain, which extends southeast of the Santa Monica and San Gabriel Mountains, southwest of the San Bernardino Mountains, and north of the Santa Ana Mountains. The Los Angeles Basin lies beneath the Coastal Plain and the Bay and was formed as a downthrown block. Sediments eroded from the surrounding mountains have subsequently filled the basin to its present surface, near sea level (Terry *et al.* 1956, Emery 1960, Miller and Hyslop 1983). Sediments near the surface of the Basin have been deposited during the last two million years (BLM 1981).

Offshore of the Los Angeles Basin is the Santa Monica Basin, which is a downthrown block that has only been partially filled with eroded sediments; hence it is still a fairly deep marine basin. The shelf in Santa Monica Bay is partly the sediment-filled Los Angeles Basin and

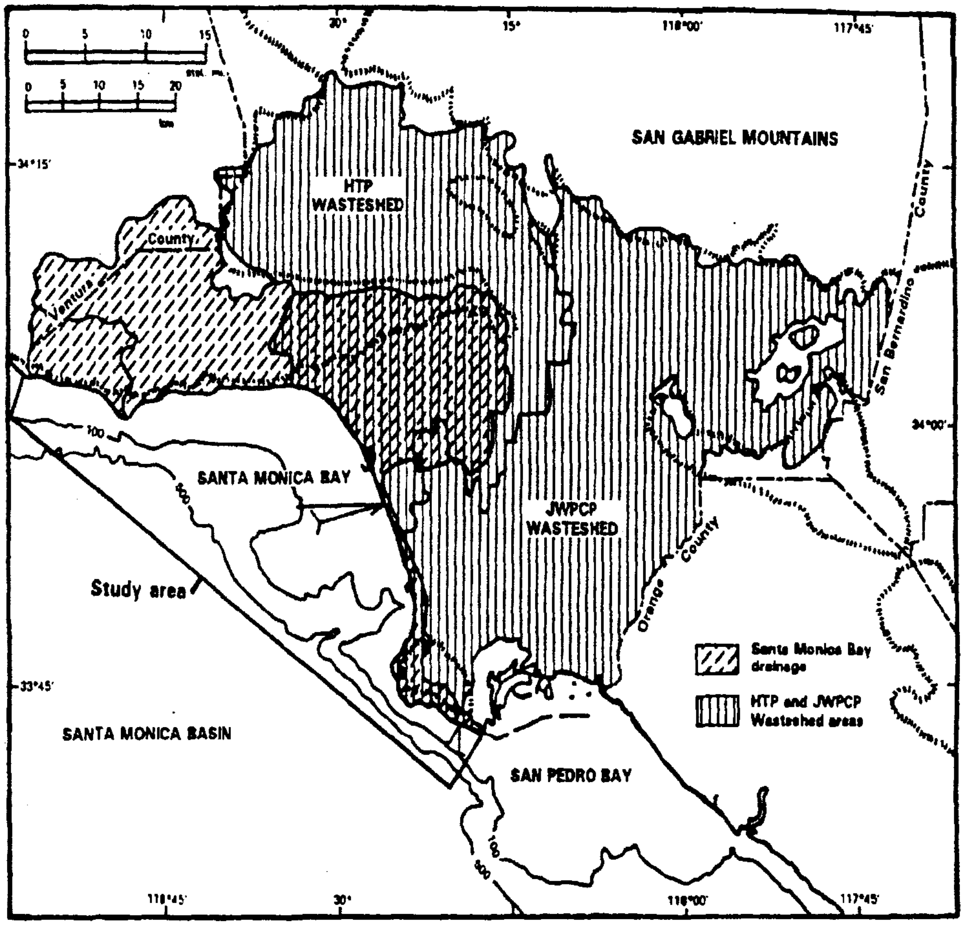


Figure 2-1. Santa Monica Bay study area, watershed, and wasteshed (modifed from MBC 1988.

partly the sill that separates the Los Angeles and Santa Monica Basins. Bedrock lies much nearer the sediment surface beneath the sill than beneath the two basins (Emery 1960).

The Palos Verdes Peninsula is an uplifted block that appeared as an island about three million years ago; it was later connected to the mainland as a result of sedimentation on the Coastal Plain (Reiter 1984). During ice ages, which occur about every 100,000 years, sea level drops as much as 425 ft because water is retained in polar glaciers (Covey 1984); during interglacial periods sea level rises, to present levels or higher. Most of the terraces which are obvious on the Palos Verdes Peninsula (and can be detected on the adjacent seafloor to water depths of 500 ft) were formed by wave erosion of the shore when sea level was at a different height for a considerable period of time. Terraces far above the shoreline on Palos Verdes Peninsula were probably exposed as a result of uplifting of the peninsula in recent geologic time.

The present continental shelf has only been submerged for the last 10,000 years and to the present depth for the last 3,000 years. During the peak of the last ice age (18,000 years ago), sea level was 384 ft lower than now (Nardin *et al.* 1981); this would have exposed the entire shelf and dry land would have extended as much as 12 miles offshore of the present shoreline.

TOPOGRAPHY OF SANTA MONICA BAY

Santa Monica Bay is characterized by a getly sloping (about 0.5°) continental shelf which extends seaward to the shelf break at a water depth of about 265 ft (Terry *et al.* 1956). At the break, the seafloor steepens along the continental slope but decreases again as the floor of the Santa Monica Basin is approached at a water depth of about 2,630 ft.

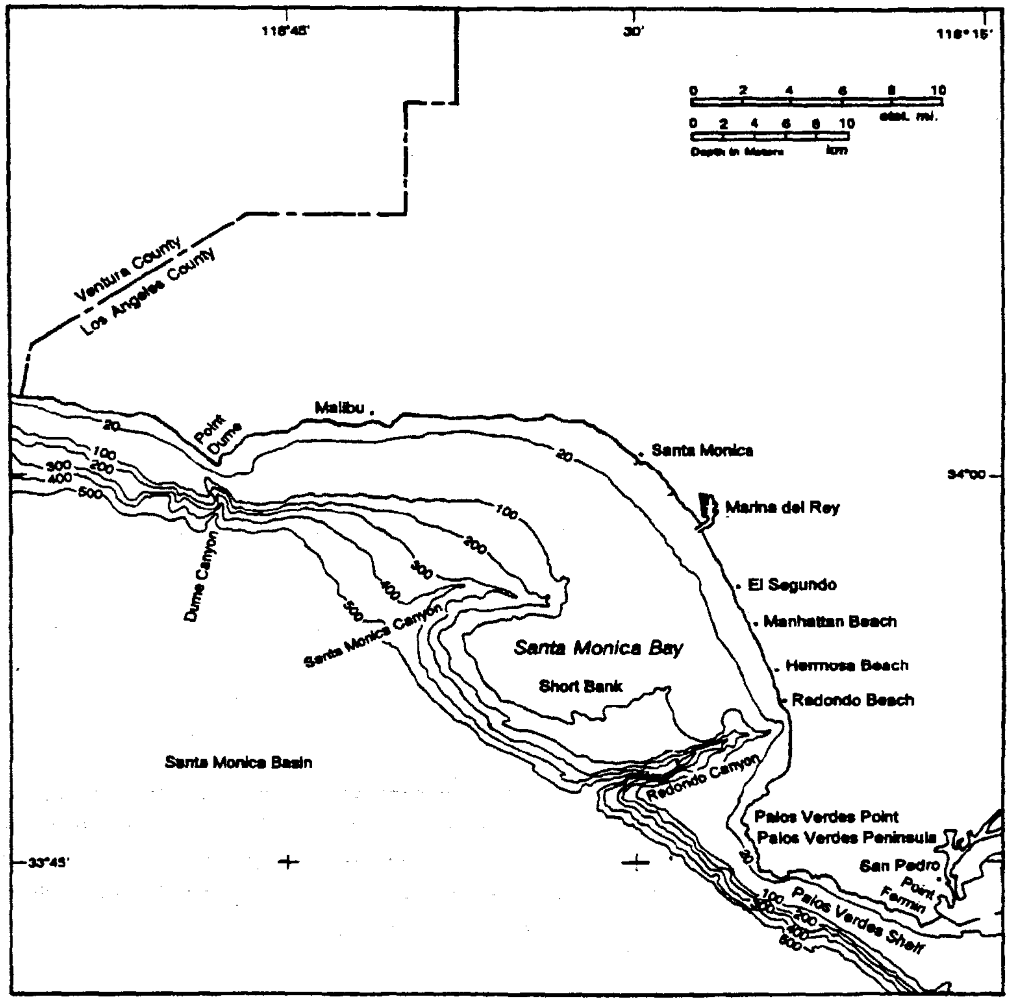


Figure 2-2 Topographic features of Santa Monica Bay (modifed from MBC 1988).

The shelf in the Bay ranges in width from a few hundred yards to about 12 miles (Figure 2-2). It is broadest off El Segundo, narrowest off Redondo Beach, and is transected by three submarine canyons: Dume Submarine Canyon across the northwestern shelf off Point Dume; Santa Monica Submarine Canyon, seven miles offshore of Ballona Creek; and Redondo Submarine Canyon, a few hundred yards off King Harbor. In this report the region between Santa Monica hand Point Dume is called the Malibu Shelf and the region between the Ventura-Los Angeles County Line and Point Dume is called the Carillo Shelf.

The Palos Verdes Shelf extends from the southern edge of Redondo Canyon around the Palos Verdes Peninsula to Point Fermin and offshore to water depths of about 245 feet (SDWG 1988). The Palos Verdes Shelf ranges in width from about 1.2 to 4.6 mi, and is steeper than in the Bay proper. The shelf break is shallower but less pronounced; below the break the seafloor is relatively steep to the boundary of the study area at depths of 1,640 feet.

SHORES

The shore of the study area is generally mountainous, with coastal cliffs between the Ventura County and Santa Monica and along the Palos Verdes Peninsula. Prior to development, the coast between the palisades at Santa Monica and Malaga Cove consisted of sand dunes; wetlands were abundant in the vicinity of Ballona Creek. At present approximately 50% of the shore of Santa Monica Bay is sandy, constituting the popular recreational beaches from Torrance Beach to Santa Monica and intermittently from there to Ventura

County. The coast from Point Dume to Pulga Canyon consists of narrow, sandy beaches interrupted by rocky outcrops or short stretches of rocky shore. Along the Palos Verdes Peninsula the shore is largely cobble with some small sandy pocket beaches (Terry *et al.* 1956); these beaches comprise coarser sand than those along the rest of Santa Monica Bay and contain some cobble.

Since creeks in the Ballona Creek drainage were channelized in the 1930s, little sand is transported to the Bay from the coastal plain. In the past, occasional shifts in the course of the Los Angeles River to Santa Monica Bay probably replenished beach sand. Now the primary source of beach sand is cliff erosion (Woodell and Hollar 1991) with some inputs from runoff from the Santa Monica Mountains (Mitchell 1987, pers. comm.) and the Santa Clara River (Kolpack 1988, pers. comm.). A landslide at Portuguese Bend has been an important source of sediment to the Palos Verdes Shelf since 1956, contributing about 9 million MT of sediment (Stull 1988, pers. comm.); it has been particularly important since 1980 (SDWG 1988).

Sandy beaches are an extension of the intertidal zone, as they are formed by the combined action of wind and waves. The source of the sand on Santa Monica Bay beaches is bluff erosion and sediment carried from the watershed by coastal streams and rivers. Sand is transported longshore and is eventually lost into Redondo Canyon. In some locations, beaches have been augmented by nourishment projects which have added more than 24 million cubic meters of sand to the shoreline (Woodell and Hollar 1991).

Dunes depend on a supply of sand which is moved onshore by waves, then further inland across low-lying areas by frequent strong winds. Coastal dunes protect low-lying inland areas from ocean storms, but they may be completely eroded during a single winter storm and reformed during calmer periods. The El Segundo Dunes are the only significant dunes remaining in the Santa Monica Bay area.

Historical. Prior to development, the coast between the palisades at Santa Monica and Malaga Cove consisted mostly of sand dunes. Adjacent to Ballona Creek were wetlands with fine sediments. Occasional shifts in the course of the Los Angeles River to Santa Monica Bay through Ballona Creek probably replenished beach sand. Since the channelization of creeks in the Ballona Creek drainage in the 1930s, little sand has been transported to the Bay from the coastal plain. Now the only natural source of sand besides bluff erosion is in runoff from the Santa Monica Mountains (Mitchell 1987, pers. comm.) or from the Santa Clara River in Ventura County via longshore transport (Kolpack 1988, pers. comm.). The few remaining natural dunes are just west of Los Angeles International Airport (Sharp 1978).

The shoreline of Santa Monica Bay is gradually eroding because sea level is slowly rising. Early developments in the Santa Monica Bay coastal zone included the construction of commercial structures on beaches and in the littoral zone and, later, other projects to protect these investments from the impacts of natural events. The first efforts to rebuild eroding beaches began in 1930 with the establishment of the Los Angeles County Coastal Studies Division. Periodic surveys of the beaches began in 1933; there have been 36 surveys to date. As a result of many efforts to counteract the erosion process (construction of groins and beach replenishment), beaches along much of Santa Monica Bay are wider than in the past (Woodell and Hollar 1991).

Location and Jurisdiction. The beaches of the Santa Monica Bay study area are variously under the jurisdiction of the state, county, city, and private groups. State beaches are run by the California Department of Parks and Recreation and include Leo Carrillo, Westward, Point Dume, Corral, Malibu Lagoon (Surfrider Beach), Las Tunas, Topanga, and Will Rogers to the west of Santa Monica and Dockweiler, Manhattan, Redondo and Royal Palms south of there. Beaches, parks, and reserves falling under the jurisdiction of Los Angeles County include Nicholas Canyon Beach, Zuma Beach Park, Torrance Beach, Abalone Cove Beach, and Abalone Cove Ecological Reserve.

City jurisdictions include beaches (Santa Monica, Venice, and Hermosa Beaches) and piers (Santa Monica Municipal, Venice Fishing, Manhattan Beach Municipal, Hermosa Beach Municipal, and Redondo Beach Municipal Piers), Seaside Lagoon , and the Palos Verdes Estates Shoreline Preserve. Private beaches include Paradise Cove and Marina del Rey Public Beach. Private piers include Paradise Cove Pier, Redondo Sportfishing Pier, and Monstad Pier.

Rocky Intertidal. On coasts exposed to the full force of incoming waves, loose sediments have been stripped away leaving underlying bedrock exposed as rocky intertidal habitat. In the study area, natural rocky intertidal habitat is found along the Carrillo coast, on the Malibu coast from Point Dume to Paradise Cove, along occasional rocky patches from there to Big Rock Beach, and along the coast of Palos Verdes Peninsula. Reefs around Point Dume are primarily bedrock, but those on the Palos Verdes Shelf include cobble, which is less stable than bedrock. Jetties, groins and piers provide artificial intertidal hard-bottom habitat along the central Bay.

The rocky intertidal can be divided into four discrete zones (Hedgpeth and Hinton 1961, Carefoot 1977). The splash zone is above the high tide mark and is essentially terrestrial, although it is splashed by waves. The upper intertidal zone extends from the bottom of the splash zone to about mean high tide, and it is exposed to the air longer than it is under water. The middle intertidal zone extends from about mean high water to mean low tide mark; it is exposed and submerged for about equal periods of time. The lower intertidal extends from mean low tide to the subtidal and is submerged longer than it is exposed.

The demarcation of zones is also affected by the prevailing wave heights. In an area which is exposed to frequent and high waves, the upper zones are displaced upward and the boundaries between adjacent zones are blurred. In protected areas where the average wave height area is low, there is no splash zone and the other zones are marked distinctly.

Sandy Intertidal. Where the coast is not directly exposed to strong waves, sand accumulates to form beaches. The sandy intertidal is exposed to extremes in temperature, hydration, salinity, and movement. During high tides it is covered with cool salt water; on hot days during low tides it dries out and heats up rapidly. On rainy days when the tide is out it may be exposed to freshwater. Organisms in the sandy intertidal are also subjected to forceful wave shock and shifting sand with each high tide. Sandy beaches are less productive of plant and animal life than most other marine habitats and zonation is less apparent than on rocky shores.

Sandy beaches have relatively large spaces between sand grains which permits the ready flow of water and oxygen well below the sediment surface. Where the sand is coarse and wave action is great, fixed burrows are impossible to maintain and most inhabitants are small enough to live between the sand grains or, if larger, to quickly bury themselves in the loose sand.

The infaunal communities of the sandy beaches of Santa Monica Bay have not been studied in detail, but data from studies conducted at beaches at Point Dume (Patterson 1974, Straughan 1982), El Segundo (MBC 1982b,c), Torrance (Straughan 1977b), and King Harbor (Straughan 1977a,b) are available. Bight-wide, sandy intertidal habitats support three slightly different communities separated along geographic lines (Straughan 1982). All sites between Point Mugu and Palos Verdes Peninsula are similar.

SOFT-BOTTOM SEA FLOOR

The bottom type of the seafloor is largely a function of the water movement in the overlying water mass, although the proximity of the sediment source can be important. Coarse sand and gravel are found under swiftly moving water whereas fine silt and clay settle to the bottom in quiet water. In most parts of Santa Monica Bay the seafloor consists primarily of fine to moderately coarse, unconsolidated sediments. However, hard bottoms of bedrock, gravel, and phosphorite are found in some areas (Figure 2-3).

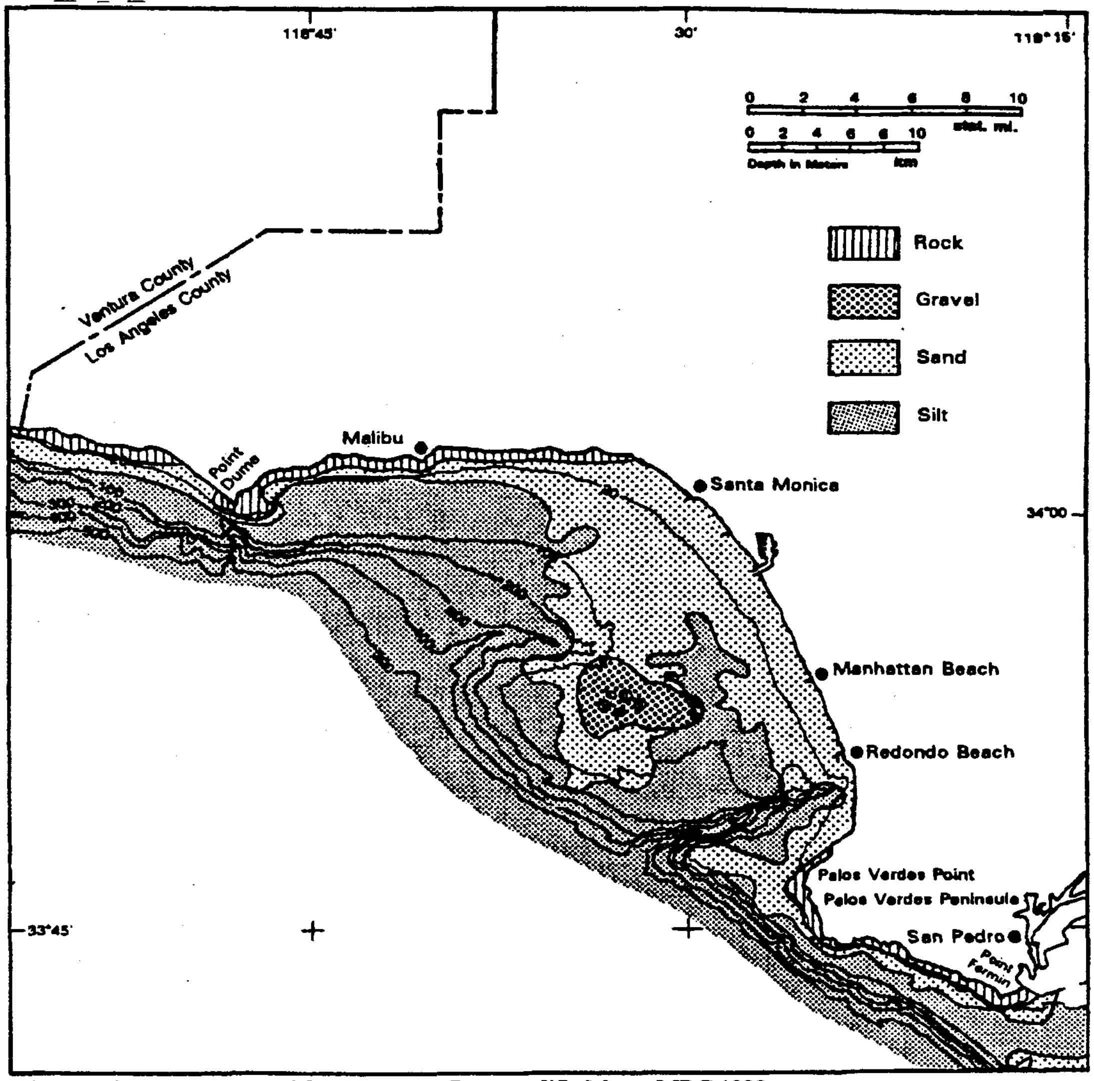


Figure 2-3. Bottom types of Santa Monica Bay (modified from MBC 1988).

Unconsolidated (soft) sediments are classified on the basis of grain size into sand, silt, and clay fractions. In general, sediments grade from coarse nearshore to fine offshore; thus sediments on the shelf are sand whereas those on the slope are silt. Most nearshore sediments of Santa Monica Bay are olive green sands, which form an elongate bed which is broadest off Manhattan Beach and extending from Venice Beach to the central shelf (Terry *et al.* 1956). Sediments on the northwestern part of the Palos Verdes Shelf are generally coarser than those on the Santa Monica Shelf whereas those on the southern part of the shelf are finer (SDWG 1988).

Silty sand is found over much of the central plateau and on the Palos Verdes Shelf, but only in a narrow, nearshore band along Malibu and on the southern portion of the central shelf. Sandy silt is characteristic of the upper portion of the basin slope, much of the middle and deep depths off Malibu, and the outer portion of the central plateau. Deeper portions of the basin slope have silty sediments (Terry *et al.* 1956). Clay was a minor fraction of Santa Monica Bay sediments in the 1950s (Terry *et al.* 1956), but was more common in the 1970s (Bascom 1978).

Most sand on the shelf is fine quartz-feldspar that is being eroded from land, although small patches of relict red sand are found on the central plateau and south of Redondo Canyon (Terry *et al.* 1956). Relict red sands were deposited when the sea level was lower; they represent ancient beaches or sand dunes that have been reexposed. Much of the sand on the basin slope and the outer portions of the shelf are glauconite; shell sand occurs on some of the basin slopes.

Sediment composition and distribution change in time and place due to prevailing currents and storms. Winter storms move beach sand offshore to deeper (10 to 20 feet) water; in summer reduced wave intensity allows the sand to reaccumulate onshore (Grant and Shepard 1939). Currents generally move sand east along the Carillo Shelf toward Dume Canyon (Kolpack, 1988, pers. comm.), east along the Malibu Shelf, south along the central shelf toward Redondo Canyon, and north from Malaga Cove to Redondo Canyon (Grant and Shepard 1939). From time to time sand flows down Redondo Canyon and is lost to the nearshore system (Drake and Gorsline 1973). Numerous dikes, groins, and jetties have been constructed to help sand accumulate (Woodell and Hollar 1991). Sediments along the upper slopes of Santa Monica Canyon and the Palos Verdes Shelf occasionally slump into basins as a result of earthquakes and turbidity currents (Haner and Gorsline 1978, Gorsline *et al.* 1984, SDWG 1988).

Sediments are typically exposed to oxygen and any organic material is processed by aerobic infauna and bacteria which live in the sediments. However, if there is insufficient oxygen in the sediments for aerobic decomposers, anaerobic sulfur bacteria may dominate, These produce hydrogen sulfide which gives the sediments the odor typical of rotten eggs.

HARD-BOTTOM SEA FLOOR

Exposed bedrock is found nearshore along the Carillo and Malibu coasts from the Ventura-Los Angeles County line to Pulga Canyon and from Malaga Cove to Point Fermin on the Palos Verdes Shelf. Exposed bedrock is also found offshore, on the central shelf (Short Bank) of the Santa Monica Shelf and in both Santa Monica and Redondo Submarine Canyons. Inshore rocky bottoms are similar in composition to those on land nearby; however, the offshore bedrock generally consists of siliceous shales with mudstone, siltstone, sandstone, and schist (BLM 1975).

Stream deposition and the erosion of rocky shore have formed nearshore gravel beds off Malibu and along the Palos Verdes Shelf. These gravels are primarily rounded pebbles of igneous rock but include metamorphic and sedimentary rock. Other gravel beds surround the exposed bedrock areas of Short Bank (Shepard and MacDonald 1938, Terry *et al.* 1956, Bascom 1978) and in Santa Monica Submarine Canyon (Bascom 1978). These presumably resulted from the erosion of outcrops at lower sea level stands or from stream deposition at that time.

Anthropogenic hard-bottom substrates in the study area include municipal wastewater outfall pipes (three from Hyperion Treatment Plant and four from the Joint Water Pollution Control Plant), as well as smaller outfall structures for generating stations and the refinery. Other artificial hard-bottom structures include jetties, breakwaters, groins, and artificial reefs.

Because subtidal, hard-bottom habitats support algal growth and attract sportfisheries species, the California Department of Fish and Game (CDFG) has constructed 14 artificial reefs in Santa Monica Bay since 1958. The first five were constructed of degradable materials (streetcars and automobiles) and have since disappeared. Nine artificial reefs (constructed since 1962 out of quarry rock, concrete, pier pilings, tires, and marine vessels) are expected to remain for much longer (Lewis and McKee 1989).

TOPOGRAPHY OF THE WATERSHED & WASTESHED

The terrestrial environment bordering Santa Monica Bay consists of two major regions: 1) the watershed and 2) the wasteshed (Figure 2-1). The watershed is the region of coastal land that comprises the natural drainage area of the Bay (i.e., the land from which surface waters drain into the ocean). The natural drainage and its potential to carry pollutants into Santa Monica Bay makes the watershed important as it pertains to the Bay's environmental quality. The wasteshed is that land area from which municipal wastes originate before being treated at municipal waste treatment facilities which discharge to the Bay and hence is not a natural physical region. Much of the surface runoff in the wasteshed is carried to the Los Angeles-Long Beach Harbor area east of the Palos Verdes Peninsula but some is carried into Santa Monica Bay. The surface area of the combined watershed and wasteshed of Santa Monica Bay is approximately 1,380 mi^2; the watershed drains about 414 mi^2 (SMBRP 1992).

The topography of the terrestrial environment bordering Santa Monica Bay is dominated by the Santa Monica Mountains, the Los Angeles Coastal Plain, and the Palos Verdes Peninsula. Mountain peaks in the Santa Monica Mountains are up to 3,111 ft high (on the western border of the natural drainage) and in the Palos Verdes Hills up to 1,480 ft (Reiter 1984). However, most of the plain is less than 500 ft above sea level (Terry *et al.* 1956, CLA,DPW 1982).

Historically, the Los Angeles River occasionally emptied into Santa Monica Bay at Ballona Creek instead of into San Pedro Bay at Long Beach. This resulted from changes in the river's course during unusually heavy storms and is known to have occurred in 1815-1825, 1862, and 1884 (Terry *et al.* 1956). When the Los Angeles River discharged through Ballona Creek, the natural drainage to Santa Monica Bay was much larger, including the San Fernando Valley and part of the San Gabriel Mountains. Because the Los Angeles River is now channelized, future discharges through the Ballona Creek are unlikely.

The area between Ballona Creek and present-day Beverly Hills was often a vast swamp (Johnston 1962, Reiter 1984); in fact, the Spanish word for swamp (la cienega) is given to a major boulevard in this region. During torrential rains in the winter of 1861-1862, the entire area from Los Angeles to the ocean, both toward San Pedro and toward Ballona, was a vast lake (Kuhn and Shepard 1981).

The natural drainage of the study area (Figure 2-1) follows the crest of the Santa Monica Mountains from the Ventura - Los Angeles County Line (and following a ridge to the sea in that area) to a point inland from Point Dume north of Lake Silverwood and from there east to Hollywood. From Hollywood it extends south and west across the Los Angeles plain to include the area east of Ballona Creek and north of the Baldwin Hills. South of Ballona Creek the natural drainage is a narrow coastal strip between Playa del Rey and the Palos Verdes Hills.

CLIMATE

AIR TEMPERATURE

The climate of southern California is Mediterranean, characterized by warm, dry summers and mild, wet winters. Although less than half of the days of the year are cloudy, insolation (i.e., sunshine) is greatest from March to September. The sun heats the air, land, and water; in turn, the land and water heat the air. The average daily (24 hr) air temperature in the study area ranges from 45 to 72°F annually (SCCWRP 1973), being coldest in January and warmest in July. In summer the Los Angeles Coastal Plain is generally cooler than the nearby mountains and inland valleys due to the onshore flow of marine air (Miller and Hyslop 1983). Relative humidity is typically about 90% at night and about 60% during the day (Kimura 1974).

A temperature inversion often develops on the Los Angeles Coastal Plain during the summer. Cool coastal air is trapped beneath warm air at higher altitudes, resulting in hazy or smoggy air. Cool air over upwelling regions of the ocean often results in fog. During late spring and early summer, fog may deepen to several thousand yards, causing drizzles throughout the Coastal Plain (Miller and Hyslop 1983). At Los Angeles International Airport there are usually about 53 days of fog per year (Kimura 1974).

RAINFALL

The average annual rainfall on the Coastal Plain is 12 to 13 inches but ranges from four to 25 inches (SCCWRP 1973, Kimura 1974, Miller and Hyslop 1983). About 90% of the rainfall occurs between November and April (SCCWRP 1973). In winter cold-front storms typically come from the northwest; in summer tropical storms called chubascos occasionally come from the southeast. Most storms originate over the ocean as low pressure cells, but thunderstorms occasionally result from hot air rising over land (Kimura 1974, Miller and Hyslop 1983).

WIND

Prevailing winds along the coast are from the west-northwest and wind speed is generally low throughout the year. At Santa Barbara Island, west of Santa Monica Bay, wind speed ranges from six to eight mph in the fall to ten to 12 mph during the spring, although gusts may reach 60 mph during the winter and spring (Kimura 1974). In summer sea breezes typically blow onshore in the morning as air over the land heats up, rises, and pulls cool air from the ocean (Miller and Hyslop 1983). At night offshore land breezes often develop as air over the land is pulled seaward as air over the warmer ocean rises.

During winter (but occasionally at other times) Santa Ana winds blow to the west off the deserts east of the Los Angeles Basin. These winds result from high pressure cells over the desert and enter the coastal zone through mountain passes. Santa Anas are very dry and hot as a result of compression as they drop in altitude, and gusts of 50 mph have been recorded. Santa Anas are responsible for dispersing dust and air-borne contaminants out over the ocean (Miller and Hyslop 1983).

OCEANOGRAPHY

Oceanographic conditions in the study area are largely a function of the California Current and other offshore currents, as modified by local topography and conditions.

CURRENTS

Oceanic Currents. The California Current is a low-temperature, low-salinity, and nutrient-rich current that flows south along the California coast (Figure 2-4). It varies in velocity from year to year but is usually weakest in winter and spring (CLA,DPW and USEPA 1977). South of Point Conception, the California Current generally flows along the Patton Escarpment (100 miles offshore) and approaches the coast again near Cape Colnett, Baja California.

Off Baja California part of the California Current flows north into the Southern California Bight as the Southern California Countercurrent. Part of this countercurrent exits the Bight through the Santa Barbara Channel and rejoins the California Current while the rest flows south nearshore (CLA,DPW 1982). Beneath the surface water mass (i.e., from the surface to depths of about 820 ft) is a relatively high-temperature and high-salinity current called the California Undercurrent which flows to the north (CLA,DPW and USEPA 1977; Jackson 1986). This current surfaces nearshore north of Point Conception during the fall and winter and is known then as the Davidson Current.

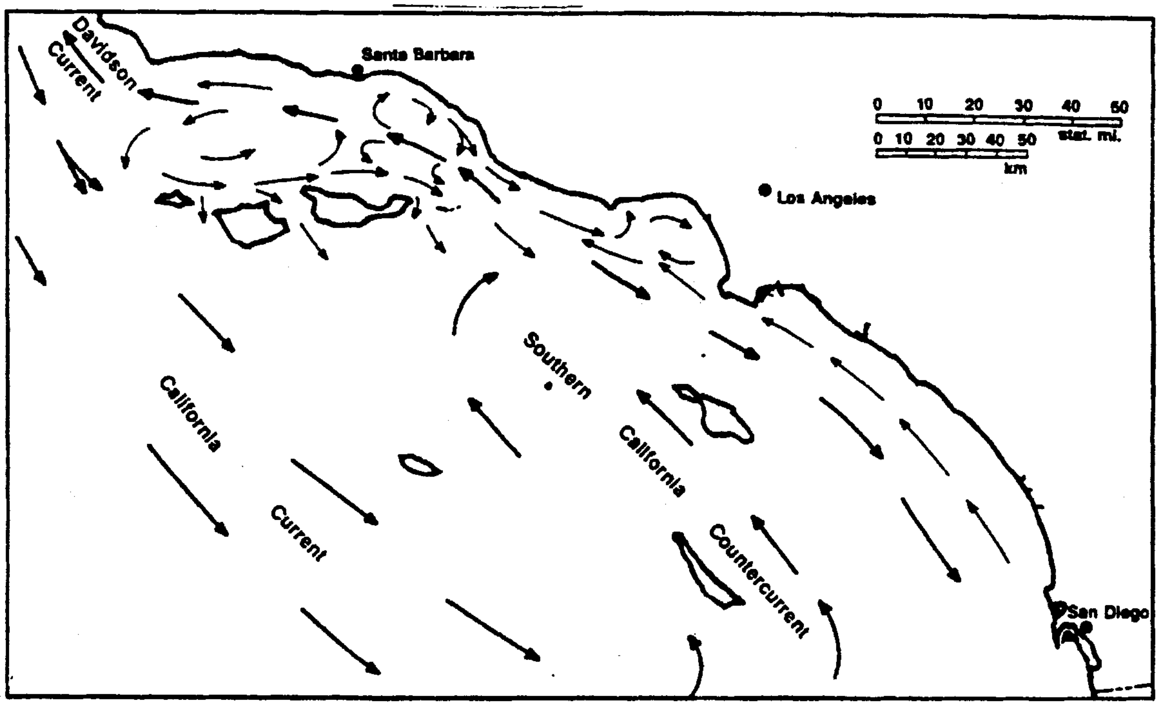


Figure 2-4. General ocean circulation of the Southern California Bight (modified from CLA,DWP and USEPA 1977).

COASTAL CURRENTS

Local currents are affected by local submarine topography, winds, and tides and are of two kinds: longshore currents which flow parallel to shore and cross-shore currents which move perpendicular to shore. Longshore currents are fastest near the surface; near-bottom they are slowed by seafloor friction. Off Palos Verdes and the seaward edge of Santa Monica Bay longshore currents flow north at approximately 0.09 kn (CLA,DPW and USEPA 1977). However, surface currents with speeds up to 1.13 kn for several days have been measured on the Palos Verdes Shelf (SDWG 1988). Cross-shore currents flow shoreward or seaward near the surface and at depth; they are generally caused by surface wind forcing or by internal waves (Jackson 1986).

Surface currents in Santa Monica Bay are complex but those below the upper 100 ft flow north (Hickey 1988, pers. comm.). Surface currents along the Palos Verdes Shelf may flow northwest or south-southeast, at all depths and throughout the year. However, during the winter they tend to flow northwest and west-southwest below 150 ft; in summer they flow northeast and south-southeast near the surface (SCCWRP 1973).

Water sometimes enters Santa Monica Bay from the south, moving in a slow counterclockwise eddy. However, when the northward current is weakened, a clockwise gyre may develop. During these periods, a southward, longshore flow with speeds of 0.04 kn is induced (SCCWRP 1973, Hendricks 1980, CLA,DPW 1982). Recent studies suggest that the clockwise gyre may dominate on the shelf, except when it reverses for a few days at a time and inshore of the 70 feet isobath due to tidal action. The residence time of surface water (0-300 ft) in the Bay is estimated to be three to four days (Hickey 1988, pers. comm.).

LITTORAL CURRENTS

Littoral currents move along shore and adjacent to the shore, and are caused by breaking waves, as modified by shore topography. The littoral currents may move as much as 8 feet per second and often transport beach sediments in a turbid layer which is denser than seawater and which may flow into submarine canyons as turbidity currents (Drake and Gorsline 1973). Point Dume and the offshore islands shelter much of Santa Monica Bay from most westerly and northerly storms. However, long period waves from southern storms may generate surf ten to 15 feet high along the Malibu coast, reworking sediments to water depths of 250 feet (Haner and Gorsline 1978). On the Palos Verdes Shelf, storm waves can resuspend sediments to water depths of 150 feet (SDWG 1988).

TIDES

Southern California has a mixed, semidiurnal tide, which is composed of two unequal high tides and two unequal low tides every 24 hours and 50 minutes. In Santa Monica Bay the high and low tides generally differ by 3.7 feet, although spring tides may differ by 5.4 feet (NOS 1986). Tidal currents tend to flow onshore-offshore, but they achieve their greatest velocities along shore (SCCWRP 1973. Down-canyon tidal flows in Santa Monica Submarine Canyon have been measured at 0.14 ft/ second and up-canyon velocities at 0.10ft/sec (Hendricks 1980, CLA,DPW 1982). Similar flows probably occur in Dume and Redondo Submarine Canyons.

UPWELLING

During prolonged northwesterly winds, nearshore surface water is transported offshore along coasts with a northwest-southeast orientation. In this process, known as upwelling deep, oxygen-poor and nutrient-rich water comes to the surface to replace the surface water. In the study area upwelling is most likely to occur off the southwest portion of the Palos Verdes Shelf during the winter and spring (CLA,.DPW and USEPA 1977).

CHARACTERISTICS OF SEAWATER

Natural seawater is characterized by a number of physical and chemical attributes, all of which vary seasonally as well as in irregular fashion. Key characteristics are described below, especially as they may be influenced by man's activities.

TEMPERATURE

Horizontal differences in the temperature of seawater are due primarily to variations in the California Current and Countercurrent. Surface temperatures in the Southern California Bight range from about 52 to 73°F and are warmest (61to 73°F) from July to December and coolest (52 to 63°F) from January to June (AHF 1965, CLA,DPW 1982; Bratkovich 1988, pers. comm.). Average annual surface water temperatures in Santa Monica Bay ranged from 60 to 65.8°F between 1956 and 1986 (Mearns 1987, pers. comm.).

Below 100 feet seasonal temperature patterns are different (Jackson 1986). At 200 feet temperatures range from 50 to 59°F and are warmest from October to March and coolest from April to September. At 500 feet temperatures are relatively constant at 47 to 50F (AHF 1965, CLA,DPW and USEPA 1977).

SALINITY

The major feature of seawater is the dissolved salts which produce its characteristic saltiness. Sality is measured in parts per thousand (ppt), which refers to the amount of salt it contains. Most of the salt is common table salt, sodium chloride (NaCl); abundant ions in seawater include sodium (Na+), chloride (Cl-), sulfact (SO_4--), magnesium (Mg++), calcium (Ca++), potassium (K+), and bicarbonate (HCO_3-). Chloride comprises about 55% of the ions, sodium about 30%, and sulfate about eight percent. The concentration of most of these ions is fairly constant and they are so abundant that even unusually high levels do not affect the overall salinity and hence are not considered contaminants.

Salinity in the California Current ranges from 33.5 to 34.1 ppt, whereas in the California Undercurrent it ranges from 33.4 to 34.6 ppt (CLA,DPW and USEPA 1977; Jackson 1986). The coastal waters of Santa Monica Bay are normally more saline during the summer due to evaporation of water and less saline in winter as a result of freshwater runoff. Salinity is usually less variable at greater depths.

DENSITY AND STRATIFICATION

The density of seawater is a function of its temperature and its salinity. Thus, layers of sharply different densities adjacent to one another (a pycnocline) can result from differences in temperature, salinity, or a combination of the two. If separated primarily by temperature, the pycnocline is also a thermocline; if separated primarily by salinity, it is also a halocline. Water above the pycnocline usually has little internal structure; it tends to be homogeneous and is called the mixed layer.

A pycnocline is a natural barrier to the exchange of water between the two layers. Wastewater is usually discharged below the pycnocline in order to prevent movement of the effluent into surface waters; except for oil and grease the plume is unlikely to reach the surface when the sea is stratified (CLA,DPW and USEPA 1977).

In Santa Monica Bay a thermocline often develops (from spring to fall) as a result of warm surface temperatures. In winter and spring there may also be a low-salinity lens at the surface which results from stream runoff. In summer a pycnocline occurs over the shelf at depths of about 35 feet. When the surface temperature drops in the fall the density of the upper layer approaches that of the lower layer, the pycnocline breaks down. The mixed layer then extends into depths of 100 feet between December and March (Jackson 1986).

TRANSPARENCY TO LIGHT

As light penetrates the ocean it is reflected, absorbed, or scattered. The depth of light penetration is greatest in transparent waters and least in turbid waters. Water transparency (as measured by a standard Secchi disk) generally ranges from 20 to 50 feet in southern California. However, within a mile of stream deltas it may be less than 20 feet and off rocky areas it is often greater than 40 ft (AHF 1965, CLA,DPW and USEPA 1977). From 1956 to 1986 it ranged from 33 to 66 feet in Santa Monica Bay (Mearns 1987, pers. comm.).

Light penetration is especially important to photosynthesis (the process by which plants utilize carbon dioxide and water to produce, in the presence of light, organic matter and oxygen. Most photosynthesis occurs in the mixed layer, from the surface to water depths of about 33 feet. As light levels decrease photosynthesis decreases. The "compensation depth" refers to the depth at which light levels are so low that no net photosynthesis can occur; this depth marks the bottom of the "photic" zone.

Because inshore waters are generally more turbid, the photic zone may be less than 160 feet deep, whereas offshore it may extend deeper. Sunlight intersects the sea surface at a steeper angle in summer than in winter, thus light penetrates more deeply in summer and the photic zone is deeper.

HYDROGEN ION CONTENT (pH)

The pH of seawater over the shelf ranges from 7.5 to 8.6. High values result from photosynthesis which removes CO_2 from the water. Because photosynthesis decreases and net respiration increases with depth, CO_2 increases and hence pH decreases with depth (CLA,DPW and USEPA 1977).

DISSOLVED OXYGEN

Oxygen is required for respiration (and thus life) of both plants and animals. As organic material decomposes, oxygen is used up, creating a biochemical oxygen demand (BOD). Dissolved oxygen (DO) levels are generally high near the surface as a result of input from the atmosphere and from photosynthesis; DO decreases with depth, as distance from the surface increases and photosynthesis ceases. The DO level near the sea surface is generally near saturation (approximately 5.5 ml/l), but saturation varies with temperature and salinity. At water depths of more than 200 feet, DO is usually about 2.8 ml/l, but is only 0.5 ml/l at depths of 1,640 feet along the slope of Santa Monica Bay. DO is virtually absent at the bottom of Santa Monica Basin (Emery 1960; BLM 1975; CLA,DPW and USEPA 1977; CLA,DPW 1982).

INORGANIC NONMETALLIC MATERIALS/NUTRIENTS

Nitrogen (ammonia, nitrite, nitrate), phosphate, and silicate are dissolved, inorganic materials which are required for photosynthesis and are called nutrients. Nutrients are especially important in the formation of amino acids (protein, nitrogen) and nucleic acids (phosphorous) as well as nonliving shells or tests (silicate).

Nutrient levels are generally low in the mixed layer and high in deeper water. This results from their utilization by phytoplankton in the photic zone and their regeneration by bacteria which are most abundant near the pycnocline. Nitrate is the predominant form of nitrogen found below the photic zone (Williams 1986).

In freshwater systems phytoplankton productivity is generally limited by the availability of phosphate. In the ocean, however, phytoplankton activity tends to be limited by the availability of nitrogen. Nutrients are replenished in the photic zone during upwelling or when the pycnocline breaks down in the winter; however, sewage and surface runoff may also add nitrogen and phosphate to local areas.

TRACE METALS

Virtually all trace metals occur naturally in seawater. Among the more abundant are copper (Cu), manganese (Mn), zinc (Zn), cadmium (Cd), cobalt (Co), silver (Ag), nickel (Ni), and iron (Fe) (Williams 1986). Iron, manganese, and cobalt are abundant in the natural surface runoff from the Santa Monica Mountains (SCCWRP 1973).

Manganese and cobalt are typically more concentrated in surface waters than at depth, whereas the concentrations of cadmium, zinc, nickel, copper, and silver increase with depth. These patterns reflect both biological and chemical processes. For instance, iron is used by fish and other organisms to secure oxygen from the water and hence its concentration may be related to the abundance of organisms requiring it. Most trace metals are required for the growth of some organisms.

ORGANIC MATTER

Both particulate and dissolved organic compounds are found in seawater. The particulate phases are described as total particulate organic carbon, particulate organic nitrogen, and particulate organic phosphorus. Particulate organic materials are most abundant in the photic zone, less so with depth. Particulates absorb trace metals and other contaminants; hence they are important in transporting these substances from the water column to the bottom (Williams 1986).

Dissolved organics include material from decaying organisms, their excretions and secretions, as well as synthetic materials produced by man. The major components are total dissolved organic carbon, dissolved organic nitrogen, and dissolved organic phosphorus. The concentrations of these components are high in the mixed layer and low at greater depths. For the most part materials are produced by phytoplankton in the photic zone and are broken down by bacteria at greater depths (Williams 1986).

EL NIÑO

Every so often, with a quasiperiodicity of three to five years (Graham and White 1988), the oceanic environment of Southern California changes dramatically as an El Niño Southern Oscillation (ENSO) event takes place. During an El Niño, the normal water mass off the California coast is replaced with water which is warmer, more saline, and lower in nutrients than usual. These conditions extend through the water column and may persist for months or years.

El Niños result from large-scale changes in the climate and oceanography of the Pacific Ocean as a whole. Normally tradewinds, which blow to the west north of the Equator, force water to pile up in the western Pacific. When the tradewinds weaken, seawater flows downhill (as a long-period wave) toward the eastern Pacific. When this wave encounters the Americas, it moves both north and south along the coast. Because currents in the North Pacific also decrease in strength, the south-flowing California Current is weakened and the warm-water mass from equatorial latitudes penetrates into the Southern California Bight. The most recent large El Niño Event was in 1982-1983, with the previous large El Niño in 1957-1959. Events of lesser magnitude occurred in 1986-1987 and in 1991-1992 (Radovich 1961, Graham and White 1988, Kerr 1992).

During an El Niño marine organisms with more southern distributions occur in the Bight whereas cold water species become less abundant: pelagic red crabs were abundant offshore southern California in 1982 and 1983. During an El Niño the sport and commercial fisheries (and success) for pelagic species may increase dramatically.

3

BIOLOGICAL SETTING

CHAPTER 3
THE BIOLOGICAL SETTING

TERRESTRIAL ENVIRONMENTS

Terrestrial organisms in the study area are largely warm-temperate species of the California Wildlife Region (Brown and Lawrence 1965). The only life zone in the watershed is the Upper Sonoran life zone (Grinnell 1935); although the altitude lies within the range normally classified as Lower Sonoran, the temperatures are cooler and humidity is higher along the coast than in areas of similar altitude elsewhere in Southern California.

HABITATS AND PLANT COMMUNITIES

The Santa Monica Bay watershed and its surrounding area includes a variety of terrestrial habitats and plant communities (often regarded as habitats because of the nature of the physical structure they provide to the habitat). Many of these would have occurred prior to European contact but several have developed since that time, particularly with urbanization. The Santa Monica Mountains alone have more than 860 species of flowering plants (Ikeda et al. 1991); the more urbanized areas of the watershed have many additional species, most of which are introduced.

Thirteen terrestrial habitats are found in the Santa Monica watershed (Figure 3-1) (Mayer and Laudenslayer 1988). Nine of these occur throughout the watershed: Eucalyptus, Valley Foothill Riparian, Coastal Scrub, Annual Grassland, Fresh Emergent Wetland, Riverine, Lacustrine, Orchard-Vineyard, and Urban. The four remaining habitats (Valley Oak Woodland, Coastal Oak Woodland, Mixed Chaparral, and Chamise-Redshank Chaparral) are specific to the Santa Monica Mountains.

Three of the ubiquitous habitats (Fresh Emergent Wetlands, Riverine, and Lacustrine) are wetlands habitats, two (Eucalyptus and Annual Grassland) consist primarily of introduced species, two (Orchard-Vineyard and Urban) result from human development, and two (Valley Foothill Riparian and Coastal Scrub) are entirely native to the area (Mayer and Laudenslayer 1988)

VALLEY OAK WOODLAND

The Valley Oak Woodland occurs exclusively in the western part of the Santa Monica Mountain portion of the study area (Mayer and Laudenslayer 1988), particularly in the Upper Malibu Creek Drainage. This habitat is dominated by valley oak, a deciduous oak 50-115 feet tall. The trees may be sparsely distributed as in a savannah or more densely distributed with partially closed canopies. It is best developed on deep, well-drained alluvial soils in valley bottoms. The Valley Oak Woodland habitat usually merges with the Annual Grassland habitat or near streams with the Valley-Foothill Riparian vegetation.

There is generally little recruitment of young valley oaks to this habitat to replace the older oaks which are being destroyed by urban and agricultural development. Most surviving stands in the state are from 100 to 300 years old, some reaching 400 years old. Valley Oak Woodland is important to mammals such as the gray fox, western gray squirrel, and mule deer, and for birds such as the redtail hawk, European starling, and California quail (Mayer and Laudenslayer 1988). At Malibu Creek State Park grasses have been planted to associate with Valley Oak Woodland in an effort to expand the potential habitat for valley oak (Danielsen and Halvorson 1990).

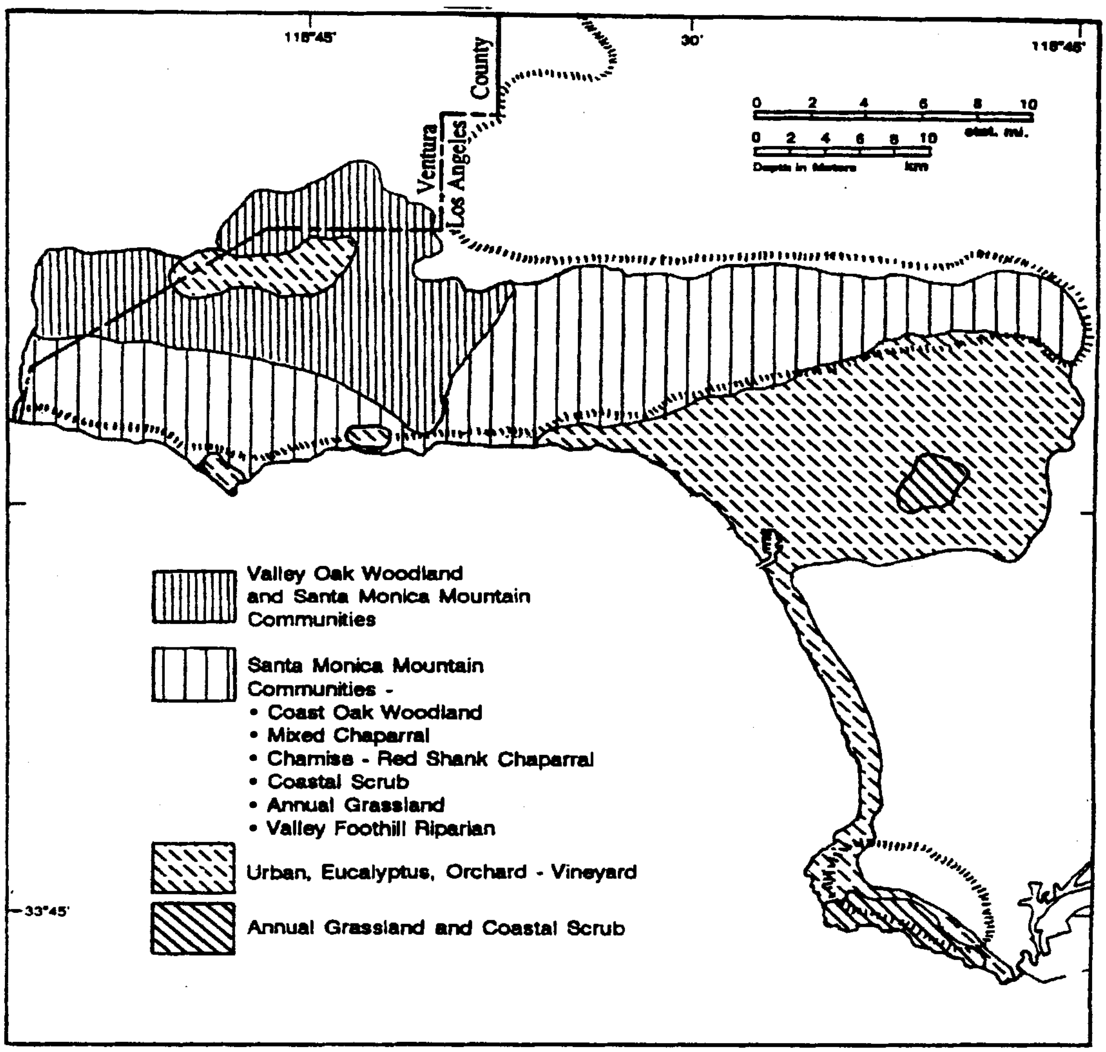


Figure 3-1. Major habitat areas of the Santa Monica Bay watershed.

COASTAL OAK WOODLAND

The Coastal Oak Woodland occurs in the Santa Monica Mountains, but not immediately near the coast (Mayer and Laudenslayer 1988). This habitat is dominated by coast oak and California walnut; the oak is evergreen and the walnut is deciduous. In moist sites, the trees are dense and form a closed canopy 15-70 feet high; in dry areas they are more widely spaced, forming a savannah. The understory ranges from lush, shade-tolerant shrubs and ferns beneath closed canopies to annual grassland in dry areas; shrubs from neighboring chaparral and coastal scrub communities may contribute to the understory (Mayer and Laudenslayer 1988).

This habitat can be further divided into a number of subhabitats based on understory plants (Allen 1990). The Coastal Oak Woodland community is best developed on moderately to well-drained soils which are moderately deep and have low to medium fertility. Coastal oak woodlands consist of slow-growing, long-lived trees that require 60-80 years to regenerate large mature trees; most stands consist of medium to large trees with a few saplings. This community has experienced an increased frequency of fires in recent years but coast oak generally survives fires. Important vertebrate species in this community include California quail, western gray squirrel, and mule deer (Mayer and Laudenslayer 1988).

EUCALYPTUS

The Eucalyptus habitat occurs throughout the watershed and wasteshed in disturbed, agricultural, or urban sites (Mayer and Laudenslayer 1988). This habitat is usually dominated by blue gum, to a lesser extent by red gum. Eucalyptus, or gum trees, were introduced into California from Australia in 1856. The structure of the habitat ranges from thickets of a single species with no understory to scattered trees with a well-developed shrubby understory. They are planted in rows to provide wind breaks or in groves for hardwood harvesting. Gum trees typically stand 87 to 133 feet high, but some reach a height of 264 feet. Understory plants range from annual grassland species in groves to coastal scrub or chaparral species; near streams, riparian plants may occur in the understory. They are also planted near orchards and vineyards. The allelopathic nature of gum tree litter prevents many other plants from developing in the understory. Gum trees regenerate rapidly following fires, reproducing vegetatively as well as by seeds. Most gum trees achieve 70-90% of their height in their first 15 years. Crows, ravens, and barn owls are common in the Eucalyptus habitat; the bark litter provides habitat for southern alligator lizards, gopher snakes, and woodrats. The habitat does not occur above 2,100 feet altitude (Mayer and Laudenslayer 1988).

VALLEY FOOTHILL RIPARIAN

The Valley Foothill Riparian habitat occurs throughout the watershed and wasteshed, in valleys, coastal plains, and foothills; next to low velocity streams on gravelly or rocky soils; and in association with annual grassland or oak woodland (Mayer and Laudenslayer 1988). This habitat is dominated by Fremont cottonwood, California sycamore, and valley oak; California sycamore is dominant in coastal areas of the Santa Monica Mountains. White alder is the dominant subcanopy tree but many shrubs (e.g., wild grapes, willows, poison oak) and herbaceous plants occur in the understory. The dominant species are deciduous. The canopy is about 100 feet high and coverage is 20-80%. Cottonwood trees become large mature trees at 20-25 years. Willows generally dominate in early stages of succession and, where there are good flows of silt, may persist indefinitely. The Valley Foothill Riparian habitat is important to many species of mammals, birds, reptiles, and amphibians (Mayer and Laudenslayer 1988).

MIXED CHAPARRAL

The Mixed Chaparral habitat is only found in the Santa Monica Mountain portion of the watershed. It is dominated by shrubs with stiff evergreen leaves (Mayer and Laudenslayer 1988). It generally occurs above the coastal scrub habitat and occurs predominantly on moist coastal or north- and east-facing slopes with Chamise-Redshank Chaparral on drier, south- and west-facing slopes. It usually is found on steep slopes with thin, well-drained rocky, sandy, or gravelly soils; soils in this habitat are deeper than in the Chamise-Redshank Chaparral. Shrubs range in height from three to 13 feet, occasionally to 19 feet, and form an impenetrable thicket of 80% cover. Dominant species include scrub oak, ceanothus (wild lilacs), and manzanita, with many other shrubs (e.g., laurel sumac, sugarbush, birch-leaf mountain mahogany, and toyon) also included in the community. Leaf litter may accumulate beneath the shrubs for years until consumed during a fire. The community is fire-adapted with large rootbases. Following a fire, annuals and perennials dominate for one to three years until seedlings and root-crown shoots appear; the shrub canopies do not overlap until ten to 30 years after a fire. Wildlife species found in mixed chaparral are also found in chamise-redshank chaparral and coastal scrub (Mayer and Laudenslayer 1988).

CHAMISE-REDSHANK CHAPARRAL

Chamise-Redshank Chaparral is found in isolated stands in the Santa Monica Mountains (Mayer and Laudenslayer 1988). Most stands in the study area are almost exclusively dominated by chamise with some redshank occurring at higher elevations (Raven and Thompson 1966). It occurs on steep slopes with thin, coarse soil. These stands are three to seven feet in height but can reach 10 feet (Mayer and Laudenslayer 1988). There is no overstory or understory and canopy cover can reach 80%. It occurs primarily on dry, south- and west-facing slopes above the coastal scrub habitat. Near the coast other shrubs (e.g., laurel sumac, toyon, and ceanothus) are also found in this community along with white sage, black sage, and California buckwheat. As with mixed chaparral, chamise-redshank chaparral is fire-adapted. Annuals and perennials dominate for one to three years following a fire until chamise and associated plants sprout from seedlings and roots. Chamise canopies do not overlap until three to 15 years after a fire. Wildlife found in this habitat are also found in mixed chaparral and coastal scrub (Mayer and Laudenslayer 1988).

COASTAL SCRUB

Coastal Scrub Habitat occurs on well-drained clay, gravelly, and rocky soils and was the dominant habitat of the Los Angeles Coastal Plain prior to urban development. At present it is found on undeveloped slopes of the Santa Monica Mountains adjacent to the ocean, in drier areas at higher levels, and in the Palos Verdes Hills (Jaeger and Smith 1966). It lies within 20 miles of the ocean between the coastal dune habitat and the mixed chaparral, chamise-redshank chaparral, and coastal oak woodland habitats of slightly higher elevations. It is typical of steep, dry, south-facing slopes with sandy to shale soils but also occurs on moderate slopes and stabilized dunes. This community consists of low to moderate-sized shrubs (to a height of 7 ft) with a canopy cover of up to 100%. The dominant species in the community varies with moisture; California sagebrush, California buckwheat, purple sage, and chaparral yucca generally dominate in the Santa Monica Bay watershed. The community is fire-adapted and takes about ten years to recover following a fire. Unburned stands can survive intact for up to 60 years. The community can invade disturbed areas (Mayer and Laudenslayer 1988). Air pollution has reduced the cover by native species in some areas of Southern California (Westman 1979). The California ground squirrel is probably the most abundant, obvious mammal (Reiter 1984). The California gnatcatcher, a species of concern, is found exclusively in this habitat and endangered peregrine falcons include this as an important habitat (Mayer and Laudenslayer 1988).

ANNUAL GRASSLAND

The Annual Grassland habitat occurs throughout the watershed and wasteshed. The habitat is found on flat plains to gently rolling hills. It consists of open grasslands dominated by annual grass and forb species (Mayer and Laudenslayer 1988). Most of the dominant species are introduced grasses (e.g., wild oats and red brome). Redstem filaree is a common forb in southern California annual grasslands and California poppy, the State Flower, is also found in this habitat. It often occurs as an understory in Valley Oak Woodlands and is found next to Coast Oak Woodland, Coastal Scrub, Valley Foothill Riparian, Fresh Emergent Wetlands, Orchard-Vineyard, and Eucalyptus habitats. Annual grasslands are generally found at lower elevations than Chamise-Redshank and Mixed Chaparral habitats. Seeds germinate following fall rains, grow slowly in winter but rapidly in spring as temperatures rise. During the summer the habitat can have a large amount of standing dead material if there is little grazing. The Annual Grassland habitat has replaced the pristine native grassland habitat in the area which was dominated by perennial bunchgrasses. Fall rains followed by extended dry periods encourage growth of deep-rooted forbs and grazing favors low-growing forbs. Important mammals in this habitat include black-tailed jackrabbit, California ground squirrel, and Botta's pocket gopher. Western meadowlark, turkey vulture, and American kestrel are common birds. Western fence lizard and western rattlesnake are important reptiles in this habitat (Mayer and Laudenslayer 1988).

FRESH EMERGENT WETLANDS

The Fresh Emergent Wetlands habitat is found in localized areas throughout the watershed and wasteshed. It is dominated by erect, rooted water plants such as the perennial sedges, rushes, and cattails (Mayer and Laudenslayer 1988). The habitat is found on periodically flooded basins; thus the roots must do well in anaerobic silts and clays. This habitat naturally accumulates silt and over centuries is replaced by an upland community. It usually occurs in association with Riverine or Lacustrine habitats; its limit lies with the deepwater limit of emergent plants (usually at about a depth of 7 ft). This habitat is highly productive and provides food, cover, and water for many species of mammals, birds, reptiles, and amphibians, with some species utilizing the habitat for their entire life cycle. The endangered peregrine falcon utilize the habitat for feeding and roosting (Mayer and Laudenslayer 1988).

RIVERINE

The Riverine habitat consists of streams and rivers with intermittent or continually running water. This habitat occurs in a natural state primarily in the Santa Monica Mountains in the watershed; in the coastal plain the stream channels have been fixed as open concrete drainage channels with urban runoff rather than springwater constituting the stream flow.

Most of the natural streams in the watershed are intermittent, with greatest flows in the winter. There are 28 stream drainage basins in the watershed (SMBRP 1992). Malibu Creek is the largest stream in the watershed and best represents this habitat. In faster or upper-level streams, water moss and filamentous algae are attached to rocks, and stream insect larvae live on the underside of gravel in riffles or pools. In slower or lower-level streams mollusks and crustaceans replace the insects and emergent vegetation grows along the edge of the stream. Many insectivorous birds feed above this habitat and some water-associated birds are also found there (Mayer and Laudenslayer 1988).

LACUSTRINE

The Lacustrine habitat is found at several sites within the watershed and wasteshed. It consists of inland depressions or dammed streams that contain standing water and is often associated with riverine and fresh emergent wetlands habitats. The largest lakes in the watershed are Lake Sherwood and Malibu Lake. Light penetration is dependent on turbidity and oxygen levels may decrease with increasing depth. Dominant phytoplankton organisms consist of diatoms, desmids, and filamentous algae; other plants include duckweed and submerged algae and pondweeds. Rotifers, copepods, and cladocerans are important members of the zooplankton of lakes. Protozoa, hydras, snails, aquatic insects, and insect larvae also occur in lakes and ponds. Most lakes and ponds support fish populations (Mayer and Laudenslayer 1988).

ORCHARD-VINEYARD

The Orchard-Vineyard habitat is sometimes found in rural areas of the watershed in the Santa Monica Mountains. It is an artificial, agricultural habitat that typically consists of a single tree (or in the case of grapes) vine species planted in rows with an open understory of low-growing grasses and herbaceous plants (Mayer and Laudenslayer 1988). In Southern California dominant fruit and nut crops grown in orchards and vineyards include almonds, apples, apricots, avocados, dates, grapes, grapefruit, lemons, oranges, olives, and walnuts (Miller and Hyslop 1983). The habitat typically occurs in deep fertile soils and is sometimes irrigated. Individual orchards or vineyards may persist for about 40 years, with replacement of orchard type resulting from a decline in market value or productivity. Deer, rabbit, and squirrels feed on orchard trees or their products (Mayer and Laudenslayer 1988).

URBAN

The Urban habitat is found over much of the Santa Monica watershed south of the Santa Monica Mountains and over most of the wasteshed (Figure 3-1) (SMBRP 1992). It is also developed in the Thousand Oaks and Malibu areas and as residential areas near Point Dume and Topanga Canyon. Most of the habitat consists of single or multiple family residential areas but large areas of Santa Monica, Los Angeles, the Los Angeles Airport area, and El Segundo are put to commercial and industrial use (SMBRP 1992). Vegetation types include tree groves, street strips, shade trees , lawns, shrub cover, and demolition sites. Vegetation consists of a mixture of native and exotic species. Commercial and industrial areas often have little vegetation but nevertheless provide habitat for some species. Subhabitat types include downtown, urban residential, and suburbs. Rock dove, house sparrow, and European starling dominate the poorly vegetated downtown areas. Scrub jay, mockingbird, and house finch are the major birds in urban residential areas. Suburban areas approximate the natural environment and provide habitat to species from adjacent habitats. Air temperatures are generally warmer in urban areas and wind velocities lower, except where high-rise buildings are found (Mayer and Laudenslayer 1988).

UNIQUE AREAS AND HABITATS

Unique areas in the Santa Monica Mountains include the Santa Monica Mountains National Recreation Area (SMNRA) developed by Congress in 1978 to protect part of the mountains from further development (Ikeda *et al.* 1991). The Santa Monica Mountains Conservancy was created at about the same time to acquire lands until the 70,000 acres necessary to complete the SMNRA could be completed; this acquisition is still in progress.

ENDANGERED SPECIES IN THE WATERSHED

Four species of flowering plants in the Santa Monica watershed are currently listed as rare, threatened, or endangered (Ikeda *et al.* 1991). The Santa Monica Mountains dudleya was listed as State Endangered in 1976. It is endemic to the Santa Monica Mountains where it has been found at less than 10 sites. It occurs on steep rocky areas along Malibu Creek. Lyon's pentachaeta has been listed by the California Native Plant Society. It occurs at less than 12 sites in the Santa Monica Mountains on the edge between annual grassland and chaparral communities. Conejo buckwheat was listed as State Rare in 1976. It occurs on dry rocky hillsides in coastal scrub and chaparral. Santa Susana tarweed was listed as State Rare in 1978. It grows on rocky outcrops in chaparral in the Santa Monica Mountains (Ikeda *et al.* 1991).

Federally endangered insect species in the study area include the Palos Verdes blue and El Segundo blue butterflies (CDFG 1992). Endangered birds in the watershed include American peregrine falcon (State and Federally Endangered), California gnatcatcher (Federally Proposed Endangered), and Belding's savannah sparrow (State Endangered).

NATURAL VARIABILITY

Many of the habitats in the Santa Monica Bay watershed are adapted to frequent fires. Plants in the chaparral and coastal scrub communities, in particular, have specialized methods by which to deal with what would ordinarily be a catastrophic event. Many perennial species, such as chamise, can resprout after the plant crown has been burned, and several species actually require that their seeds be exposed to the high temperatures of fires to germinate (Head 1989). Annual species have dispersal mechanisms which allow them to be transported long distances beyond the burned area (O'Leary 1989). Fire provides a means by which old growth and senescent plants are removed, making room for new individuals or new growth. The resulting ash, when carried by winter rains, provides nutrients to streams and coastal plains and wetlands (Faber *et al.* 1989). Fire also promotes greater diversity in the community, both among the plants and the animals which use them for food and shelter, by increasing the number of plant species available and providing more levels of habitat, such as open ground, opening-chaparral interfaces, and different age-class individuals. Fire also helps to maintain native plant communities by suppressing nonadapted, invasive, introduced plants (Wells 1990).

DROUGHT

The climate of Southern California is classified as Mediterranean, with mild, rainy winters and hot, dry summers. Near the coast, rainfall varies from about ten to 20 inches per year, and temperatures range from highs of 68°F to 90°F in summer to lows of 37°F to 48°F, with infrequent frosts. Further inland, average rainfall is a little greater, up to 25 inches per year, and temperatures vary more, with summer highs up to 94°F (or over 100°F during a Santa Ana wind) and winters down to 29°F (Munz 1973). However, the distribution of rainfall, with most of it occurring in the cool, nongrowing season, requires that plants accomplish their warm-season growth during a period of little rainfall. Precipitation is also extremely variable from year to year, and periods of several consecutive years of below-normal rainfall result in extreme fire danger in the chaparral plant communities. Even within a normal-rainfall year, uneven distribution of the precipitation, with most occurring during only one or two storms rather than spread more evenly over the season, will affect how much of the available moisture is able to soak into the soil. Native vegetation is most affected by the worst conditions than by the average (Clark 1992). Prolonged drought may predispose plants to diseases and disorders caused by opportunistic parasites (Brooks 1992).

Native plants deal with drought conditions (annual or cyclical) in various ways. Many species have hard or waxy-coated leaves to prevent evaporation or white, shiny, or fuzz-covered leaves to reflect light. Some species (drought-deciduous) drop their leaves during the hottest period of the year, or turn their leaves to avoid the direct rays of the sun (Head 1989). Deep root systems and water-storage capabilities are also present in many species. Physiological mechanisms are also employed, such as resistance of xylem embolism (Davis *et al.* 1992).

WET PERIOD

Periods of greater-than-normal precipitation may adversely affect plants which are adapted to low-moisture conditions. Soil oxygen may be lowered, affecting the root systems or promoting the growth of infecting disease organisms. The absence of fires which are required for germination of seeds of some species may result in a shift of dominance by some species within the plant community.

WETLANDS HABITATS

BACKGROUND

The California Coastal Act of 1976 defines wetlands as "land within the coastal zone which may be covered periodically or permanently with shallow water and includes saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens."

Wetlands generally occur where the slope of the land is sufficiently flat to retain water for some length of time. Freshwater wetlands usually occur along streams or in depressions which may fill with rainwater (vernal pool). Marine wetlands develop where streams enter the ocean across low, flat coasts; they are characterized by freshwater or saltwater marshes and channels. If stream flow is sufficient some salt marshes alternate between fresh and saltwater. Thus, the dominant natural factors which affect wetlands habitats bordering the sea are variable salinities and the tidal cycle which alternately exposes and covers it with water. Marshlands are depositional in nature; because wave forces are minor, fine silts and clays accumulate. Thus, regardless of man's impact they are slowly filling in with fine sediments by natural forces.

IMPORTANCE

Historically, the ecological importance of wetlands was overlooked and wetlands were only considered useful for reclamation for more "constructive" purposes. However, this outlook has changed dramatically because the vital ecological roles that wetlands served have been documented. Wetlands mitigate flooding and recharge groundwater; provide feeding and breeding habitat for fish, waterfowl and other wildlife; filter pollutants from sewage and agricultural runoff; and stabilize the biosphere by using carbon dioxide and producing oxygen. Energy flow patterns involve the direct consumption of green plants, such as eelgrass, by grazers and the breakdown and consumption of detritus, or organic debris, by bacteria and other organisms. The patterns are complex and often intertwine.

located five miles upstream. The natural channel of Malibu Creek enters the ocean on the downcoast (southeast) side of Malibu Point and is normally open only during the winter rainy season. The sand bar which develops across the mouth is purposely breached by the Los Angeles County Department of Parks and Recreation for flood control purposes (CDPR 1978). As a result of the varying salinities, the species diversity is low compared to other coastal lagoons.

Water quality is a main concern in Malibu Lagoon. High nutrient loading makes the Lagoon susceptible to eutrophication, and coliform levels are frequently high due to various unidentified point and nonpoint sources of pollution, such as horse stables and septic tanks. The approved expansion of TWRF, which will increase the volume of freshwater input, may escalate the existing problems with the Lagoon entrance and water quality.

BIOLOGICAL RESOURCES OF WETLANDS

Wetlands support a wide variety of plants and animals, and are populated by marine, estuarine, or freshwater organisms, depending upon the salinity of the water. Upstream wetlands are populated entirely by freshwater and terrestrial organisms. As a result of fine sediments and high organic content, wetlands support abundant bacteria (Pollock 1971). For the same reasons, oxygen concentrations in the sediment decrease rapidly with depth and reach zero within a few inches of the surface. Anaerobic bacteria in these zones produce hydrogen sulfide. Most of the Santa Monica Bay wetlands exhibit decreased biological diversity and productivity because of their degraded condition.

PLANTS

The present Ballona Wetlands Complex supports marine algae as well as marine and terrestrial flowering plants. Microalgae are abundant in the water column and on the sediments; the subtidal substrate (only in Basin D in Marina del Rey) supports eelgrass (Stephens *et al.* 1991) and sea lettuce occurs on mudflats. Immediately above the mudflats the saltmarsh plant assemblage consists of five species, dominated by one or more species of pickleweed. Upstream, the marsh grades into freshwater plant communities which include willows and freshwater marsh plants (Gustafson 1981). The higher areas of the wetlands and the adjacent sandy coastal strand and disturbed land contain 23 terrestrial plant species (Bakus 1975, Ford and Collier 1976).

Many marsh plant species which typify the pristine saltmarsh environments of southern California are absent from the Ballona Wetlands, possibly because of restricted water flow between the marsh and Ballona Creek proper (Gustafson 1981). Related factors (stagnation, salinity, and temperature fluctuations) have kept species density in the marsh low. Pickleweed is the dominant saltmarsh plant; topographically it occurs lower than in other Southern California saltmarshes with greater tidal influence. The saltmarsh is lacking in a low and middle marsh flora and has reduced the breeding, nursery, and foraging areas for fishes, birds, and reptiles.

There is a small pickleweed marsh at Malibu Lagoon, but this wetland differs from the Ballona Wetlands Complex in that riparian woodland, with cottonwood and alder trees, and chaparral are found upstream (Dock and Schreiber 1981). Trancas Lagoon, Zuma Beach, and lower Topanga Canyon are less saline, and support a limited number of plant species. Their contributing creeks support riparian woodland species. El Segundo Dunes supports native dune species, but the native wetlands plants have been mostly replaced by invasive introduced species.

The endangered (state- and federally-listed) salt-marsh bird's beak, a low-growing annual, historically occurred in wetlands along the northern part of Santa Monica Bay. In other coastal wetlands of Southern California and Baja California, it occurs at the landward edge of the salt marsh, where it is frequently disturbed. Introduced species often threaten to invade its habitat but no displacements have been documented (Zedler 1991).

INVERTEBRATES

The shallow subtidal, marsh channel, and mudflat communities integrate the flow of energy through the wetlands. The marine invertebrates (primarily nematodes, annelids, crustaceans, and mollusks) in these environments recycle organics in the muds and are primary food sources for resident and transient fishes and shorebirds (Peterson 1975, Quammen 1980). Thus, the water and sediment quality and abundance of benthic invertebrates are likely to influence the distribution of higher trophic level organisms in the area.

The marine benthic invertebrate communities of the mudflats and tidal channels of the wetlands of Santa Monica Bay resemble those found in the sandy intertidal, but nematodes may be more abundant (Soule and Oguri 1985). Polychaetes, molluscs, and crustaceans dominate the invertebrate fauna of the Ballona Lagoon, however, oligochaetes are abundant in some places. Although the Ballona Wetlands are not well described, they are comparable to those of nearby Marina del Rey (Soule and Oguri 1987), Ballona Lagoon (Bakus 1975, Ford and Collier 1976), Playa Vista (Reish 1980), and other modified, shallow subtidal or mudflat embayments in southern California such as Sunset Bay, Anaheim Bay, and Upper Newport Bay. In these environments, combinations of physical and chemical stresses limit biological diversity, and community structure is dominated by hardy forms with life histories that are tolerant of the stressful conditions, whether natural or man-made (Kauwling and Reish 1975, McCall 1977, MBC and SCCWRP 1980, MBC and Marsh 1985, MBC 1986b). Several of the abundant species are indicators of organic enrichment and low dissolved oxygen. Ballona Lagoon may support the northern-most population of the fiddler crab on the west coast (Dorsey 1988, pers. comm.).

In the mid-1970s, invertebrate assemblages of Ballona Lagoon were diverse and similar in species composition to those of the larger and more natural Tijuana Estuary, suggesting that the flora and fauna represented a reasonably natural and healthy assemblage of estuarine organisms. These conditions were attributed to adequate tidal exchange and flushing, despite the Lagoon's long and narrow configuration and restricted entrance (Ford and Collier 1976). In 1980-1982 the marine molluscan fauna of Ballona Lagoon was comparable in diversity and abundance to Mugu Lagoon and Mission Bay; the same species were present in all three saltmarshes, in approximately the same numbers (Ramirez 1981).

Nagano *et al.* (1981) identified 474 insect species from the Ballona Wetlands saltmarsh and estimated that as many as 1,200 may actually inhabit the region. On the basis of the presence of known indicator species, the Ballona region was characterized as a natural coastal salt-marsh and associated sand dune habitat. At least ten of the species found have restricted coastal distributions, and destruction of Ballona Wetlands habitat could result in their elimination.

VERTEBRATES

Fishes. The Ballona Wetlands, primarily Ballona Lagoon, support a number of transient fish species but only nine resident species. The dominant species are the arrow goby, which lives commensally in burrows of other organisms in the intertidal zone; the mosquitofish, a freshwater species which was introduced to control mosquitos; and topsmelt, a pelagic marine species which moves in and out with the tides (Swift and Frantz 1981).

Marine lagoons and back bays in Southern California serve as spawning and nursery grounds for resident species (such as several species of gobies, California killifish, Pacific staghorn sculpin, and possibly topsmelt) (Fitch and Lavenberg 1975) and as important nursery grounds for the California halibut (Haaker 1975). The imponance of Ballona Lagoon and Marina del Rey to these species in the past is not known.

Rainbow trout (steelhead) and tidewater goby were present at Malibu Lagoon in the past, and those species might return there if the entrance to the ocean were kept open to improve water quality (WRA 1990). Topsmelt and gobies (and possibly other bay species) which occur in Marina del Rey probably also occur in the Oxford Flood Channel and the Venice Canals.

Amphibians and Reptiles. Three species of amphibians and six of reptiles are known from the Ballona Wetlands. Most of the amphibians are frogs and toads and most of the reptiles are lizards (MBC 1988). All are associated with freshwater areas in the wetlands.

Birds. Numerous terrestrial birds, shorebirds, and water fowl are found in the Ballona Wetlands Complex and Malibu Lagoon. However, diversity is greater at Malibu Lagoon because it is adjacent to riparian woodland and chaparral habitats. Most species in the Ballona Wetlands Complex are shore birds, perching birds, and waterfowl. Relatively few birds breed in the Ballona Wetlands Complex due to both human disturbances and limited habitat diversity (Dock and Schreiber 1981).

Two endangered species live and/or breed in the Ballona Wetlands: Belding's savannah sparrow and California least tern. The savannah sparrow is a year-round resident which forages and nests in pickleweed, while the least tern is present only during spring and summer, feeding in the shallow waters and nesting at nearby Venice Beach (Dock and Schreiber 1981, Atwood and Minsky 1983).

Two species of birds which have not been observed in the Ballona Wetlands in recent decades probably bred there early in the 19th century. The range of the light-footed clapper rail (a federally-listed endangered species) presently extends between the saltmarshes of northern Baja California and those of southern California. Clapper rail nesting was recorded in nearby Santa Monica marshlands early in the century (Grinnell and Miller 1944) and they have been found in various marshes in Los Angeles County (LFCRRT 1983). Their absence at Ballona may be a result of a lack of suitable nesting habitat, preferably cordgrass (Massey and Zembal 1979). Although it will nest in upper marsh areas, especially following flooding of lower marsh habitat, this habitat is generally lacking at Ballona. Overharvesting by museum collectors and hunters, which occurred early in the century from Santa Barbara to San Diego, may also have contributed to their limited population size (Bent 1926). Since the clapper rail is a poor flyer, its natural immigration into Ballona is unlikely.

The same considerations probably also apply to the black rail, which occupies similar habitats (Grinnell *et al.* 1918). Early in the century the black-necked stilt bred at Playa del Rey (Willet 1933) and may have attempted to breed in the Ballona Wetlands during the summer of 1980 although no nests were found.

Mammals. Seventeen species of mammals are known to live in the wetlands complex and at least 21 more have occurred there in the past or forage in the area. Carnivores (including the introduced red fox), rodents, and rabbits are the most diverse groups (Friesen *et al.* 1981).

ENDANGERED SPECIES

Salt Marsh Bird's Beak. The salt marsh bird's beak was placed on the California and Federal Endangered Species Lists in 1978. This plant has suffered major population declines at all of the California coastal wetlands, and no longer occurs at any of the wetlands along Santa Monica Bay. The decline in numbers is due to loss of habitat (CNPS 1988).

Belding's Savannah Sparrow. The Belding's savannah sparrow depends on the upper salt-marsh habitat and is particularly abundant in areas dominated by pickleweed (Massey 1973, Zedler 1982), which it uses for foraging, breeding, and perching. This species is present year round in upper saltmarsh areas of the Ballona wetlands, but is limited to nesting territories between January and August (Dock and Schreiber 1981).

A beneficial, but short term, impact of placing dredge-spoil on the northern parcel of the Ballona wetlands during the construction of Marina del Rey was to increase the amount of suitable nesting habitat for Belding's savannah sparrows. Because of the long active breeding season and sensitivity to disturbance, human activity in this high marsh habitat may cause both habitat degradation and reproductive failure (Zedler 1982).

Territorial males have been observed on Playa del Rey and Ballona saltflats between 1973 and 1991, although there are no records of fledglings (Zembal 1992, pers. comm.). During the period from 1973 to 1987, the population was fairly stable, with 23 to 39 breeding pairs occurring in the wetlands each year (Table 3-1). Starting in 1990, the number of pairs started to decline, partly due to predation by introduced red foxes (Jurek 1992, pers. comm.) (Attempts have been made to trap and remove the foxes from the wetlands, but the program has encountered strong opposition from the animal-rights activists, to the extent that biologists were afraid to conduct surveys for fear of retaliation. Therefore, despite declining numbers of birds, surveys were not conducted in 1992.) The number of breeding pairs in the area may also be affected by changing habitat conditions, such as increased amounts of standing water during flooding and, in the case of the dredge spoil nesting site, a reduction in the quality and quantity of pickleweed habitat (Dock and Schreiber 1981).

Year	Number of Breeding Pairs	Area
1973	23 [a,b]	Playa Del Rey
1977	27 [a,b]	Playa Del Rey
1979	39 [c]	Ballona
1980	28 [c]	Ballona
1981	23-26 [c]	Ballona
1986	32 [a,d]	Playa Del Rey
1987	29 [e]	Ballona
1990	12 [e]	Ballona
1991	5 [e]	Ballona

a Based on sightings of territorial males.
b Massey 1979
c Dock and Schreiber 1981
d Dembal, 1988, pers. comm.
e Jurek, 1992, pers. comm. (based on USF&WS data).

Table 3-1. Number of breeding pairs of Belding's savannah sparrow in the Ballona Wetlands, 1973-1991.

California Least Tern. The California least tern is a summer visitor which breeds in Southern California coastal habitat from late April to September. It builds its nests in shallow depressions in hard or soft dirt, dried mud, or sandy areas, usually on beaches or islands cleared of vegetation. The closest breeding site to any of the Bay wetlands is the Venice Beach site (Table 3-2).

Least terns commonly utilize the open waters of Ballona Creek and, to a lesser extent, Ballona Lagoon to forage for food, principally northern anchovy, topsmelt, various surf-perches, killifish, and mosquitofish (CLTRT 1980). Topsmelt, killifish, and mosquitofish are probably principal items in the tidal channels, creeks, and lagoons of the Ballona Wetlands, whereas northern anchovy is most important in offshore waters. Breeding success is partially dependent on food availability (Massey 1972).

Western Snowy Plover. Snowy plovers nest on beaches and salt flats which have some vegetation, and feed on mud flats in the wetlands. Historically, snowy plovers nested on the beaches at Malibu and on a stretch between Santa Monica and Redondo Beach (Page and Stenzel 1981). A few snowy plovers winter on the beaches of Santa Monica Bay (Page *et al.* 1986). However, nesting in the area has not been observed since 1949. The number of breeding birds in the U. S. in 1988-1989 (roughly 7,900 birds) was about 20% lower than 10 years earlier (Page *et al.* 1991). This observed decline has raised concern for the future of this species, and the process of listing as threatened or endangered has been initiated.

	Breeding Pairs		Fledgings	
Year	Venice Beach	Playa Del Rey	Venice Beach	Playa Del Rey
1978	60-75	25-30	75	30
1979	80-95	18-25	140	25
1980	157	na	240	0
1981	150	16	195	0
1982	170	na	na	na
1983	145	0	140	0
1984	83	0	94	0
1985	96	0	113	0
1986	104	0	113	0
1987	109	0	82	0
1988	165	0	192	0
1989	137	0	134	0
1990	206	0	279	0
1991	198	0	200	0
1992	229	0	245	0

Sources: CDFG, unpubl. data; Massey and Fancher 1989; Jurek 1992, pers. comm.
na = Data not available.

Table 3-2. California least tern breeding data in the Ballona region, 1978-1992.

NATURAL VARIABILITY

Although there is little information on the natural variability of wetlands plants and invertebrates in the area, seasonal and interannual variation would be expected under most conditions. Phytoplankton (and other seasonal plants) are most abundant in the spring and least abundant in winter. In addition, the aquatic and saltmarsh organisms would vary in abundance with regard to the relative influence of freshwater (runoff) and seawater, which may vary either seasonally or interannually.

Intertidal zones are used as classrooms for amateur and professional naturalists. Rocky tidepools, in particular, are visited by school classes and casual beach-goers, and may be heavily impacted during extreme low tides. Fisherman collect mussels for bait and some ethnic groups collect limpets and abalone for food, thereby depleting the shoreline of these species in some areas.

SANTA MONICA BAY HABITATS

The biological community and the physical environment function together as an ecological system or ecosystem (Odum 1959). The term ecosystem is usually applied to naturally defined systems to describe systems with unique physical and biological attributes. The biological environment of Santa Monica Bay is not a naturally defined ecosystem but rather an integral part of the larger Southern California Bight and California Current ecosystems; the study area is artificially defined here as the Santa Monica Bay ecosystem, with that understanding.

The following section includes a description of the plants and invertebrates found in most habitats. The marine vertebrates of Santa Monica Bay and their responses to human activities are discussed in Chapter 9. A complete list of scientific and common names of species used in this report are given in Appendix C.

Most marine organisms found in Santa Monica Bay and its watershed are temperate species with geographic ranges extending far beyond the immediate area. The majority are members of the San Diegan Province, which extends from about Point Conception, California, to Magdalena Bay, Baja California Sur, but some belong to the Oregonian Province, which ranges from southern Canada to northern Baja California (Hubbs 1974, Allen and Smith 1988).

Life zones are areas with distinct organisms with adaptations for special physical conditions (e.g., pressure, darkness). Life zone schemes usually divide the marine environment into pelagic (open-water) and benthic (bottom) environments, with these being further divided, usually by depth (Hedgpeth 1957, Allen and Smith 1988). Intertidal and estuarine environments are also included as separate categories (Hedgpeth 1957). Each of these environments can be divided into smaller habitat units, each characterized by particular physical attributes and a suite of specially adapted organisms.

The marine ecosystem is divided into the pelagic and benthic environments. The pelagic environment includes the entire water column from the surface to the bottom of the sea. Pelagic organisms typically meet their needs for food, space, and refuge in the water mass itself, with relatively little to no direct interaction with the underlying seafloor. Horizontally, the pelagic realm can be divided into two zones: neuritic and oceanic. The neuritic includes the water column that overlies the continental shelf. Oceanic zone includes all other open waters. The pelagic environment can be further divided vertically. Two life zones of the pelagic realm are represented in Santa Monica Bay: Epipelagic and Mesopelagic. The Epipelagic zone (euphotic zone) is part of the pelagic environment that is lighted; its lower boundary is the limit of light penetration and varies in depth with water clarity. The mesopelagic extends from the permanent thermocline and extends to about 1,500 ft - the artificially defined deep boundary of the study area.

The benthic environment (Figure 3-4) has three major habitats based on substrate type (hard-bottom and soft-bottom) or the presence of kelp beds. Benthic communities generally show a change in composition along a gradient of water depth. The sublittoral zone (from shore to a depth of about 600 ft) is divided into inner shelf (5-100 ft), middle shelf (100-300 ft), and outer shelf (300-600 ft) zones (Allen 1982, Allen and Smith 1988); the mesobenthal zone extends from a depth of 600 to 1,500 feet (the deepwater boundary of the study area) (Allen and Smith 1988). Kelp beds are only found in the inner shelf zone, where waters are warmer and with sufficient light for kelp growth. The term benthos is used variously to describe both the habitat and the organisms which live on or in the seafloor. Some organisms move about in the water column and feed or find refuge on the bottom; these are called demersal.

PELAGIC HABITATS

The pelagic habitat is the most obvious habitat in Santa Monica Bay, encompassing approximately 306 mi^2 (since it extends from the surface to depths of 1,640 ft) and a total water volume of about 914 billion ft^3 (6,840 billion gallons, using an average depth of 820 ft).

The pelagic environment varies on a fairly regular, seasonal basis as well as periodically. Temperature and phytoplankton production are two of the most important factors which affect the abundance of pelagic animals. Natural surface water temperatures in Santa Monica Bay range from 11.7°C to 22.0°C annually (EQA/MBC 1973). Seawater temperatures in the Bay are higher in late summer and fall and lower in the winter and spring. Stratification and increased light levels in spring and summer enhance phytoplankton production, which forms the basis for the pelagic food web and the bacteria which recycle waste products into nutrients.

Organisms of the pelagic habitat are planktonic or nektonic. Planktonic organisms are too small (or are otherwise unable) to swim against the prevailing currents and thus drift with the water mass. However, some are able to move vertically through the water, undertaking-daily migrations to the surface (usually at night). Nektonic organisms are those which are large enough or strong enough to swim against prevailing currents; they can remain in one place or move to another at will. The largest of these (macronekton) are whales, sharks, and large fishes.

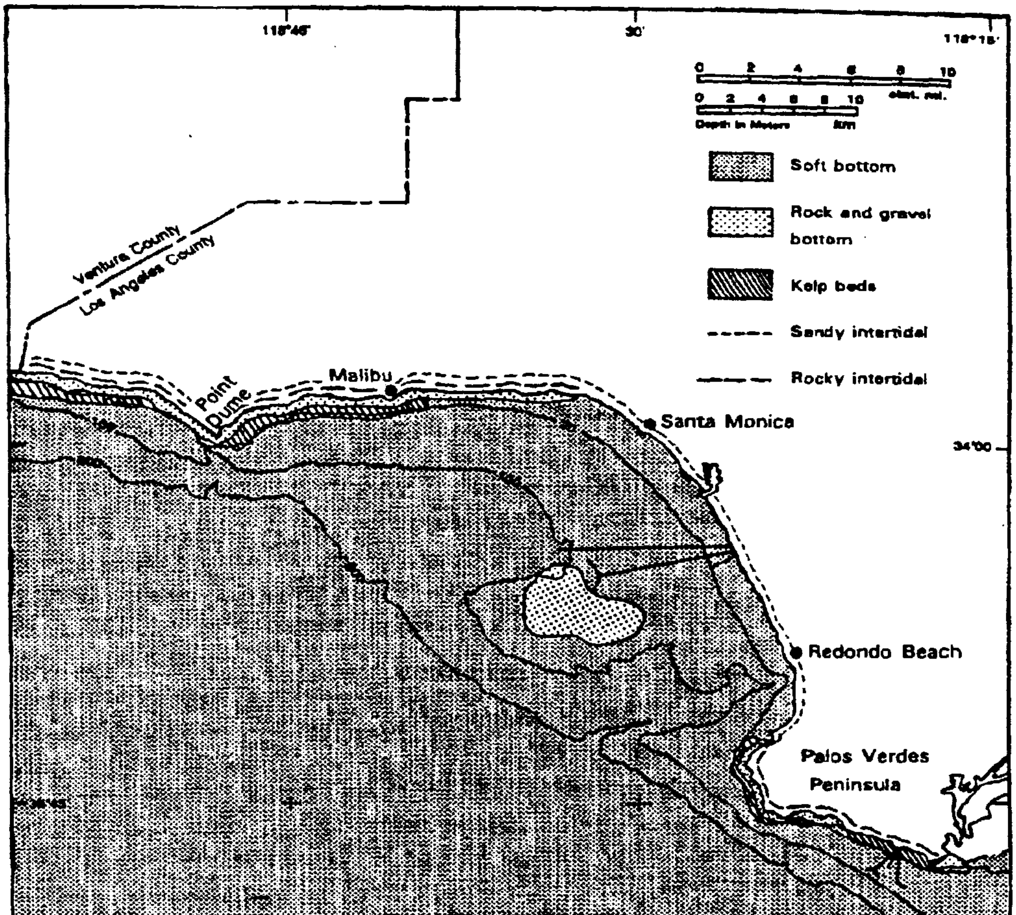


Figure 3-4. Major benthic and intertidal habitats of Santa Monica Bay.

PELAGIC ORGANISMS

PHYTOPLANKTON

The major plants of the pelagic realm are phytoplankton (blue-green algae, flagellates, and diatoms) and their primary production forms the basis of the pelagic marine food web. Phytoplankton are found most abundantly in the photic zone, both nearshore and well offshore. Dinoflagellates (some of which are responsible for "red tides") are characteristic of waters over most of the shelf in Santa Monica Bay, while diatoms are typically more abundant in colder water. During upwelling diatoms may dominate the phytoplankton community; when upwelling ceases, dinoflagellates become dominant again (Mullin 1986).

In general, phytoplankton abundance is greatest in spring when nutrients are abundant in the mixed layer and there is ample sunlight. However, blooms may occur in the fall when stratification breaks down and nutrients enter the photic zone from below. Most phytoplankton blooms in Santa Monica Bay result in response to local conditions such as surface runoff, upwelling, and sewage discharges that increase nutrient levels. Primary production in the study area ranges from 75 to 175 g carbon/m^2/year; that of the Santa Barbara channel is approximately 142 g carbon/m^2/year (Eppley and Holm-Hansen 1986).

INVERTEBRATES

Smaller invertebrates comprise most of the zooplankton whereas larger invertebrates are often important members of the nekton. The most abundant animals of the pelagic environment are the zooplankton, which are small animals which drift with the currents. Zooplankton includes protozoa, crustaceans (copepods, euphausiids or krill, and mysid shrimps), pelagic snails, polychaete worms, arrow worms, comb-jellies, and jellyfish. Zooplankton are typically less than an inch in size, but some jellyfish are over six feet long (Beers 1986).

Most zooplankton are primary consumers and eat phytoplankton. In turn, they are consumed by larger, secondary consumers. However, many zooplankters are secondary consumers themselves. Zooplankton are found throughout the water column, although certain species are characteristic of various depths. Mysids are typical of shallow, nearshore waters while euphausiids are typical of middle and upper layers of deep offshore water. Many planktonic crustaceans undertake a daily vertical migration, swimming to the surface at night and to deeper waters during the day.

Most zooplankton species reproduce several times in a single year, the life span of individuals being measured in weeks or months. Eggs are usually broadcast into the water and develop through a variety of larval stages to mature adults.

Zooplankton abundances typically increase immediately following plankton blooms, especially in spring; in fact, predation by zooplankton contributes to a decline of phytoplankton. However, a decline in phytoplankton is primarily caused by depletion of nutrients. The volume of zooplankton in the surface waters of the Southern California Bight generally range from 90 to 300 ml/100 m^3 (Mullin 1986). In 1980, zooplankton (mostly copepod) volumes in Santa Monica Bay ranged from 100 to 1,300 ml/1,000 m^3 (Kleppel *et al.* 1982).

The eggs and larvae of many invertebrates are planktonic, even though the adult stages may not be. These meroplankton may last for only a short period (days to months) before the larvae become nektonic or settle to the bottom. The pelagic nekton includes larger mobile invertebrates such as squid and shrimp. The most important large nektonic invertebrate is the California market squid, although the pelagic red crab and the jumbo squid may be abundant locally during El Niño periods. Ocean shrimp feed in the water column at night but rest on the bottom during the day. The production of phytoplankton (and secondarily of zooplankton) in the water column provides the primary basis of the food web that supports most of the larger organisms in the Bay.

NATURAL VARIABILITY

Phytoplankton assemblages in Santa Monica Bay are relatively distinct from those elsewhere in the Bight. Dinoflagellate abundance is higher in the Bay than in other areas along the coast. This has been attributed to high concentrations of ammonium, a result of nutrient regeneration at the bottom of the relatively broad shelf or from anthropogenic inputs. In addition, maximum phytoplankton production is at shallower depths (mostly less than 30 ft) in Santa Monica Bay than in other coastal and offshore areas of the Bight (Mullin 1986); it is greatest nearshore and decreases offshore. The distribution of bacterioplankton abundance parallels that of the phytoplankton (Azam 1986).

Most of the variability of plankton in Santa Monica Bay is natural (SCCWRP 1973), and its abundance may vary by an order of magnitude at periods of several years. Thus, in 1979 the concentrations of chlorophyll (a measure of total phytoplankton abundance) were less than one-tenth those in 1975 (Eppley 1986). During El Ni:o periods, phytoplankton productivity drops as the thermocline deepens and the availability of naturally occurring nutrients decreases (McGowan 1984). Cool surface waters are generally from the productive California Current whereas warm surface waters are generally from the less productive southern waters which move into the area during an El Niño.

Phytoplankton abundance in the Bay also varies seasonally, as a result of variations in light levels and nutrient availability. Primary production may vary by a factor of three between seasons. In general, phytoplankton abundance and production increase in spring as the sun m waters) traps nutrients in the mixed layer. However, as phytoplankters deplete the nutrients, they become less abundant; predation by zooplankton also contributes to this decrease. A bloom may also occur in the fall when stratification breaks down and nutrients enter the photic zone.

Both spring and fall blooms are less pronounced in southern California than to the north; most local phytoplankton blooms are the result of local nutrient conditions from runoff, upwelling, and sewage discharge (Eppley and Holm-Hansen 1986). Upwelling in the Bay, particularly along the southern Palos Verdes Shelf, may lead to phytoplankton blooms which are dominated by diatoms rather than dinoflagellates (Eppley and Holm-Hansen 1986, Mullin 1986). In 1980 diatom abundance was sometimes high over Santa Monica and Redondo Submarine Canyons, suggesting upwelling there (Kleppel *et al.* 1982).

"Red tides" (which are typically dominated by dinoflagellates) sometimes develop in nearshore areas when warm temperatures, high light levels, abundant nutrients, and a shallow pycnocline occur together (Mullin 1986). Localized red tides occur almost every year, extensive ones less frequently. A red tide which developed in Santa Monica Bay in 1945 extended from San Luis Obispo to Los Angeles Harbor (Sommer and Clark 1946).

Zooplankton abundance also varies with oceanic conditions; it is generally low at high temperatures and high at low temperatures. Zooplankton abundance generally increases during a phytoplankton bloom (as during the spring) and decreases as phytoplankton abundance decreases. The abundance of microzooplankton in Santa Monica Bay generally parallels primary productivity (Eppley and Holm-Hansen 1986).

Because many zooplankters migrate between deep water during the day and the surface at night, zooplankton abundance in surface waters varies between day and night. Larger species such as euphausiids and mysids are generally more abundant in the surface waters of the Bay at night than during the day. Smaller species such as calanoid copepods do not migrate as much and day-night differences are less pronounced.

INTERTIDAL HABITATS

ORGANISMS

PLANTS

Plants in the rocky intertidal display vertical zonation, with distinct species assemblages at different tidal levels, although the patterns may be disrupted by grazing, by dominant attached invertebrates, or by trampling. Lichens dominate in the splash zone, whereas the upper intertidal flora includes green algae such as sea felt and sea lettuce, brown algae (rockweeds), and various red algae. The middle intertidal includes a more diverse algal assemblage with foliose, filamentous, and coralline red algae and brown algae. The lower intertidal zone has red and brown algae as well as surfgrass (Hedgpeth and Hinton 1961, Dawson 1966).

Few plants are found in the sandy intertidal, although one-celled algae may be abundant on beaches with fine particle sizes (Pollock 1971). Benthic diatoms sometimes form a brownish green layer on sands where wave action is not too great and green algae, such as sea felt and sea lettuce, may occur on protected beaches where there is little sand movement. On the mudflats of backbays, cordgrass forms dense stands at the lower tidal level, while pickleweed dominates the upper level.Where conditions are favorable for dune formation, above the high-energy intertidal zone, the sand may be sparsely vegetated with salt-tolerant sand verbena, silver beachweed, beach primrose, beach morning glory, salt bush and salt grass.

Many introduced exotic plant species, such as Hottentot fig and sea fig (both known as iceplant), and sea rocket have taken over much of the extant dunes in Southern California (Munz 1964, 1973). The vegetative cover helps to stabilize the dunes but is fragile. Its disturbance by vehicles and foot traffic may lead to eventual loss of the dune system.

INVERTEBRATES

On rocky shores, only shelled species can live at the highest zones; soft-bodied forms cannot tolerate exposure to the air for very long. The splash zone is best characterized by periwinkles, barnacles, limpets, and rock lice. Periwinkles and limpets graze on diatom films, barnacles filter-feed when the tide is in, and rock lice are scavengers.

In the upper intertidal zone, species diversity increases with additional species of snails (periwinkles, turbans, limpets), attached bivalves, chitons, hermit crabs, and striped shore crabs. The upper limit of this zone is marked by California mussels and Pacific goose (or gooseneck) barnacles both of which are filter feeders and which are preyed upon by ochre starfish. A variety of sea anemones, snails (including black abalone), sea slugs, octopus, polychaetes, barnacles, isopods, crabs, shrimp, and brittle stars is also found here.

The lower intertidal is very similar to the subtidal; sponges, sea anemones, polychaetes, snails, sea slugs, attached bivalves, octopus, bryozoans, crustaceans (amphipods, isopods, shrimp, hermit crabs, crabs), sea stars, brittle stars, sea cucumbers, sea urchins, and tunicates are all abundant (Hedgpeth and Hinton 1961).

The meiofauna, the smaller organisms of sandy beaches, is found in the upper sediment layers to a depth of several feet in coarse sand, to only two inches in fine sediment. Abundance is generally highest in coarse sands, but diversity is greater in fine sands. Similar species occur here as are found on the subtidal soft-bottom habitat.

The macrofauna of the sandy intertidal consists largely of polychaetes, bivalves, and crustaceans, the most obvious of which is the sand crab. This species is an important food for many surf zone fishes and is collected commercially for fishing bait. It filters particulate matter from the incoming waves but rapidly burrows deeper into the sand as the wave retreats.

The bloodworm is an infaunal polychaete which feeds on bacteria, microalgae, and meiofauna beneath the sand. Bean clams are abundant in some years; in other years they are rare. The pismo clam is a popular recreational species which is found on sandy beaches, and along with the little bean clam, extend subtidally. Populations of these two species appear to have declined over the past few years. The reasons are not clear, although recruitment has been very low, perhaps due to overfishing of parent stocks or habitat degradation (Shaw and Hassler 1989). The Pacific littleneck is found in coarse sand and gravel near rocky areas; this clam is also a popular recreational species. Although the status of this species is not known, it is subject to the same problems of overfishing and habitat degradation as Pismo and bean clams (Chew and Ma 1987). Amphipods are also important species on the intertidal sandy beach: beach hoppers (gammarid amphipods) live in burrows at low tide or under and around drift kelp (Hedgpeth and Hinton 1961). Further inland, on undisturbed, vegetated dunes, there are numerous species of insects, including the endangered El Segundo blue butterfly (WRA 1990).

Fishes. Rocky tidepool fishes are typically small and well-camouflaged. Woolly sculpin, opaleye, rockpool blenny, spotted kelpfish, and California clingfish are all found in the study area (Cross 1982a). The spotted kelpfish associates with turf algae, while the others are found where algae are not abundant. The rockpool blenny and California clingfish are most common in cobble areas whereas the woolly sculpin and opaleye are typical of fixed tidepools.

California grunion is a small, silvery fish, which deposits its eggs in the sandy intertidal zone. It spawns from late February to early September on the second night after a full moon, the so-called "grunion runs" of Southern California beaches. Spawning occurs near the peak of the high tide during and just after high spring tides. Female grunion burrow tail-first into the sand and lay their eggs; males follow the females, wrap themselves around the females, and fertilize the eggs. They leave on succeeding waves and the eggs remain until the next spring tides two weeks later, when the eggs hatch and the larvae are carried out by waves. While buried on the beach, grunion eggs may be eaten by sand worms, isopods, flies, beetles and shorebirds (Fitch and Lavenberg 1971, USFWS 1985). Grunion may be caught (legally) by hand during the spawning season; they are taken incidentally in commercial nets along with other species (Fitch and Lavenberg 1971, USFWS 1985).

Several fishes live nearshore or in the surf zone. California corbina, barred surfperch, and shovelnose guitarfish all feed on sand crabs and are caught by sport fishermen. Surf fishermen often take California halibut as they move inshore to feed on grunion.

Shore Birds. Numerous shorebirds forage on crustaceans, mollusks, and polychaetes in the rocky intertidal zone. These include spotted sandpipers, willets, ruddy turnstones, black turnstones, surfbirds, wandering tattlers, black oystercatchers, Heermann's gulls, and western gulls (Jaeger and Smith 1966, MBC 1985). These species are most common locally during the winter; many migrate north in summer to breed.

Sandy beaches also provide foraging habitat for several species of shorebirds and nesting habitat for one endangered species, the California least tern. Western snowy plovers and willets are present on local beaches all year round; whimbrels, marbled godwits and sanderlings spend the winter only; and ruddy turnstones visit southern California beaches during spring and fall migrations (Garrett and Dunn 1981).

Marine Mammals. California sea lions sometimes haul out in rocky intertidal areas in Santa Monica Bay or rest on sandy beaches when sick or injured.

IMPORTANCE

Beaches are the part of the marine ecosystem where the land meets the sea. As such, they present a unique and difficult environment for which a few species have become specially adapted. On sandy beaches, sand crabs and clams must cope with shifting sands (caused by waves) and with intermittent exposure to air during low tide. Species such as sand crabs and bean clams (also known as coquinas), move up and down with the tide, while others simply burrow deeper to avoid desiccation and predators. Pismo clams prefer the lower intertidal and are vulnerable only during the lowest tides. California grunion spawn in the sandy intertidal. All of these species are preyed upon at some time in their life cycle by other intertidal organisms, shorebirds, and humans.

Dunes provide protection for inland areas and serve as living and breeding areas for many species. Plants which have colonized dunes, in turn, act to stabilize the dunes, preventing them from blowing out during strong winds.

Rocky shores support a very different intertidal community. They provide points of attachment for algae which are primary producers and so are a source of algal as well as shell detritus. Rocky shores are the sole habitat for many species and they constitute nursery areas for the young of some fish and invertebrates.

RARE, THREATENED, OR ENDANGERED SPECIES

California Least Tern. California least tern is a spring and summer visitor which breeds in southern California coastal habitat from late April to September. It builds its nests in shallow depressions in hard or soft dirt, dried mud, or sandy areas.

Historically, least tern nested on the upper reaches of sandy beaches along much of Southern California. As nesting habitat and suitable feeding grounds were lost and disturbance by humans increased (CLTRT 1980), terns made use of alternative sites (Dock and Schreiber 1981). California least terns formerly nested on salt- and mudflats at Playa del Rey in lieu of the larger and permanent site on Venice Beach. As a result of a program to protect least tern nesting grounds, the numbers of nesting pairs and fledglings at Venice Beach have almost tripled since 1984 (Table 3-2).

Breeding success of least terns varies greatly from colony to colony each year due to predation, unfavorable weather (CLTRT 1980), flooding (Dock and Schreiber 1981), and availability of food (Massey 1972). Least terns forage in the shallow, open waters of Ballona Creek, and to a lesser extent, Ballona Lagoon and Marina del Rey, principally for northern anchovy, topsmelt, surfperches, killifish, and mosquitofish (CLTRT 1980). Topsmelt, killifish, and mosquitofish are found in the tidal channels, creeks, and lagoons of the Ballona wetlands, whereas northern anchovy occurs in nearshore marine waters.

No studies have linked contamination of least tern food resources to reproductive success. However, since they prey on northern anchovy and topsmelt like the brown pelican, they may also have been impacted by the accumulation of chlorinated pesticides and PCBs in the 1970s.

Western Snowy Plover. The western snowy plover has recently been proposed for Federal threatened status (CDFG 1992). Its population has declined due to loss of beach nesting habitat in California (Garrett and Dunn 1981). Snowy plovers flock on the beach at Malibu and Hermosa Beach during winter but apparently do not nest there (Stenzel 1993, pers. comm.). The closest breeding colony is at Bolsa Chica in Orange County; other colonies nest at the Santa Clara River mouth, McGrath Lagoon and Mugu Lagoon in Ventura County, and some Channel Islands.

El Segundo Blue. The El Segundo blue is a subspecies of butterfly which inhabits (almost exclusively) dunes where its sole host plant, coastal wild buckwheat, is found (Emmel and Emmel 1973). It is presently limited to the dunes at the west end of LAX and Chevron USA's 1.6 acre butterfly preserve at the northwest corner of the refinery (Coonan 1992, pers. comm.). At one time the dunes encompassed 2,900 acres and included small seasonal pools and marshes; currently there are 338 acres of dunes, although potential enhancement sites are present within dunes owned by the airport and Chevron USA (WRA 1990). Attempts to protect the El Segundo blue from extinction have included protecting and propagating its host plant.

Wandering Skipper. The El Segundo Dunes are also inhabited by another rare butterfly, the wandering skipper. Wandering skipper larvae are restricted to one host plant, saltgrass. The decline in wandering skipper populations is due to loss of undisturbed beach dunes and coastal wetlands habitat (Zedler 1991). Thus, it is a valuable indicator of an ecosystem in continual decline. The wandering skipper has been a candidate for endangered status, and was listed in the Federal Register review of endangered or threatened invertebrate species (USFWS 1984).

Black Abalone. Black abalone are found in the intertidal and shallow subtidal of rocky shores from central Oregon to the southern tip of Baja California. Because they are large and easily noticed, they have been collected for food, beginning with the prehistoric coast-dwelling native Americans (Haaker *et al.* 1986). Indian middens along the southern California and Baja California contain great numbers of black abalone shells.

The black abalone population in Southern California has been drastically reduced by commercial and sport harvesting as well as a mysterious "withering syndrome". Abalones also compete with sea urchins (which have increased along the coast) for the same food, brown algae. Collecting of black abalone has been banned in Southern California from Palos Verdes Point to Dana Point and commercial harvesting is prohibited in Santa Monica Bay. The legal harvest size for black abalone is 5 in., but currently very few legal-sized animals are found in Santa Monica Bay (Harris 1992, pers. comm.).

Potential recovery strategies for black abalone include completely closing the fishery for up to five year; continuing research on "withering syndrome" (evidence suggests that other abalone species may also be susceptible); and stricter enforcement of poaching regulations. Transplantion of larval or juvenile abalone onto Santa Monica Bay rocky beaches would not be practical until the cause of the withering syndrome is ascertained and until it can be demonstrated that transplantion actually works.

NATURAL VARIABILITY

Under normal sea conditions, beaches exposed to wave surge erode or accrete in response to changing sea conditions. During winter storm events, beaches erode and sand is transported offshore. The resulting beach and nearshore profile are in equilibrium with the prevailing sea conditions. Typically, winter beaches are characterized by a steep beach face, relatively coarse sediment, and a sea cliff or winter berm (Anikouchine and Sternberg 1973). During summer much of the eroded sands is transported back to the beach by smaller waves (Bascom *et al.* 1980) and the beach profile becomes less steep, with a smaller berm and finer sediments. During a severe storm, there may be insufficient sand on the beach to shape the equilibrium profile, and the upper beach dunes may be eroded to supply sand to the beach and nearshore zone. In winter 1982-83 there were four successive major storms with insufficient time between them for the beach to recover its stable protective profile (Armstrong 1991). Where the continental shelf is steep, waves cannot return sediment back to the beach after a severe storm and permanent erosion results (Woodell and Hollar 1991).

The coastline of Santa Monica Bay is naturally eroding because of the rise in sea level (more than six inches. per century) (Woodell and Hollar 1991). The general long-term trend of shoreline erosion is very irregular and is punctuated by storm events, leading to a gradual, long-term trend of beach erosion. Major storm events during the last century which impacted Santa Monica Bay beaches occurred in 1905, 1915, 1926, 1931, 1939, 1941, 1952-53, 1957-58, 1972-73, 1977-78, 1982-83, and 1988. Recently, it has been recognized that these storms are associated with the El Niño-Southern Oscillation phenomenon.

Rocky intertidal habitats are subject to natural alteration by wave turbulence, inundation by sand, desiccation during hot, dry days, and freshwater dilution during rains. Storm surf damages these areas because they typically take the brunt of breaking waves; small cobbles are hurled about, damaging attached organisms. During winter the rocky intertidal is typically free of sand because beach sand is carried offshore; during summer, rocky intertidal areas may be covered with beach sand which is pushed ashore. Hot, dry weather subjects exposed organisms to desiccation and warms tide pools. During rain, attached organisms may be exposed to freshwater and tidepools may be affected by both freshwater and sediment carried in the runoff waters.

Thus, the abundance of intertidal organisms is expected to vary seasonally and interannually. Catastrophic destruction of individuals and habitat may occur at irregular intervals corresponding to major storms or dry periods. The natural variability of intertidal organisms in the Bay has not been quantified.

SOFT BOTTOM HAITATS

The soft-bottom habitat is by far the most extensive benthic habitat in Santa Monica Bay. Most of the seafloor of the study area consists of unconsolidated (soft) sediments, which consist of mixtures of sand, silt, and clay (Figures 2-3, 3-4). Most of the energy entering this habitat is detrital fallout and phytoplankton from the water column, although detritus from surface runoff and sewage may be important.

ORGANISMS

PLANTS

The few photosynthetic organisms that live on the soft-bottom habitat of the Bay include diatoms, blue-green algae, green algae, and flagellates which attach to sand grains or move about on the surface of the sediments. These are most abundant on the inner shelf, at depths of less than 30 feet, where sufficient light reaches the bottom (Round and Hickman 1971). A few green, filamentous red, and small brown algae attach to worm tubes and cobbles on the bottom; these have the same light requirements as the one-celled plants and only occur in shallow water.

MEIOFAUNA

The meiofauna are the smallest (less than 0.5 mm in one dimension) infauna. Meiofauna (organisms which live in the sediments) includes small organisms such as one-celled protozoans, small roundworms (nematodes), small polychaetes and oligochaetes, copepods, gastrotrichs, flatworms, kinorhynchs, and tardigrades. These organisms are dense in aerobic sediments throughout the year, feeding on bacteria, one-celled plants, detritus, and other meiofauna. The meiofauna of the Bay has not been well studied, but organically-enriched sediments generally have higher proportions of nematodes and oligochaetes than normal sediments.

MACROFAUNA

The invertebrate macrofauna which are less than about 0.5 in. in one dimension are the dominant members of the soft-bottom infauna. The soft-bottom habitat of the shelf supports an extremely diverse (numbers of different species) and abundant (numbers of individuals) infauna. As many as 1,200 infaunal species have been reported from Santa Monica Bay (Dorsey 1988). Samples from uncontaminated sediments along the 200-feet isobath in the Bight averaged 71 species and 423 individuals in 0.1 m^2 of bottom sediment. However, because these animals are usually quite small, the biomass is small averaging 7.0 g/0.1 m^2 (Word and Mearns 1979). These values vary with depth and sediment type.

The infauna is usually dominated, in numbers of species and numbers of individuals, by polychaete worms. Polychaetes are soft-bodied, and may be free moving or sedentary. The free-moving ones generally crawl along the surface or burrow through the soft sediments like earthworms; sedentary forms move, but usually within a tube which they construct in or on the sediments. Most soft-bottom polychaetes feed on the bottom, engulfing sediments and digesting off the attached bacteria, or filter feed on bits of organic detritus in the water. A few polychaetes are predatory, feeding on other infauna. Polychaetes are important constituents in the diet of many demersal fish and are important in reworking (bioturbating) the sediments.

Crustaceans are usually the second most diverse and abundant group of soft-bottom infauna. Among this group of animals, amphipods are the most common, but others such as cumaceans, isopods, and ostracods are also important. Some species of amphipods and all of the benthic cumaceans and ostracods burrow in the sediments; some amphipods live in tubes while others, hide among debris. All of these crustaceans brood their eggs and hence do not have pelagic larvae; the males of many amphipods, cumaceans, and ostracods migrate up into the water column at night. Some crustaceans filter plankton and detritus from the water column and others feed on meiofauna, diatoms, and detritus in or on the sediments. Still others scavenge on dead organisms. Amphipods are particularly important prey for many demersal fishes (Allen 1982).

Mollusks are usually the third most diverse and abundant group of soft-bottom macrofauna. Bivalves (clams, mussels, etc.), snails, and sea slugs make up most of the molluscan portion of the benthos. Most bivalves are infaunal but scallops and mussels are epifaunal. Clams generally filter the water for bacteria, phytoplankton, and detritus but some species engulf sediments as they burrow. Snails and sea slugs tend to scrape material from the sediments or hard surfaces, but many are predatory, preying largely on clams and other snails by drilling holes through their shells.

Echinoderms (especially brittle stars) are also quite abundant and diverse. Brittle stars feed on detritus in the sediments or filter it from the water. Other less common invertebrate groups may be important at particular times or places. For instance, the spoonworm (an echiurid) is occasionally dense in some areas and is important in bioturbating sediments. Many benthic macrofaunal species have do not survive in contaminated areas, even though the sediment texture may be appropriate. Therefore, the benthic community composition differs with the degree of sediment pollution as well as with normal differences in sediment type.

MEGAFAUNA

The soft-bottom, invertebrate megafauna (excluding nektonic forms) of the Bay includes epibenthic sea stars, sea cucumbers, sand dollars, sea urchins, crabs, snails, and sea slugs. Being larger than the macrofauna, these species are less common and are spaced further apart. However, sand dollars and sea urchins often occur in very dense, single-species patches which limit the abundance of other species. Because they are larger, they often comprise the bulk of the biomass in an area. Most of these species feed on detritus and infaunal organisms. Sea cucumbers ingest sediments, sand dollars filter water, and sea urchins feed on detritus. However, moon snails, crabs, and the California sea slug are predatory.

Nektonic megafaunal species swim occasionally, but most spend much of their time on the bottom. Important invertebrate species include octopus, eastern Pacific bobtail (a squid), bay shrimp, ocean shrimp, and ridgeback rock shrimp.

NATURAL VARIABILITY

Sewage was discharged into the study area long before information on the infaunal communities of the area was available. The earliest large scale investigation of the infauna in the area was conducted (in 1952 to 1954) prior to operation of the HTP 5- or 7-mi outfalls. This study (Hartman 1956) did not sample sites off the Palos Verdes Peninsula, but included about 150 samples from the remaining portion of Santa Monica Bay. Six faunal assemblages were recognized, based mainly on physiographic differences in the habitat.

The above study was expanded into a survey of the entire Southern California Bight from 1957 to 1958 (CSWPCB 1959) which included stations on the Palos Verdes Shelf. Analyses of the data from this survey continued for years and these provide a background for impact studies (CSWQCB 1965, Jones 1969).

Historical information on the megafauna of Santa Monica Bay was not collected regularly nor is it comprehensive. The distribution of crabs and shrimp in the area are discussed by Wicksten (1984) on the basis of collections made prior to 1930. Qualitative comparisons of these data with those from 1958 to 1963 (Carlisle 1969) show little change in the species composition of Santa Monica Bay, but provide no information on abundance or fine scale distribution.

The abundance and distribution of individual species of the infauna and megafauna may vary seasonally and interannually, although most accounts of this are in studies concerned with human impacts. Most of this natural variability is difficult to separate from the variability associated with human impacts (Bernstein *et al.* 1984). However, any natural disturbance of the sediments or oceanographic changes, is likely to affect benthic soft-bottom invertebrate populations. For instance, a change in the species composition of the inshore megafauna assemblage of the Bight occurred after 1981, perhaps as a result of the 1982-1983 El Niño or because of severe winter storms in 1983 (SCCWRP 1986e). These events may also have been important in changing the composition of the infauna assemblages off Palos Verdes during this period (Swartz *et al.* 1986).

HARD BOTTOM HABITATS

Hard-bottom substrate includes natural hard bottom and artificial structures. Natural hard bottom substrates may be formed by rock or animals, such as Sabellarid worms which form tubes of cemented sand grains. Artificial structures include outfall pipes, artificial reefs, jetties, groins, and piers. Hard-bottom habitats have a diverse and abundant assemblage of organisms that are often unique to the habitat. Reefs provide forage, shelter, and nesting sites for many animals. Hard-bottom in the photic zone is generally dominated by algal growth whereas that in deep water lacks algae altogether. Nearshore reefs may also provide habitat for giant kelp, which in turn provides habitat an additional diverse assemblage of organisms. Because of the diverse and abundant assemblage of unique organisms, reefs are important sites for recreational diving and fishing.

The rocky subtidal bottom off the Palos Verdes Peninsula is composed of sedimentary strata. Shale boulders and shelves are often isolated by reaches of sand and cobble. Reefs are more diverse, with two to four times higher vertical relief on the western side of the peninsula. The eastern rocky subtidal (36-54 ft depth) is characterized by greater water turbidity and associated bottom sediment derived from the Portuguese Bend landslide. Most rock substrate is covered by a 1-2 cm layer of fine grained material and the surrounding soft bottom channels may have up to 20 cm of this sediment (Stull 1993, pers. comm.).

ORGANISMS

PLANTS

Although, hard bottoms support diatoms and other one-celled plants, they are distinguished for their growth of kelps and other macroalgae. Macroalgae are anchored to the bottom with a root-like structure called a holdfast and reproduce in a complex system which produces both spore and gamete stages. In the study area macroalgae are only abundant along the Carillo and Malibu coasts, the Palos Verdes Peninsula, and artificial structures along the shore.

The major plants of the rocky subtidal in Santa Monica Bay are red and brown algae. Typically, the red algae form a low turf or understory of coralline, foliose, and filamentous forms from shore to the edge of the photic zone. Brown algae are generally larger and form an overstory; locally the feather-boa kelp is dominant nearshore while giant kelp dominates deeper areas of a reef (Quast 1968).

INVERTEBRATES

Hard-bottom invertebrates include sessile and motile forms. Sessile forms are firmly attached to the surface of the rocks whereas motile forms move about on the reef or swim near the reef. Most hard-bottom invertebrates have planktonic larvae, although some amphipods and isopods brood eggs and larvae; sea squirts and sea anemones also reproduce asexually to form colonies.

The most obvious forms on this habitat are sessile species: mussels, barnacles, sponges, sea anemones, sea fans, tube worms, and sea squirts. Date mussels and piddock clams actually burrow into the rocks. Most of the sessile invertebrates feed by filtering plankton and detritus from the passing water mass. They are generally less abundant where macroalgae cover is high but are the dominant organisms elsewhere.

Most of motile invertebrates hide in crevices in the habitat or are protectively colored. Large species include abalone and other snails, octopus, shrimp, lobsters, and crabs. Smaller species include polychaetes, bivalves, snails, amphipods, and isopods. A variety of small motile forms live in and among the bases of the relatively large sessile species. Among the motile forms, abalone feed on drift kelp while sea urchins graze on macrophytes and diatoms. Many of the small crustaceans (amphipods, isopods, shrimp) eat algae but crabs, shrimp, lobsters, snails, sea slugs, polychaetes, and sea stars are carnivorous or omnivorous.

Abalone, California spiny lobster, yellow rock crab, Pacific rock crab, red sea urchin, and Pacific purple urchin are fished recreationally in shallow water and spot shrimp in deep water.

NATURAL VARIATION

Natural variations in the plant and invertebrate populations of subtidal hard-bottom areas occurs seasonally (particularly in shallow water) and during El Niño periods but these have not been well documented in the Bay. Studies of artificial reefs in the Bay indicate that the plant and invertebrate assemblages on newly-exposed hard substrates undergo a succession in dominant species and area coverage of epifaunal growth with increasing time (Carlisle *et al.* 1964). A red tide which occurred from San Luis Obispo to the Los Angeles Harbor in 1945 killed California spiny lobster and sheep crab, both hard-bottom species (Sommer and Clark 1946).

Additional factors which affect the shallow habitat include turbidity, sea urchin predation, water movement, temperature, and inundation by sand. Changes in the biota of a shallow reef may be seasonal or long-term. Turbidity and sea urchin predation reduce the algal growth whereas the turbulence, scouring, and inundation by sand affects the suitability of the habitat for sessile and crevice-seeking species. Seasonal changes are caused by differences in light intensity and temperature, which affect photosynthesis and may trigger spawning in a variety of organisms.

Annual inundation by sand is common in shallow areas; it may smother the existing biota, resulting in a bare surface when the sand is gone. As a newly exposed hard surface appears, the process of succession, from small sessile forms to a dense cover of macroalgae and mussels begins. Thus, shallow reefs may be almost constantly in an early state of development.

KELP BEDS

Kelp beds are associated with the hard-bottom habitat. However, most hard bottom in the Bay is of low relief and the presence of kelp extends this relief to the sea surface. Giant kelp is probably the best known of the macroalgae. It generally grows on hard, subtidal bottoms at depths of 20 to 70 feet, where the water is clear (Abbott and Hollenberg 1976). More than other macroalgae, giant kelp becomes a part of the habitat, providing food, shelter, nursery, or a point of reference for invertebrates and fishes.

Giant kelp is harvested to produce compounds such as algin, which is used in the manufacture of ice cream, cosmetics, and many other commodities. Kelp beds are also important for sport fishing, commercial harvesting of abalone and sea urchins, and recreational diving (North and Hubbs 1968).

Giant kelp has a complex life history which is normally completed in 12 to 14 months (Neushul and Haxo 1968). The mature kelp plant (a sporophyte) produces spores which are shed into the water column. When the spores settle and survive, they develop into a microscopic plant (a gametophyte) which produces eggs and sperm. The eggs and sperm unite to form a young sporophyte which grows to become a mature kelp plant. Kelp may live for more than five years (North 1968) and may grow as much as 12 to 20 inches per day, making it among the fastest growing plants known.

Mature giant kelp consists of a root-like holdfast, the stem-like stipes, and leaf-like blades. Gas-filled bladders at the base of each blade buoy up the plant, keeping the blades near the surface where light levels are maximal.

Giant kelp is found in the northeastern Pacific from Alaska to southern Baja California (Abbott and Hollenberg 1976). Not only are there replacement species along this latitudinal and temperature gradient, but within species there are strains which are adapted to particular temperature ranges. At present and in the recent past, giant kelp in Santa Monica Bay has been limited to rocky bottoms along Leo Carillo beach and the Malibu coast and along Palos Verdes Shelf (Figure 3-4).

The cover provided by California kelp beds provide protection and habitat for more of than 800 species of fishes and invertebrates, some of which are uniquely adapted for life in the beds. When kelp is absent from a reef, many of the associated invertebrates and fishes are also lacking.

ORGANISMS

PLANTS

Many other algae associate with giant kelp, adding to the complexity and productivity of the habitat. These shrub or understory algae are similar to those found in other rocky bottoms at similar depths and include foliose, filamentous, and coralline red algae, smaller kelps and brown algae, and some green algae. In a dense bed, the canopy of kelp blades can actually limit the amount of light reaching the bottom so that understory algae (especially turf species) are less abundant. Feather-boa kelp is sometimes found on the inshore side of giant kelp, thus extending the bed shoreward (North 1976).

INVERTEBRATES

The invertebrates found in kelp beds are similar to those found on hard-bottom environments without kelp. Because turf algae is often lacking, encrusting animals such as sponges, hydroids, sea fans, moss animals, and tunicates are more abundant. Pink abalone and California spiny lobster are often common in kelp beds, and red sea urchins and Pacific purple urchins are generally present. Several sponges, sea stars, and snails are unique to the holdfasts of giant kelp, as are file shells and warty sea cucumbers (Limbaugh 1955).

Kelp fronds become senile in about six months and individual blades deteriorate in one or two months; therefore, long-lived encrusting organisms like mussels and barnacles do not develop on them. However, some encrusting moss animals settle and form flat, white colonies that can completely cover a blade in three weeks. Broadtail isopods, carinate dovesnails, and kelp scallops are common on the stipes and many other invertebrates are found on the blades, though not exclusively (Limbaugh 1955).

NATURAL VARIABILITY

The history of kelp beds in the study area can be traced from records dating to 1911. Because kelp beds are licensed for harvesting each year they have been numbered by the California Department of Fish and Game (CDFG), which manages the resource (Figure 3-5). Beds 11, 12, 13, and 14 are located along the Palos Verdes Peninsula, between Point Fermin and Lunada Bay. Giant kelp has not been dense in this century along the sandy, central portion of Santa Monica Bay, although individual plants may have grounded there or grown on temporarily exposed rocks. Beds 15 and 16 are located between Santa Monica and Point Dume; Bed 16 is in the Mugu-Latigo Area of Special Biological Significance (CSWQCB 1979). In the early part of this century, the Malibu coast beds extended from Point Dume to Santa Monica Canyon (Ulrey and Greeley 1928), but they now extend from Point Dume to Malibu.

From 1940 through 1974, the general trend in giant kelp was one of decline and appears to have been centered on the White Point outfall (North 1968). By 1959, following the strong El Niño Event of 1957 and 1958, kelp was almost completely gone; only small patches remained in Abalone Cove and at Portuguese Bend. By the fall of 1968 the last of these

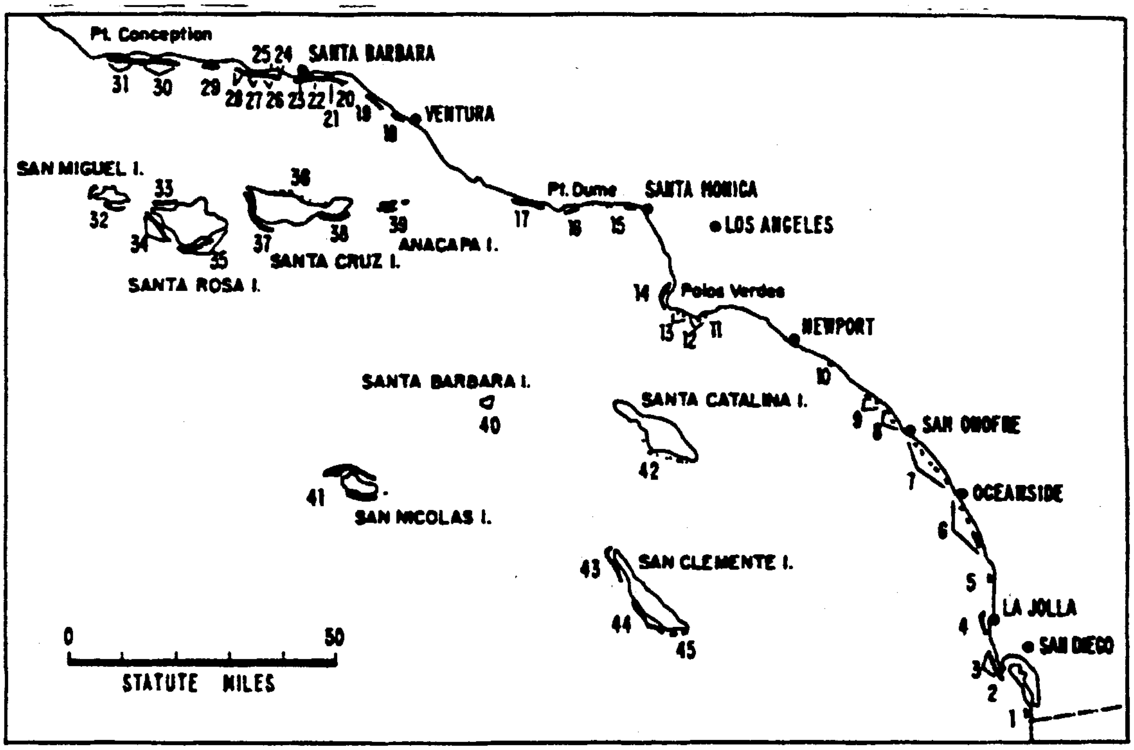


Figure 3-5. Kelp bed designations by the CDFG (CSWQCB 1964).

plants had perished (North 1970) and only transplanted kelp remained. Efforts to re-establish the Palos Verdes beds had begun in June 1967, initially with little success. During 1950-1960 as a result of increased urbanization, the marine environment became the disposal site for industrial and domestic waste. A decline in the size and number of productive kelp forests was documented during this time (Carter *et al.* 1985).

Between 1970 and 1977, the CDFG attempted to restart kelp at nine separate sites along the Palos Verdes Peninsula (Wilson *et al.* 1977). By 1975, kelp was thriving in Abalone Cove and was redeveloping in Bluff Cove (Figure 3-6). The total canopy area in 1982 was nearly what it was in the mid-1940s; it continued increasing, reaching a peak off Palos Verdes in mid-1987 which was 36% greater than recorded in 1911 (Neushul 1981). Kelp acreage was still high (617 acres) in early January 1988 (CDFG unpubl. data), but as in 1983, storms in mid-January decimated the bed, severly reducing canopy cover. Storm decimation of the beds is a natural, ephemeral event with active regrowth following.

The history of Beds 15 and 16 in the western part of the Bay is not as well documented. Bed 15 (Figure 3-5) covered 182 acres in 1911 but has had a maximum canopy of seven acres since 1955 (Neushul 1981). Between 1930 and 1980, the average cover was about five acres but kelp was often altogether absent (Harger 1983). Bed 16 in Paradise Cove is much larger and has been present continuously. In 1911, it covered 376 acres, but between 1959 and 1979 never exceeded 222 acres (Neushul 1981).

CAUSES OF NATURAL VARIABILITY

The reasons for fluctuations in kelp bed canopy area and in health of the plants have been studied and argued for decades. Over-harvesting, recreational boating, waste discharge, storms, oil spills, turbidity, and warm water have all been identified as contributing to the disappearance or decline in kelp. To date no single cause has been identified and the luxuriant regrowth of kelp in areas from which it had disappeared has reassured many that declines are reversible. Many factors appear involved in the success or failure of any particular kelp bed, and neither natural nor contaminant related causes are of overwhelming importance.

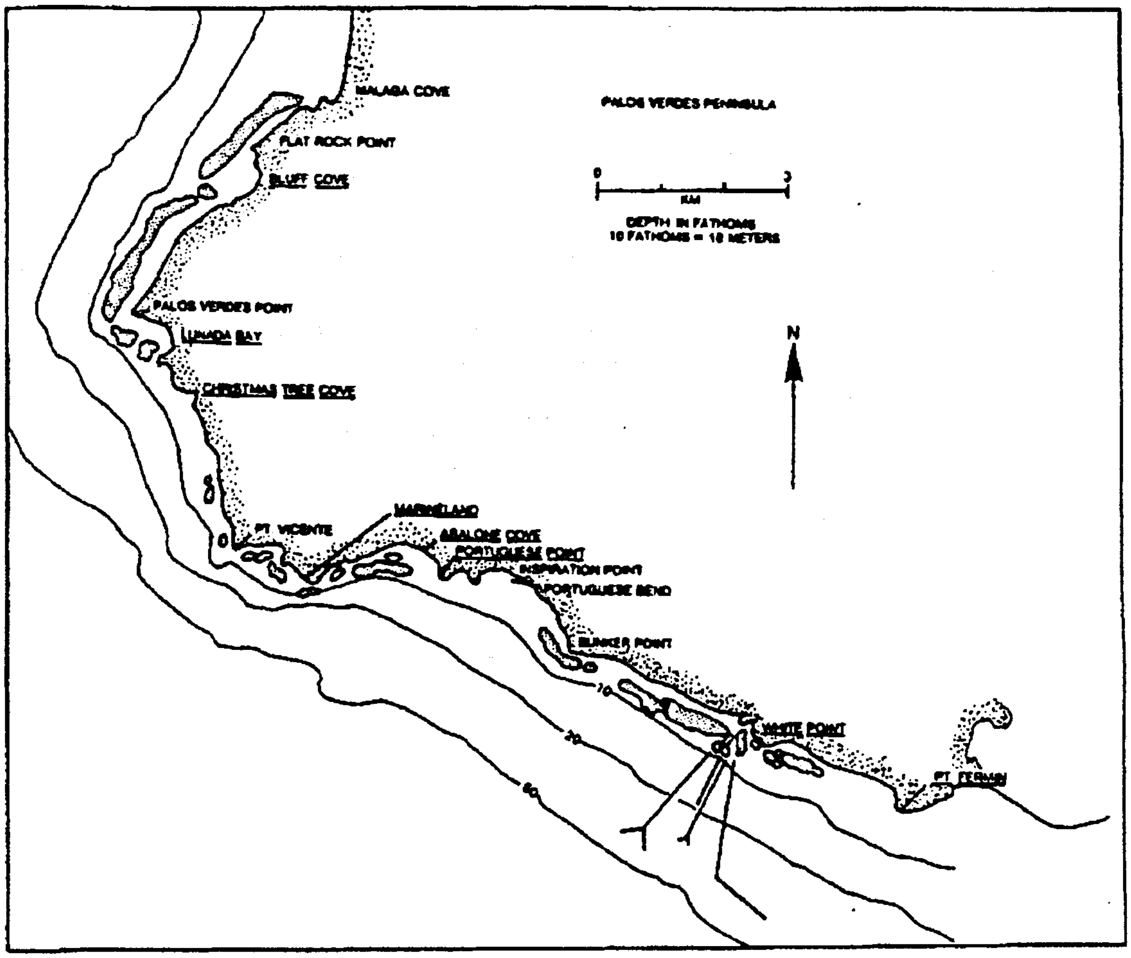


Figure 3-6. The kelp beds along Palos Verdes Peninsula in 1982 (MBC 1988).

Nutrient availability and storms seem to be the major natural factors which influence the health and survival of kelp. For a long time it was thought that warm summer temperatures and warm El Niño events caused the deterioration of giant kelp fronds. However, evidence indicates that lack of nutrients rather than warm temperature causes the summer degeneration (North 1983). The complicating factor is that in summer a density gradient (pycnocline) forms in nearshore waters, preventing nutrients (either natural or from sewage) from reaching surface waters. Thus, there may be both a yearly cycle in canopy extent and an irregular multi-year cycle which reflects El Niño influence.

Although low nutrient levels reduce canopy cover, they seldom result in the death of the plant. However, storms frequently do lead to complete loss of kelp. Whole beds may be uprooted during major storms and cast on or off shore. During the storms of winter 1987-1988 most kelp in the study area was lost. This repeated the 1983 winter storm decimation of beds in the study area (Wilson and Togstad 1983), and throughout Southern California (Dayton and Tegner 1984) In both cases, high levels of growth followed.

Natural turbidity may also be important. Turbidity reduces light levels reaching the bottom and hence reduces plant growth. In addition, sediments settling to the bottom from turbid water may smother young plants or make the bottom unsuitable for settlement of sporophytes. Turbidity in near-bottom waters is greater in the eastern area of the peninsula primarily due to sediments from the Portuguese Bend landslide (Stull 1993, pers. comm.). Since 1980 the landslide at Portuguese Bend has supplied more than seven times the suspended solids than the JWPCP outfall (SDWG 1988) and may have reduced kelp beds in the immediate area.

UNIQUE AREAS AND HABITATS

There are several unique habitats within Santa Monica Bay; these areas include Torrance Beach, Marina del Rey, and Short Bank. The shallow nearshore protected areas of the Bay (e.g., Torrance Beach, Redondo Beach) serve as important nurseries for local marine fishes (e.g., juvenile California halibut, juvenile white seabass), comparable to the productive estuaries of the East Coast (Barnett 1984). Marina del Rey (and King Harbor) are artificially deepened calm areas; Marina del Rey also has Estuarine organisms. Short Bank is the only naturally occurring deep rocky area in Santa Monica Bay with a thriving population of several rockfish species and invertebrates.

Several areas within SMB had been recommended for consideration as potential "Ecological Reserves." There are only two areas within SMB that provide rocky bottom habitat, Palos Verdes Peninsula (from Palos Verdes Point to Flat Rock Point) and Malibu (from Point Dume to Paradise Cove). Los Angeles County has designated these sites as "significant ecological areas." These areas along the coast provide important habitat for many species of fish, marine mammals, and birds. These areas also serve as important habitats for the recruitment of various fish species taken by sport anglers as a result of kelp beds located offshore of these sites.

The marine habitat north of Point Dume up to the Ventura County line is considered an area of biological significance by the California State Ocean Plan; therefore no discharge of municipal waste or thermal effluent should be discharged in that area.

4

HUMAN POPULATION

CHAPTER 4
THE HUMAN POPULATION

During the last ice age (about 18,000 years ago) sea level was about 384 ft lower than at present (Nardin *et al.* 1981) and the continental shelf of Santa Monica Bay (which is presently submerged) would have been dry land and beach, probably backed by steep cliffs and rocky shores. Much of the land behind these cliffs was a broad, flat plain; Ballona Creek probably extended across this plain to enter what is now Redondo Submarine Canyon.

The land around Santa Monica Bay would have resembled that presently found near Monterey California, with forests of cypress and pine near the coast, brush and grasslands more inland, and riparian forests along the Ballona Creek drainage. In addition to the mammals and birds, which are still present, the area supported species which have since become extinct — mammoths, mastodons, giant ground sloths, sabertooth tigers, camels, and llamas.

Smoke from brush fires would have lingered in the valleys as "smog" and fallout from them would have contributed the same kind of "background" materials as they do today. The offshore oil seeps of today may have constituted tarpits near the mouth of Ballona Creek (at what is now Redondo Submarine Canyon). The sea was cooler and populated by marine life more typical of cooler waters than at present, and probably more abundant.

Sea level gradually rose, covering previously dry land, until the present sea level and coastline were attained about 3,000 years ago. Sandy beaches were the predominant shoreline during this period as the sea gradually progressed to higher levels across the plain; sea temperatures increased and the climate became warmer and drier.

THE NATIVE AMERICAN PERIOD

The earliest record of native Americans in the area is from about 6,000 years ago at Malaga Cove, although they were probably present much earlier (Reiter 1984). From 6,000 years ago to the 1700s, the area was populated largely by Indians with a hunting and gathering economy that emphasized plant foods such as seeds and acorns. Those living near the shore relied heavily on marine life for food.

Northern anchovy were more abundant, and large fishes, sea birds, and marine mammals which prey on anchovy may have been more abundant than at present (Soutar and Isaacs 1969). Hunting and fishing pressure increased with the native population and began to impact the plants and animals of the watershed, wetlands, and Bay. Some larger mammals may have been hunted to extinction and the food organisms along the shore were also probably impacted (Reiter 1984).

Although intermittent Spanish contact with the Indians occurred during the Cabrillo expedition of 1542 and the Vizcaino expedition of 1602, it was not until the late 1700s that the Venturano Chumash, Gabrieleño, and Fernandeño Indians of the Santa Monica Bay watershed area had sustained contact with white men. The Gabrieleños lived from the Santa Monica Mountains south to the Aliso Creek Drainage in Orange County. The Fernandeños occupied the San Fernando Valley and the Santa Monica Mountains from the Topanga Canyon watershed east. The Venturaño Chumash were found west of the Topanga Canyon watershed to Ventura and inland to the Thousand Oaks area (Kroeber 1925). The entire Chumash population probably never exceeded 15,000 (Green 1980); less is known of the Gabrieleños, although their entire population was less than 5,000 in 1770 (Johnston 1962).

Early Spanish and Mexican navigators had passed Santa Monica Bay, but did not land, possibly because they did not see the Indians' huts and the coves did not appear suitable for anchoring. Inland journeys of 1769 and 1774 also by-passed the coastal areas occupied by the Chumash, although they encountered some inland Gabrieleños settlements. Chumash villages were at the mouths of canyons (Robinson 1959); a Venturaño Chumash village named Maliwu was located near the present city of Malibu, which took its name from this village (Kroeber 1925, Johnston 1962). Gabrieleño villages were located throughout the Los Angeles Coastal Plain. Their villages were generally located on bluffs overlooking rivers or wetlands, some being located at Santa Monica (Kuruvangna), Los Angeles (Wenot), Culver City (Sa'angna), Redondo Beach (Engnovangna), and Palos Verdes Peninsula (Masau) (Kroeber 1925, Johnston 1962). In the late 1700s the Chumash Indians moved further inland using trails forged by explorers who had landed further north (Robinson 1959).

Little is known of the Venturaño Chumash, Fernandeño , or Gabrieleño Indians; their tribal names are unknown and their current names are derived from their later association with missions in the area San Buenaventura, San Fernando, and San Gabriel Mission (Kroeber 1925; Reiter 1984). Acorns were the staple food of all three tribes, but other plants and animals were also eaten. Coastal Chumash and Gabrieleños were skilled fishermen, the former using plank canoes and the latter using boats of made of rushes and tules. They fished for Pacific sardine, California halibut, lingcod, and tunas; hunted marine mammals such as dolphins, sea lions, seals, and sea otters; and gathered shellfish from the intertidal zone. In inland areas, they hunted deer, rabbits, and other small mammals (Johnston 1962). Indians made use of beach tar to waterproof their baskets and caulk their canoes.

SPANISH/MEXICAN PERIOD

The influx of Europeans in the late 1700s marked the beginning of the end of native Americans in the Los Angeles area. The Spanish occupation began in 1769 with the Portola expedition which founded Franciscan missions throughout California, the first being San Gabriel mission in 1771 (Josselyn *et al.* 1992). The missionaries encouraged the Indians to give up their traditional lifestyle and to live at the coastal missions but the stress of the mission routines and exposure to new diseases only hastened their demise. Some women practiced voluntary abortion rather than have their children grow up under such conditions (Robinson 1959). As the numbers of European and Mexican settlers increased, many natives deserted the area, and by 1852 there were approximately 3,700 "domesticated" Indians and 4,000 Europeans in southern California (Green 1980).

Several of the early explorers settled and purchased land in the Santa Monica Bay area. In 1775 Jose Bartolame arrived in Malibu with 240 colonists from Sonora, Mexico (Robinson 1959). He had a Spanish land grant for 13,000 acres which he called the Rancho Topanga Malibu Sequit and which was used primarily for cattle grazing. Bartolame cultivated a small area, planted a vineyard and cornfield, and built a mill, but after gold was discovered in the Sierra foothills in 1848, he sold Rancho Topanga. The three subsequent owners were a Frenchman, an Irishman, and a Puritan from New England who continued to raise cattle, the leading industry at the time.

In Santa Monica, Francisco Sepulveda purchased the majority of the land for cattle grazing (Robinson 1959). Other ranchos in the area included Rancho San Vicente y Santa Monica at Santa Monica, Rancho Rodeo de las Aguas at Beverly Hills, Rancho Ballona at Ballona Creek, and Rancho Sausal Redondo at Hermosa Beach (Josselyn *et al.* 1992).

From the mid-1700s to the mid-1800s, inland vegetation was altered. Coastal scrub was converted to grassland as a result of burning and grazing (Johnston 1962). Smoke levels probably increased and bacteria from livestock entered streams draining to the sea. Without the Indians, intertidal organisms may have received a brief respite from fishing pressure, as the Europeans focused on fish, whales, and game. However, fishing and hunting pressure increased with firearms and better fishing methods, with marine mammals, seabirds, and water fowl probably the most affected (MBC 1988).

Although they occurred throughout history, major storms were first recorded in the 1800s. Storms from the southeast were common in the early 1800s and they often generated waves to 40 feet or higher (Kuhn and Shepard 1981).

EARLY STATEHOOD: 1850 TO 1899

In 1850, California became the 31st State. The collection of warm-water fish species in southern California in the 1850s suggest that El Niño events occurred during this time (Hubbs 1949). Extremely heavy rain fell in 1862 and from 1884 to 1891, causing the Los Angeles River to shift course between Ballona Creek and San Pedro (Kuhn and Shepard 1981). These storms probably affected beach erosion, offshore sedimentation, and coastal turbidity for months (MBC 1988).

Between 1864 and 1885, a whaling station was operated at Portuguese Bend (Sayers 1984) and by 1879 commercial and sport fishing had begun in Santa Monica Bay. Commercial landings at Los Angeles were dominated by pelagic and nearshore fishes (Jordan 1887).

Through the early 1870s, the Santa Monica Bay region was largely open land used for cattle grazing, and very few Americans held land in the area. In 1872, 38,000 acres of Spanish Ranchos were purchased by New Englander Robert Baker, who hoped to develop a railroad terminus and shipping port. In 1875, when the local population was about 1,000, Baker sold two-thirds of his land to Senator John P. Jones of Nevada, who wanted to build a railroad to transport silver to ocean ports (Ingersoll 1908). Shortly thereafter the population began to grow, out of interest in Jones' plans and the emerging popularity of the area as an ocean resort. By 1877, the Comstock Crash forced Jones to sell the Los Angeles and Independence Railroad to Collis Huntington. The large ranchos were subdivided and sold to easterners and property values began to rise.

In 1878, the Southern Pacific Railroad dismantled the Santa Monica wharf, whereupon business declined. Santa Monica attempted to offset the loss of railroad and wharf resources by promoting its image as an ocean resort. This image was enhanced in 1886 with the construction of the luxurious Arcadia Hotel, which attracted people from all over the world. Santa Monica was also convenient for residents of Los Angeles and increasing numbers of people moved to Santa Monica and commuted to jobs in Los Angeles.

In 1891, Collis Huntington built a larger wharf in Santa Monica, intending to regain the shipping trade. Santa Monica and San Pedro vied for over five years as the location of a deep water port for the Los Angeles area, as the region had no natural harbor. The selected city would receive $3 million in federal funds to construct the new port. The Free Harbor League, an association of 400 members, supported San Pedro as the port site. Both public officials and private citizens feared that if located at Santa Monica, Collis Huntington and his Southern Pacific Railroad would dominate the port and form a monopoly. In 1897, the Army Board of Engineers selected San Pedro because it was better protected from winds, storms, and prevailing westerly swells (Marquez 1975).

By 1897, the population of Santa Monica had grown to approximately 2,000 people, twice that of 1875. With hopes of a shipping industry shattered, Santa Monica residents and entrepreneurs again tried to develop tourist and recreational opportunities. Since then, there has been opposition to large-scale industrial development (McQueen 1979).

1900 TO WORLD WAR II

The period from 1900 to 1920, was one of rapid population growth. Increases were especially pronounced between 1900 and 1905, when the population increased from 3,057 to 7,208 (136%), and again between 1910 and 1920, when it nearly doubled, from 8,700 to 15,000. These increases set the stage for dramatic regional growth and development between 1920 and World War II.

Establishment of the Douglas Aircraft Company (DAC) in the 1920s opened a new era for the Los Angeles area. Donald Douglas had moved to Santa Monica from the east coast to raise his children and to establish his own aircraft manufacturing company. With financing from David R. Davis, Douglas began work on an airplane which could fly coast to coast nonstop. With east coast associates, Douglas and his company received its first formal contract from the Navy in 1921. Douglas also secured the signatures of ten prominent Los Angeles businessmen on a $15,000 promissory note (Maynard 1962), and as the company grew, Douglas moved first to an abandoned movie studio in Santa Monica and in 1929 to Clover Field. The number of DAC employees increased from 20 in 1922 to 112 in 1924 (Maynard 1962) and at its wartime peak in 1944 DAC employed 160,000 persons in six plants. The firm manufactured 16% of all aircraft built in the U.S. between 1942 and 1945. Three of Douglas' plants closed in 1946, bringing employment down to 27,000, although there was an increase in sales during the Korean conflict in the 1950s. In the 1960s most of the company's operations were relocated to Long Beach.

The population of Santa Monica continued to grow substantially during this period, increasing from 15,000 to 37,000 between 1920 to 1930 (147%), from 37,500 to 53,000 (41%) between 1930 and 1940, and from 53,500 to 72,000 between 1940 and 1950 (35%) (USBC 1890-1970).

WORLD WAR II TO PRESENT

CITY OF SANTA MONICA

The population of Santa Monica has increased dramatically since 1910 but the rate of increase was less after 1960 (Figure 4-1). In 1949, Santa Monica was characterized as a middle class community with a moderate degree of urbanization and little ethnic and social integration (McQueen 1979). Between 1950 and 1958, the population increased to 78,000, but residents were predominantly white, native-born American citizens. Ten percent of the population were foreign-born residents and 5% were non-white, predominantly black (90%) and Hispanic.

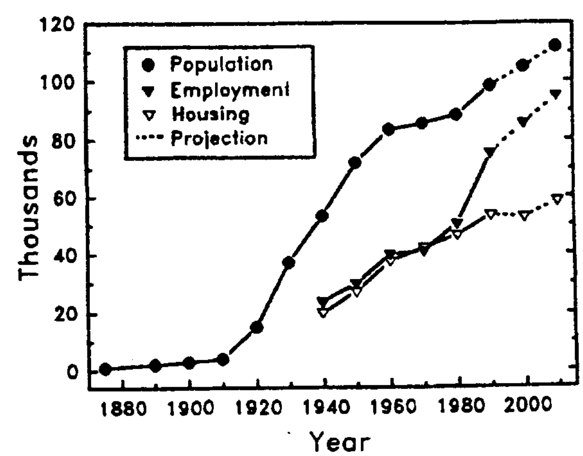


Figure 4-1. Population, housing, and employment trends in Santa Monica 1875 - 2010 (data from MBC 1988, SCAG 1991); USCB 1940, 1950, 1960, 1970, 1980, 1990).

By 1990, the population of Santa Monica (including the City of Malibu) had increased to 98,388, 75% of whom were white, 14% Hispanic, 6.2% Asian, and 4.3% black. The median age of the residents was 37.9 years, significantly higher than the statewide median of 31.5. Santa Monica is home to a number of retired and senior citizens, 20.8% of whom are over 60 years old. Employment in Santa Monica increased dramatically between 1980 and 1990 (Figure 4-1) (MBC 1988; SCAG 1991). In 1990 18.6% of the employed residents were in managerial, executive, and administrative positions (USBC 1990; CSM,PPD unpubl. data)

The income of Santa Monicans is also higher than the statewide average: in 1990 the mean household income in Santa Monica was $55,522, 20% higher than the state mean of $46,247. The number of housing units has increased at a slower rate than that of population or employment (Figure 4-1) (MBC 1988; SCAG 1991). Most Santa Monica residents rent; in 1990 only 26% of the 47,753 housing units in Santa Monica were owned by the occupant (USBC 1990; CSM,PPD unpubl. data). Rent control ordinances enacted in the 1980s have stabilized housing costs and apparently residents are reluctant to relocate from their current, low-cost homes.

Santa Monica continues to grow: the population is expected to increase 20% between 1990 and 2000 to approximately 104,683 persons (Figure 4-1) (USBC 1940, 1950, 1960, 1970; MBC 1988; SCAG 1991). A large percentage of residents continue to hold managerial, administrative and professional positions, but retail positions account for 13.6% of total employment (USBC 1990; CSM,PPD unpubl. data). The predominant land use is residential (61%), followed by commercial (22%), and industrial (6%) (Table 1-3) (SCAG 1992a). The tendency to keep industry to a minimum is still apparent: in 1991 9.8 million ft^2 were in commercial use and only 1.7 million ft^2 in industrial use (CSM 1991).

LOS ANGELES COUNTY

In the past decade, many Los Angeles area businesses and industries have been bought by out-of-state and foreign companies. For example, in 1987 Pacific Southwest, Western, and Aircal airlines were taken over by U.S. Airgroup of Washington D.C., Delta of Atlanta, and American of Dallas, respectively. As of September 1992, 45.8% of the large downtown office buildings were foreign-owned (Cushman Realty Corp. 1992).

Trade is a major factor in this trend. The Ports of Los Angeles and Long Beach (located just outside the study area in San Pedro Bay) constitute the fastest growing major cargo center in the world. The value of import-export cargo going through the Ports increased from $35.4 billion in 1983 to $56.2 billion in 1985, and from $61.8 billion in 1986 to $1 trillion in 1990 (Leinberger 1988, Journal of Commerce 1990).

The population of Los Angeles County has increased rapidly since 1920 (Figure 4-2) (MBC 1988, SCAG 1991). As of 1990 Los Angeles County had a population of 8,863,164 (Figure 4-2), 57% of whom were white, 32% foreign-born, and approximately 11% black. Twenty-two percent of the residents were over 60 years (up from 13.3% in 1970) and the median age of 30.7 was very close to the statewide median of 31.5 years. Employment in the County has increased steadily, but at a lower rate in 1980-1990 than the population (Figure 4-2) (MBC 1988, SCAG 1991). The mean household income of Los Angeles County was $47,252, comparable to the statewide mean of $46,247 (USBC 1990).

The number of housing units in Los Angeles County has increased steadily since 1920, but at a much lower rate than either the population or employment (Figure 4-2) (MBC 1988, SCAG 1991). Los Angeles has a young homeowners market; 32% of households are headed by people under the age of 35, compared to 29% nationally. The national average for households with a college degree is 21%; Los Angeles is slightly higher with 24%. Managerial and professional positions are held by 27.5% of employed residents, while technical, administrative, and sales positions account for 32.3% (USBC 1990).

FUTURE PROJECTIONS

The population of Los Angeles County is projected to increase by 2,514,032 or 28.3% between 1990 and 2010, an annual increase of 125,701 residents per year (Figure 4-2) (MBC 1988, SCAG 1991).

Housing in Los Angeles County is projected to increase by 879,538 units or 27.8% between 1990 and 2010, an increase which is close to the 28.3% increase projected for the population as a whole (Figure 4-2) (SCAG 1991).

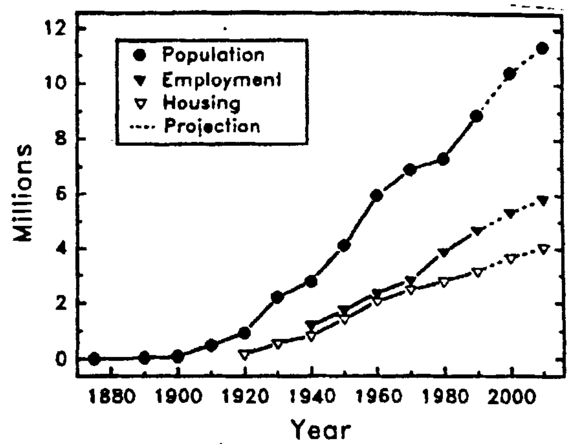


Figure 4-2. Population, housing, and employment trends in Los Angeles County, 1875 - 2010 (data from MBC 1988, SCAG 1991).

The three basic components of population dynamics are births, deaths, and net migration. The first two components make up natural increases; net migration can be further separated into domestic migration (people moving to and from other parts of the nation) and foreign migration (including both legal and illegal immigration).

Immigration to California from elsewhere in the United States has eased due to the economy. In Los Angeles County there is an emigration of residents to surrounding counties. The major unknown is the rate of undocumented immigration from Mexico into Southern California. In 1991, 539,436 aliens were apprehended at the San Diego Zone of the Mexican border. The general rule is that for every apprehension at least two people enter the United States (Economic Development Corporation 1992).

Employment in Los Angeles County is projected to increase by approximately 1.2 million employees (25%) between 1990 and 2010 (Figure 4-2) In recent years Southern California has been shifting from a goods-producing, manufacturing economy into an information-based service economy. In 1991, the largest industry in the five-county Los Angeles area was business and management services (Calif. Employment Development Department 1992). The trend toward a service-based economy is expected to continue through the 1990s, the moderate between 2000 and 2010.

POINT SOURCES OF CONTAMINATION

5

CHAPTER 5
POINT SOURCES OF CONTAMINATION

GENERAL CONSIDERATIONS

Numerous substances enter the waters of Santa Monica Bay via a variety of pathways. Some of these substances are neutral, some are beneficial, and some are detrimental to the Bay's environment. Some may not be particularly harmful alone but may have harmful synergistic effects when found with other substances. Those which have harmful effects on the ecosystem or on human health are generally considered to be contaminants or pollutants. "Pollutant:" is often applied to contaminants resulting from human activities. The two terms, "contaminants on human health and on the ecosystem are discussed in subsequent chapters.

The point at which a body of water becomes contaminated differs for each contaminant and impact of concern (e.g., marine life, human health). The critical level for each contaminant is generally determined by scientific studies which test the toxicity or carcinogenicity of the contaminant against living organisms. Based on these studies regulations are made which restrict contaminant levels in input sources.

There is no single number or index by which the level of contamination of a water body can be measured; usually a water body is polluted in terms of some substances and perfectly normal as far as others go. The contamination of the body of water as a whole is determined by the diversity and levels of contaminants found but may also be determined by extremely high levels of specific substances alone. In general, unless a specific contaminant is extremely important (as with mercury in the Minimata disease of Japan; Eisler 1978), the degree of contamination of a body of water must be determined by comparison with other bodies of water with similar geographic and/or population settings.

REGULATION OF CONTAMINANTS

The U.S. Environmental Protection Agency (USEPA) has periodically issued ambient water quality criteria since 1969. The technical basis for water quality objectives are described in section 304(a) of the Federal Clean Water Act of 1977 and toxic pollutants are listed in section 307(a). The priority pollutant list includes about 126 substances and the list grows as more synthetic substances are develop and tested. Most of these substances are man-made compounds which have been shown to be toxic or carcinogenic, at least in laboratory animals. The EPA provides water quality criteria for 136 water contaminants; of these, 99 (73%) are priority pollutants and 50 (37%) are carcinogens. The remaining priority pollutants have not been studied sufficiently to define water quality criteria and standards at present (OWRS 1987).

The California Ocean Plan sets water quality objectives for contaminants discharged into the ocean off California from point and nonpoint sources. The plan sets criteria that apply to all discharges excluding enclosed bays and estuaries (which are covered by the Enclosed Bays and Estuaries Policy) and thermal pollution (which is covered by the Thermal Plan). State-adopted numerical objectives have been set for 23 toxic materials and apply to all ocean discharges. Effluent limits have also been set for six other constituents or properties common in publicly-owned treatment works and industrial discharges but for which effluent guidelines were not established in sections 301, 302, 304, or 306 of the Federal Clean Water Act (CSWRCB 1990).

The agencies which regulate contaminants in the study area and the pertinent regulations are described in SCAG (1988). In general, the U.S. Environmental Protection Agency (EPA) provides guidelines for water and air quality and human health. State agencies such as the California State Water Resources Control Board (CSWRCB), Regional Water Quality Control Board, Los Angeles Region (RWQCB,LAR); California Air Resources Board (CARB), and California Department of Health Services (CDHS) implement regulations prescribed in California law. The Bay is also governed by Chapter 5.6 of the California Water Code: Bay Protection and Toxic Cleanup. Other state and federal agencies including the South Coast Air Quality Management District and the U.S. Food and Drug Administration, as well as city and county agencies also play important roles in regulating contamination in and around the Bay.

PHYSICAL/CHEMICAL PROCESSES

Most contaminants enter the marine environment by way of the water column. Once in the ocean the movement of contaminants is dictated by water turbulence, the direction and strength of currents, and the presence (or absence) of a pycnocline. The presence of a density gradient in the water column (pycnocline) restricts upward mixing of wastewater effluent and downward mixing of material discharged to the surface. The HTP and JWPCP sewage outfalls are located near the edge of the continental shelf, at the 200-ft depth contour. The HTP sludge outfall, which was inactivated in 1987, is located in about 300 ft of water, near the head of the Santa Monica Submarine Canyon. The configuration and location of these outfalls were designed to maximize dispersion and minimize transport of contaminants to the water surface or to the beach.

Drainage channels, on the other hand, provide a different input pathway, discharging into surface waters adjacent to the shoreline. Flow from these channels tend to form a freshwater surface layer, or lens, that is resistant to mixing with the underlying water.

The dilution and dispersion of dissolved or colloidal pollutants is entirely a function of the mixing and advection of water masses. Nutrients such as ammonia and phosphate are highly soluble and can be used to trace the dissolved component of sewage effluent plumes in the early stages of mixing. Dissolved contaminants can become associated with or transformed into particulates by the processes of sorption, precipitation, and ion exchange. Sorption occurs more readily on fine-grained silts and clays than on coarse, sandy sediments. Fine suspended organic particles such as living or dead plankton and sewage particles have high sorption capacities, especially for dissolved organic contaminants. Trace metals absorb onto organic particles and iron or manganese oxyhydroxide phases, which form in oxygenated marine environments and coat the surfaces of particles.

The pathways followed by particle-bound contaminants are a function of particle density and current strength. Fine particles are easily transported by relatively slow currents; therefore they are easily dispersed. Studies of the distribution of suspended particulate material near the HTP 5-mi outfall indicate that the sewage plume rises rapidly from the discharge depth of 200 ft to about 66 ft below the water surface (Kolpack 1979). The initial direction of transport is toward the shoreline southeast of the outfall for most of the year, with wave action dispersing the plume over a large part of the Santa Monica shelf. Subsequent transport offshore occurs in well-defined zones near the sea surface.

Coarse-grained or dense particles are more resistant to transport. Sand accumulates on beaches because it is resistant to the wave energies that erode fine material. Similarly, coarse-grained material, which is resistant to turbulence and currents, accumulated near the HTP sludge outfall (Bascom *et al.* 1980). The settling of a particle onto bottom sediments does not mean that its journey is over. Stronger currents can rework the sediments, resuspending material and transporting it until the current velocity diminishes and the particles once again are deposited. Current velocities necessary for sediment resuspension in the vicinity of the JWPCP outfalls are often met (Hendricks 1976).

Water depth determines the susceptibility of sediments to resuspension by storm waves. Storm waves introduce energy that is proportional to their frequency and size. Although shallow water sediments are most affected, severe coastal storms can resuspend accumulated contaminant-laden particles from greater depths. Chemical concentrations in vertical sediment profiles on the Palos Verdes Shelf indicate that surface sediment losses in the nearshore region were induced or accelerated by several severe storms (Stull *et al.* 1986a). Recent studies have indicated that DDT-laden sediments are periodically resuspended in relatively shallow shelf areas, transported and redeposited elsewhere along the shelf (Hendricks 1987).

The accumulation rate and the physical mixing of surface sediments also influence the fate of particle-borne contaminants. The accumulation rate is a function of the rate of supply from both natural and anthropogenic sources and current velocities at the sediment-water interface. Mixing of the sediments can result from the activities of benthic organisms, a process called bioturbation. Both sediment accumulation and mixing act to bury freshly settled particles, thereby minimizing the potential for resuspension. Because benthic mixing derives from the activity of organisms, it is either absent or reduced in sediments with low abundances of benthic organisms. In a recent 301(h) waiver application (LACSD 1988), it is argued that decreases in solids discharged from the JWPCP outfalls could increase contaminant levels in surface sediments on the Palos Verdes Shelf. In this scenario the contaminated subsurface sediments from historical discharges would be mixed with the less contaminated sediments from more recent discharges and would be available for resuspension. The combination of reduced sediment accumulation rate and enhanced benthic mixing (greater densities of organisms which resulted from decreased levels of contamination in surface sediments) were identified as the primary determinants of DDT distribution along the 200-ft depth contour on the Palos Verdes Shelf.

Several processes enhance the size of particles and thus the speed at which they sink through the water column. Flocculation is aggregation of colloidal material as freshwater mixes with seawater; differences in ionic strength (electrical charge) between fresh and salt water cause changes in the charges of the colloids and they attach to one another. Coagulation is the aggregation of particles brought about by physical contact. The higher the concentration of particles, the greater the chances of collision, and the greater the possibility of particle aggregation. Coagulation is probably an important process in the vicinity of sewage outfalls and storm drains where the concentration of particles, particularly particulates rich in organic matter, is high.

Pollutants can be incorporated into biologically produced particles such as fecal pellets, which are relatively large and sink quickly. It has been suggested that vertical transport by fecal pellets is an important mechanism for transporting particles to the sediments.

The behavior of oil spills illustrates the complex array of pathways and processes followed by a single kind of waste. Crude oil consists of a variety of organic compounds, a small fraction of which are soluble in water. The lighter, less dense fraction floats to the water surface, the atmosphere; or degraded by exposure to sunlight. Denser materials aggregate into tar balls that sink to the bottom, where they are subject to erosion, burial by accumulating sediments, or degradation by organisms. Oil and grease in sewage effluent tend to rise to the water surface and undergo similar processes.

BIOLOGICAL/CHEMICAL PROCESSES

Biological processes further complicate the fates of contaminants. Organisms can store contaminants, or can transform and decompose them through their metabolic processes. The microbially mediated degradation of organic matter is an oxidative process that transforms it into basic inorganic components (i.e., carbon dioxide, water, ammonia, orthophosphate). Biodegradation can also be a less drastic process that changes an organic contaminant to a more oxidized form that may be more or less toxic than the original compound. The chemical form of a contaminant can also be changed by the process of biotransformation, whereby a pollutant form is altered by an organism to make it less toxic to that organism. Biological processes also affect the fate of contaminants indirectly by altering environmental parameters. Degradation of organic matter lowers the pH (increasing the acidity), reduces the oxygen concentration and redox potential, and produces chemicals such as ammonia and sulfide that can impact aquatic life and interact with contaminants.

DEGRADATION OF ORGANIC MATTER

Many types of microorganisms derive energy by degrading organic matter, which also triggers changes in pH and redox potential in the environment. Marine aquatic systems are well-buffered by the presence of carbonate alkalinity, and relatively small changes in pH typically accompany organic matter degradation (seldom decreasing below a pH of 7). Changes in redox potential are more extreme. The degradation (i.e., oxidation) of organic matter by microorganisms requires the concurrent reduction of an electron acceptor, which in most environments is oxygen. If organic loading is sufficient and available oxygen has been consumed, nitrate, sulfate, and carbon dioxide are utilized sequentially as electron acceptors, producing reduced forms of these chemicals. The change in redox potential that accompanies organic matter degradation can change the oxidation state of some metals. Iron and manganese, which are present as insoluble oxyhydroxides under well-oxygenated conditions, are much more soluble in their reduced form. Moreover, metals that are sorbed to the surfaces of iron and manganese oxyhydroxides under well-oxygenated conditions may become mobilized as the phase undergoes dissolution in reducing environments. The reduction of sulfate is a particularly important process because sulfide is the degradation product. Many metals react with sulfide and precipitate as metal sulfides.

BIOACCUMULATION

The uptake and retention of chemical contaminants by organisms is called bioaccumulation. Chemical properties that make a particular contaminant more prone to bioaccumulation (i.e., that increase its solubility in fatty tissue) were described in the section on Chemical Properties and Behavior. Characteristics of organisms that result in high bioaccumulation potential include: 1) having a high fat content, 2) living on or near the bottom sediments, 3) filter-feeding on organic particles, and 4) being high on the food chain. Examples of such organisms include demersal fish (e.g., Dover sole), mussels and clams (filter feeders), and seals (high in fat and the top carnivore). Greater accumulation of a contaminant by organisms higher on the food chain is termed biomagnification. The accumulation of contaminants by the biota may result in biological effects to contaminated organisms or their predators.

Studies of the spatial distribution of hazardous substances in mussel tissues indicate that elevated concentrations of silver and chromium are found in the vicinity of the JWPCP and HTP outfalls, while elevated concentrations of lead and PCB are more widespread. Interpretation of fish bioaccumulation patterns indicates that the JWPCP and HTP outfalls may have been major sources of PCB, but elevated tissue concentrations of PCB are found far from these outfalls because fish are mobile. The highest concentration of DDT in fish tissue occurs near the JWPCP outfall, a documented historical source. Spatial and temporal patterns in contaminant bioaccumulation in Santa Monica Bay are described in greater detail in Chapter 12.

BIOTRANSFORMATION OF CONTAMINANTS

Microorganisms are responsible for most of the biotransformation or biodegradation of contaminants that occurs in the environment. Highly chlorinated hydrocarbons like PCB and DDT are relatively resistant to degradation, but are slowly degraded over time. DDT, a major contaminant in Santa Monica Bay, is slowly degraded to DDD and DDE. Measurements in sediments on the Palos Verdes Shelf, described in Chapter 9, indicate that degradation of DDT is more rapid in shallow water than in deep water, as indicated by a comparison of DDE/DDT ratios. The redox potential may influence the rate of contaminant degradation. The degradation of anthracene and naphthalene (PAH) is not observed in sediments in the absence of oxygen. Under toxic conditions, these lower molecular weight PAH compounds are more susceptible to degradation than higher molecular weight PAH compounds.

The microbial synthesis of methylmercury is a good example of the process of biotransformation. The microbial synthesis of methylmercury and other organometallic compounds has advantages for cellular elimination because nonpolar compounds are more easily transferred across the cell membrane (Wood and Wang 1983). Unfortunately, these compounds are more easily bioaccumulated by higher organisms for similar structural reasons.

SOURCES OF CONTAMINATION

Contaminants entering Santa Monica Bay may originate on land, in the air, or at sea outside of the Bay itself. The ultimate source of a contaminant, as used here, refers to the place at which it is introduced into the system that carries it to the ocean. The proximal source of a contaminant is the point or pathway by which it actually enters Santa Monica Bay. The ultimate source of most lead in the local environment was the leaded gasoline used in automobiles. After combustion, some lead entered the atmosphere and eventually landed on the ocean surface as aerial fallout — a proximal source. Other lead particles adhered to material on streets and driveways and eventually entered Santa Monica Bay with storm runoff — another proximal source.

The variety of ultimate sources of contaminants found in Santa Monica Bay is great, (Table 5-1) and it would be nearly impossible to identify all the possible sources for all the possible contaminants in the Bay. Knowledge of ultimate sources is especially important when source control programs are at issue, whereas knowledge of proximal sources helps to explain the distribution of contaminants in the Bay. There are two general kinds of proximal sources — point sources and nonpoint sources — although the distinction is sometimes difficult to make.

A point or discrete source is an identifiable place at which substances enter the receiving waters (usually continuously) and at which water quality samples can be taken repeatedly; it is usually a pipe or open drain built specifically to carry the waste material. Point sources include outfalls for municipal wastewater discharges, power plant cooling water discharges, and industrial waste effluent. All point sources which discharge to the Bay are issued National Pollutant Discharge Elimination System (NPDES) permits by the Regional Water Quality Control Board with the concurrence of the U.S. Environmental Protection Agency.

A nonpoint or diffuse source is widespread, changing, or not identifiable; as such it may be difficult to sample. Nonpoint sources include aerial fallout, surface runoff, advective transport, ocean dumping, and boating and shipping activities. Aerial fallout and advection are clearly diffuse, whereas surface runoff and ocean dumping have some discrete aspects.

TRACE METALS:	
Dissipative decay of products containing the contaminant. Combustion of coal, residual oil, distillate oil, gasoline, and other fossil fuels.	
Cadmium:	Oil and gasoline combustion, batteries, pigments, plastics, synthetics, plating, galvanized pipe, photoelectric cells
Copper:	Oil and gasoline combustion, paint, electrical, building, automobiles, manufacturing, antifouling paint, pipes, roofing insecticides
Chromium:	Oil and gasoline combustion, Chemical industrial (Chromite, chromic acid, sodium dichromate), pigment, plating, protective coating
Lead:	Oil and gasoline combustion, paint, antifouling paint, lead metal, storage batteries, pigments, lead arsenate
Mercury:	Oil and gasoline combustion, industrial catalysts, agriculture, dental preparations, thermometers, barometers, electrical, paints, antifouling paint, pharmaceuticals, batteries
Nickel:	Stainless and heat-resistant steel, alloys, cast iron, electroplating, catalysts batteries, protective coating
Selenium:	Electronics, photographic uses, catalyst
Silver:	Chemical industry, electronics, plating, alloys
Tin:	Antifouling paint, pewter, plating, alloys
Zinc:	Oil and gasoline combustion, alloys, paint, pigment, plating, batteries, auto parts
INORGANIC, NON-METALLIC CONSTITUENTS:	
Chlorine:	Antifouling agent for generating stations, disinfectant
Phosphate:	Fertilizer, detergent
Nitrogen:	Fertilizer, refrigeration
PESTICIDES:	
DDT:	Montrose Chemical corp., Torrance (past) agricultural application to: grains, vegetables, small fruits, grapes, nuts
Chlordane:	Private and industrial application to structures and vegetation; primary use for termite control
BHC/lindane:	Agricultural application to vegetables, grapes
Aldrin:	Agricultural application to vegetables
Dieldrin:	Agricultural application to vegetables, small fruits, hay
Endrin:	Agricultural application to vegetables, cereals
Heptachlor:	Agricultural application to vegetables, hay
Toxaphene:	Agricultural application to vegetables, grains, cereals
PCBs:	
Direct discharge from production facilities into holding reservoirs, receiving waters, municipal sewerage	
Decay of products releasing the contaminant to the environment: transformers (approx. 2150 lbs each); capacitors (approx. 25 lbs each); antifouling paint; plasticizers; lubricants; heat transfer fluids;hydraulic fluids; wax extenders; fluid in vacuum pumps; and compressors	
OTHER ORGANIC COMPOUNDS:	
PAH:	Crude Oil, fuel oil, crankcase oil; combustion releases contaminated soot which falls back on land
Phenol:	Phenolic resin, fuel-oil sludge inhibitor, solvent, rubber chemicals
Detergent:	Emulsifier, soap
BOD:	Organic material including human and animal waste and food refuse
Source: CSWRCB 1983, SCCWRP 1986a, Sax and Lewis 1987, Versar 1988.	

Table 5-1. Ultimate sources of contaminants found in Santa Monica Bay.

Offshore petroleum activities which may occur in the area in the future also have point and nonpoint aspects. Offshore oil production platforms, for example, are required to have NPDES permits for the discharge of treated sewage, drilling muds, and cuttings; however, deckwash from a moving work boat is diffuse.

The Clean Water Act considers storm drains to be a nonpoint source of contaminants even though the effluent from a single drain can be sampled repeatedly. However, many channels drain to the Bay, resulting in a diffuse input of contaminants along the shore after a storm. At present, storm water is not treated and there are no facilities for storing it for later treatment. The operating and regulatory agencies have only limited power to control what is discharged into the drainage system upstream and little or no power to enforce effluent limitations or water quality objectives.

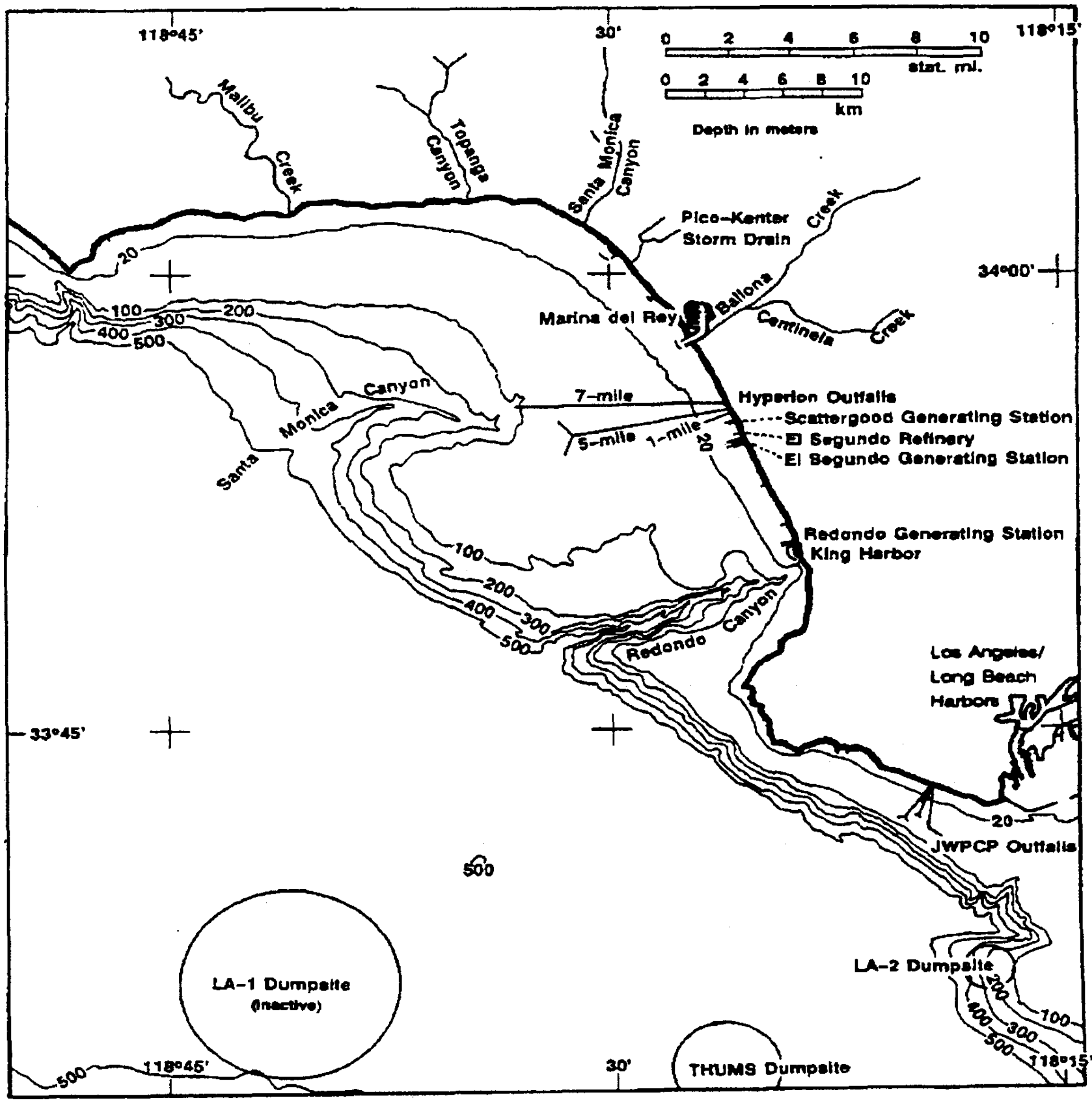


Figure 5-1. Major point and nonpoint sources in the Santa Monica Bay area.

Los Angeles County and 89 cities in the Santa Monica Bay watershed have received NPDES permits requiring them to control pollution from urban runoff. In addition, industrial facilities and construction sites also receive general stormwater discharge permits. Operators and regulators must encourage source control programs (Best Management Practices) which reduce the likelihood of contaminants entering the system.

There are seven facilities in the study area with NPDES-permitted point discharges: three municipal waste treatment plants; three coastal generating stations; and one oil refinery (Figure 5-1). With the exception of the Joint Water Pollution Control Plant (JWPCP) outfalls at White Point on the Palos Verdes Peninsula, and the Tapia Water Reclamation Facility (TWRF) on Malibu Creek, these facilities discharge offshore in the south-central part of the Bay between Playa del Rey and Redondo Beach.

POINT SOURCES

MUNICIPAL WASTEWATER TREATMENT PLANTS

Municipal wastewater in the Los Angeles region includes sewered wastes from domestic, commercial, and industrial sources. Storm water runoff is collected in a separate system, although some infiltrates into sewers during exceptionally heavy rains. Residential sewage contains a variety of household cleaners and detergents; oil, grease, and solvents; food wastes; and enteric bacteria from human fecal waste. Commercial and industrial wastes include oils and grease, metals, and a variety of synthetic organic substances. About a 100 gallons of sewage per capita per day is discharged into the study area (Barletta and Webber 1986; CLA,DPW 1988; Stull 1988, pers. comm.). Human fecal waste is produced at the rate of about 75 g (dry weight) — just under one-sixth of a pound — of solids per person per day (Bascom 1977).

Municipal wastes are collected by an extensive network of main and feeder sewers which drain into central treatment plants. The level of treatment which is attained can vary widely. Raw sewage (i.e., untreated sewage) is ordinarily not discharged to the ocean or any stream discharging into the ocean. Sewage is initially subjected to preliminary treatment, which consists of screening, comminution (pulverization), and grit removal. Primary treatment consists of the removal of much of the suspended solids by sedimentation but not colloidal and dissolved matter. It does not include biological oxidation and usually consists of clarification with or without chemical treatment. At the end of this stage substantially all floating and settleable solids have been removed (Rogers *et al.* 1981).

Secondary treatment is defined by the U.S. EPA in terms of BOD-5, suspended solids, and pH, and is primarily a biological process (e.g., activated sludge) followed by settling that produces an effluent very low in solids, BOD, and sludge (Dorsey 1993, pers. comm.). Tertiary treatment (advanced waste treatment) includes the removal of nutrients (e.g., nitrogen and phosphorus compounds) and most of the remaining suspended solids. Finally, the effluent may be subjected to disinfection, whereby the effluent is treated with a disinfectant (e.g., chlorine or sulfur dioxide) to kill bacteria and viruses (Rogers *et al.* 1981, Dorsey 1993, pers. comm.).

The Clean Water Act (Public Law 92-500) of 1972 requires all domestic wastewater dischargers in the nation to achieve a minimum of secondary treatment. The effluent may have no more than 30 mg/l of biological oxygen demand (BOD) and of total suspended solids (TSS) (CLA,BE 1977). However, in 1977 Congress amended the Clean Water Act to add section 301(h) which provides for a NPDES permit with modified secondary treatment requirements (i.e., less than secondary). At present the Los Angeles County Sanitation Districts (LACSD) have been granted an evidentiary hearing after being denied a 301(h) waiver for the JWPCP discharge and judgment is pending. Hyperion Treatment Plant was denied a waiver and is presently upgrading their treatment to full secondary treatment, which is scheduled to be in place by 1998. Although full secondary treatment has not been attained by these dischargers, the quality of discharged wastewaters has improved greatly in recent years. This is the result of more stringent regulations with better enforcement; improved waste treatment technology and facilities; and better source control through education and enforcement.

Two municipal wastewater treatment plants discharge directly into Santa Monica Bay: Hyperion Treatment Plant (HTP) and Joint Water Pollution Control Plant (JWPCP). The Tapia Water Reclamation Facility (TWRF) discharges tertiary-treated wastewater into Malibu Creek.

HYPERION TREATMENT PLANT

At one time raw sewage from the City of Los Angeles was used, untreated, for irrigation. The first ocean outfall was completed in 1894 and discharged across the beach near the present site of HTP. In 1907, a new outfall was constructed which discharged at a water depth of 16 ft. After the Los Angeles-Owens River Aqueduct was completed in 1913, much of the San Fernando Valley was annexed to the City of Los Angeles. Because of population growth and storm overflows in the 1920s, a screening plant and a new submarine outfall was built at HTP in 1925. In 1943, because of nearshore odors, discoloration, grease, and high levels of the bacteria E. coli (Dorsey 1993, pers. comm), the State Board of Health quarantined about 10 mi of beach from Hermosa Beach to Venice Beach. Soon an upgraded HTP was designed to implement full secondary treatment, with a high-rate activated sludge system, digestion, and sludge-drying facilities. HTP was placed on-line in 1950 and began discharging 193 mgd of chlorinated, secondary effluent through a 12-ft diameter concrete pipe one mile offshore, at a water depth of 50 ft (WSED 1982, CLA,DPW 1987; Dorsey 1988, 1993, pers. comm.).

Continued growth and the threat of beach contamination resulted in the construction of a 12-ft diameter pipe which discharges 5 miles offshore at a water depth of 190 ft. This pipe, built in 1959 and in full service by 1960, has a Y-shaped end with 83 diffuser ports (WSED 1982; Dorsey 1993, pers. comm.). HTP was also modified at this time to provide 100 mgd of activated-sludge, secondary treatment, and up to 420 mgd of primary treatment.

Beginning in 1950, an effort was made to recycle digested solids as fertilizer but this resulted in air pollution and was uneconomical to operate. The excess solids which could not be processed were discharged into nearshore shallow waters and created a water pollution problem. To rectify this, a 7-mi long 20 inch diameter sludge pipe was constructed to discharge at the head of Santa Monica Canyon to a depth of 320 ft (WSED 1982). This pipe became operational in 1957 (Carlisle 1969, SCCWRP 1986b, CLA,DPW 1987) but use was discontinued in November 1987 (CLA,BE 1977; CLA 1987). At that time about 80% of the dewatered sludge was being transported to a landfill with the remaining 20% being treated by Chemfix, a chemical fixation process whereby the sludge is mixed with lime and silicate to produce a clay-like product (CLA 1987; Crosse 1988, pers. comm.).

By 1989, all sludge, now referred to as biosolids, was being recycled; none went to landfills. Presently, about 1,100-1,200 wet tons per day of biosolids are used as follows:

- 14% Dehydrated and combusted in HTP's cogeneration facility (Hyperion Energy Recovery System - HERS)
- 31% Directly injected into agricultural fields for crops not used for human consumption

- 39% Composted along with bulking materials (e.g., farm wastes, some green trimmings from the City) to produce a soil amendment for agriculture and horticulture

- 16% Chemically stabilized with lime and silicate to produce part of a clay-like substance used for covering landfills (Dorsey 1993, pers. comm.).

In 1988, HTP increased secondary treatment to 165 mgd from 90 mgd in 1985 (CLA,DPW 1988). This increase in secondary treatment is a direct result of the replacement of the air delivery system with a fine-bubble diffuser system, chemical addition to enhance capture of solids during the primary treatment phase, and development of innovative operating parameters which produced a high rate, secondary treatment operation (Dorsey 1993, pers. comm.). The improvements in the quality of effluent can be attributed to the Hyperion Interim Improvement Plan of 1986. The plan set compliance limitations which were revised in 1991 for BOD, total suspended solids, oil and grease, and settleable solids (CLA,DPW 1991).

To achieve the 1991 levels, upgrades in chemical addition and aeration resulted in a 35% reduction of BOD in primary effluent, which allowed for an increase of up to 200 mgd of secondary effluent treatment (CLA,DPW 1991). HTP continues to decrease mass emissions of constituents in effluent discharged from the 5-mi pipe and in 1992 reached the 1998 mandated limitations for all constituents except BOD (Dorsey 1993, pers. comm.). The Hyperion Full Secondary Expansion Program is expected to be fully operational by 1998.

Influent Waters. As of 1990 the City of Los Angeles was treating wastewater of 3.5 million people over an area of 600 mi^2 (Figure 5-2). Most waste is processed at HTP but waste from San Pedro, Wilmington, and Terminal Island is processed at the Terminal Island Treatment Plant and discharged into outer Los Angeles Harbor (Barletta and Webber 1986). The wasteshed of HTP is about 480 mi^2.

HTP is supplied via four main collector lines (Figure 5-2). A new main sewer pipe, the North Outfall Replacement Sewer (NORS), was completed late in 1992 and is expected to be fully on-line by spring of 1993. When NORS goes on-line, the North Outfall Sewer (NOS) will be refurbished (Figure 5-2) (Dorsey 1993, pers. comm.). The influent sewage delivered by the present four tributary lines has remained fairly consistent since 1975, fluctuating annually due to wet and dry years. Influent sewage flow generally increases during heavy rainfall periods as surface runoff enters the system (Dorsey 1988, pers. comm.). About 85% of the influent sewage is domestic and about 15% is industrial (Crosse 1988, pers. comm.). Approximately 52% comes from the north collector, 35% from the north-central, and 6 to 7% each from the coastal and central collectors. Most constituents (i.e., potential contaminants) are also from the north outfall, followed by the north-central collector (CLA,DPW 1988).

In 1986, the total influent averaged 1.26 g/l of solids, about 75% dissolved and 25% suspended. The north-central line was the major contributor of phenols, cadmium, total chromium, nickel, sulfate, total identifiable chlorinated hydrocarbons (TICH), total pesticides, heptachlor, and lindane. The coastal line contributed most of the chloride, magnesium, and sodium, probably a result of saltwater intrusion into the outfall (CLA,DPW 1988).

Treatment. In 1991, HTP processed about 349 mgd of wastewater. Presently 60% of the flow receives secondary treatment and sludge digestion (CLA,DPW 1991; Dorsey 1993, pers. comm.). The influent is initially treated with chemicals to enhance the capture of solids and to control odors; the raw sewage is then screened and grit is removed. Next it is sent to primary settling tanks and from there to the secondary treatment system. In the secondary treatment system the primary effluent is pumped to aeration basins where oxygen and acti-

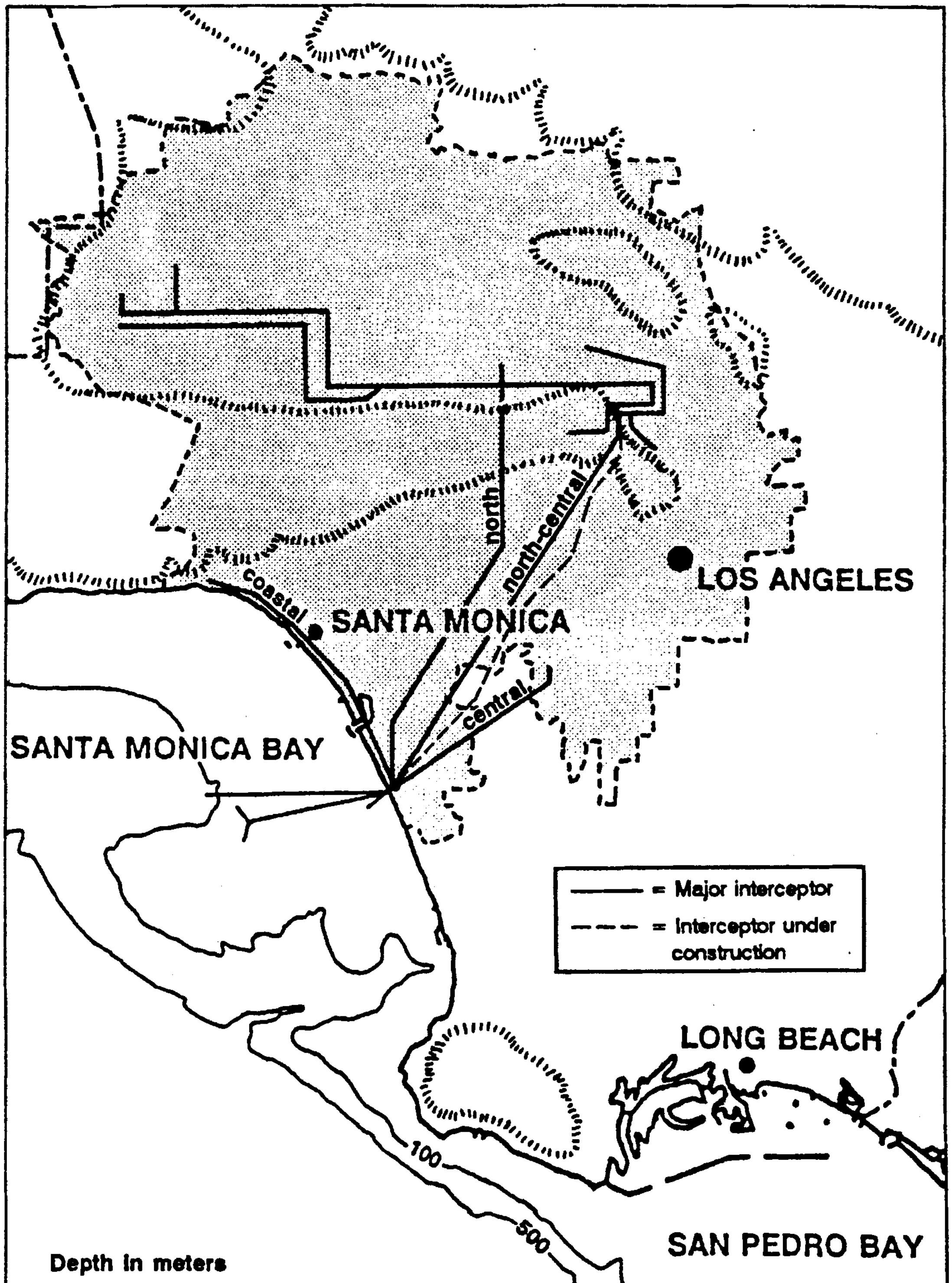


Figure 5-2. HTP watershed and influent collector lines (modified from CLA,DPW 1987 and 1993).

vated (biological) sludge are added to reduce the amount of organic matter. After four hours this effluent is pumped to secondary clarifiers which allow the activated sludge to settle out and be recycled. Of the secondary effluent, 30-40 mgd are recycled within the plant (mainly in the HERS process). The remaining effluent is blended with primary effluent and discharged from the 5-mi outfall (Dorsey 1993, pers. comm.). Most volatile organics are lost to the air during secondary treatment and metals (particularly chromium and copper) concentrations are reduced by adsorption to the particulates which are removed during treatment (Young 1978; Dorsey 1988, pers. comm.).

Mass emissions of most constituents have decreased in recent years due to improved chemical treatment and an increase in secondary treatment from 100 mgd in 1986 to 200 mgd in 1991. HTP expects to provide full secondary treatment by 1998, a project that is expected to cost $1.1 billion (CLA,DPW 1987; Biagi 1988, pers. comm.). The Hyperion Energy Recovery System (HERS) became fully operational in 1989 producing over 100 million kwhs of electricity and up to 28,000 tons of steam used for the energy recovery system (CLA,DPW 1988, 1989, 1990, 1991). By 1991 it produced 146 million kwhs, an increase of approximately 45% from 1988. Increases in the amount of electricity and energy recovery were due to improvements in on-line availability of turbines, generators, and the retrofitting of new gas burners into all of the combustion trains (CLA,DPW 1991).

Volumes Discharged. The volume of wastewater discharged from HTP has generally increased since 1950, when 193 mgd was discharged (Dorsey 1988, pers. comm.). During the first six years of operation, the combined flow from the 5- and 7-mi outfalls ranged from 261 to 283 mgd (Carlisle 1969); between 1974 and 1987 the combined flow averaged 371 mgd. During this period, flow from the 7-mi sludge pipe averaged 1.2% of the combined flow (Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986a; CLA,DPW 1987, 1988).

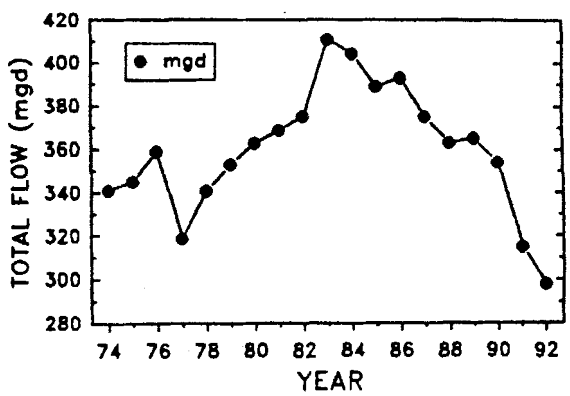


Figure 5-3. Average flow from the HTP 5-mile outfall, 1974-1992. (Data from Mitchel and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; CLA,DPW 1987, 1988, 1989, 1990, 1991, 1992).

From 1987 to 1992, the total volume discharge from the 5-mi effluent pipe decreased from 375 mgd to 298 mgd (Figure 5-3 and Appendix D). In 1989 the flow increased slightly to 365 mgd then continued to decrease to the current level of 298 mgd in 1992. The average flow between 1988 and 1992 was 339 mgd, which is approximately 10 percent lower then the 1974-1987 period.

5-mile Effluent. The 5-mi outfall discharges a nonchlorinated mixture of primary and secondary effluent. This effluent is usually discharged by pumping during daily peak periods or storm flow; however, during low flow periods it is usually discharged by gravity (Dorsey 1988, pers. comm.). From 1974 to 1987 an average of 367 mgd of effluent was discharged from this outfall. This compares with an average discharge of 343 mgd for the period 1987 to 1992, a decrease of approximately 07% over the previous 13 year period (Figure 5-3 and Appendix D).

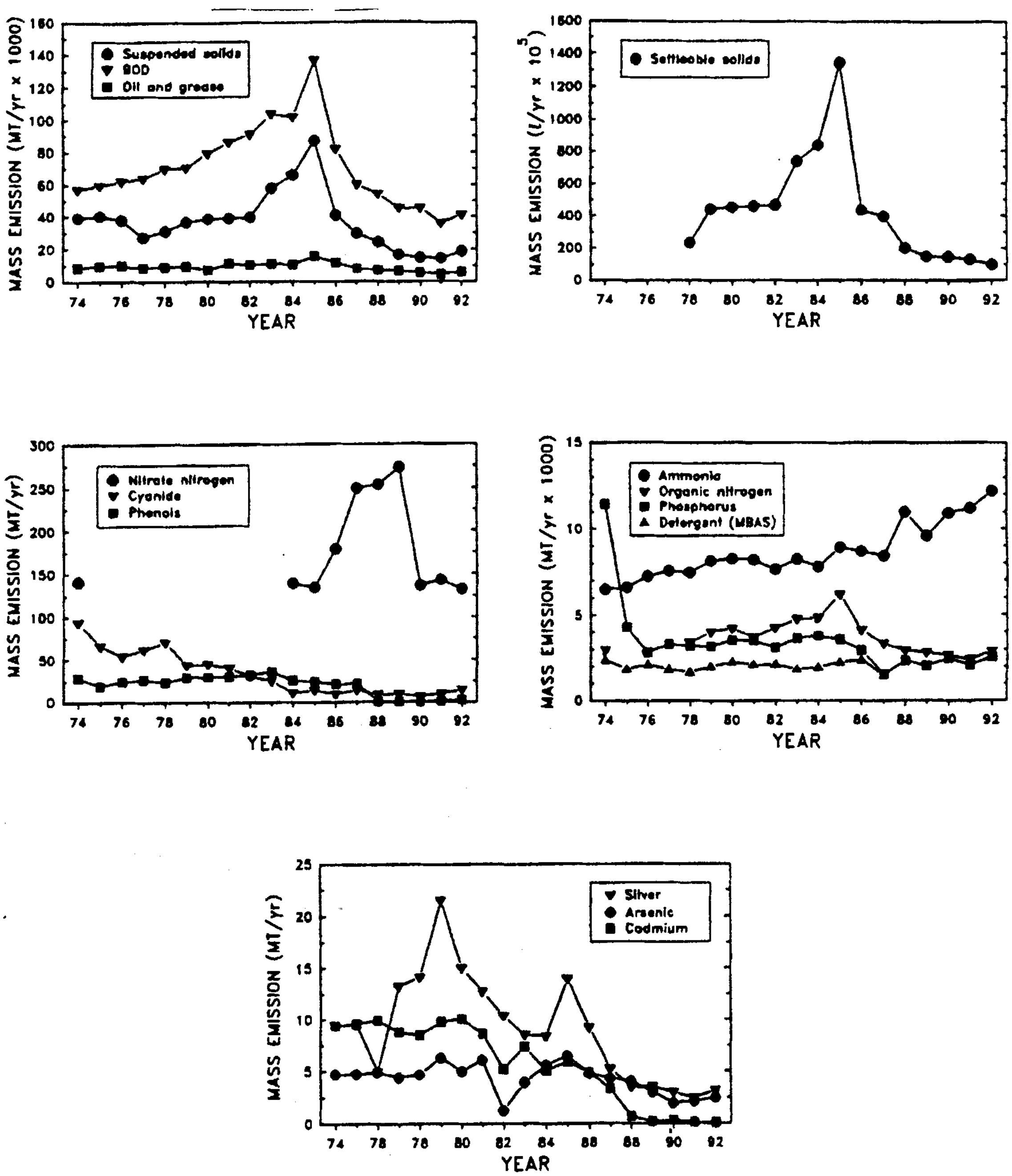


Figure 5-4. Annual mass emission rates of selected contaminants discharged from HTP 5-mi outfall from 1974-1992. (Data from Mitchel and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; CLA,DPW 1987, 1988, 1989, 1990, 1991, 1992).

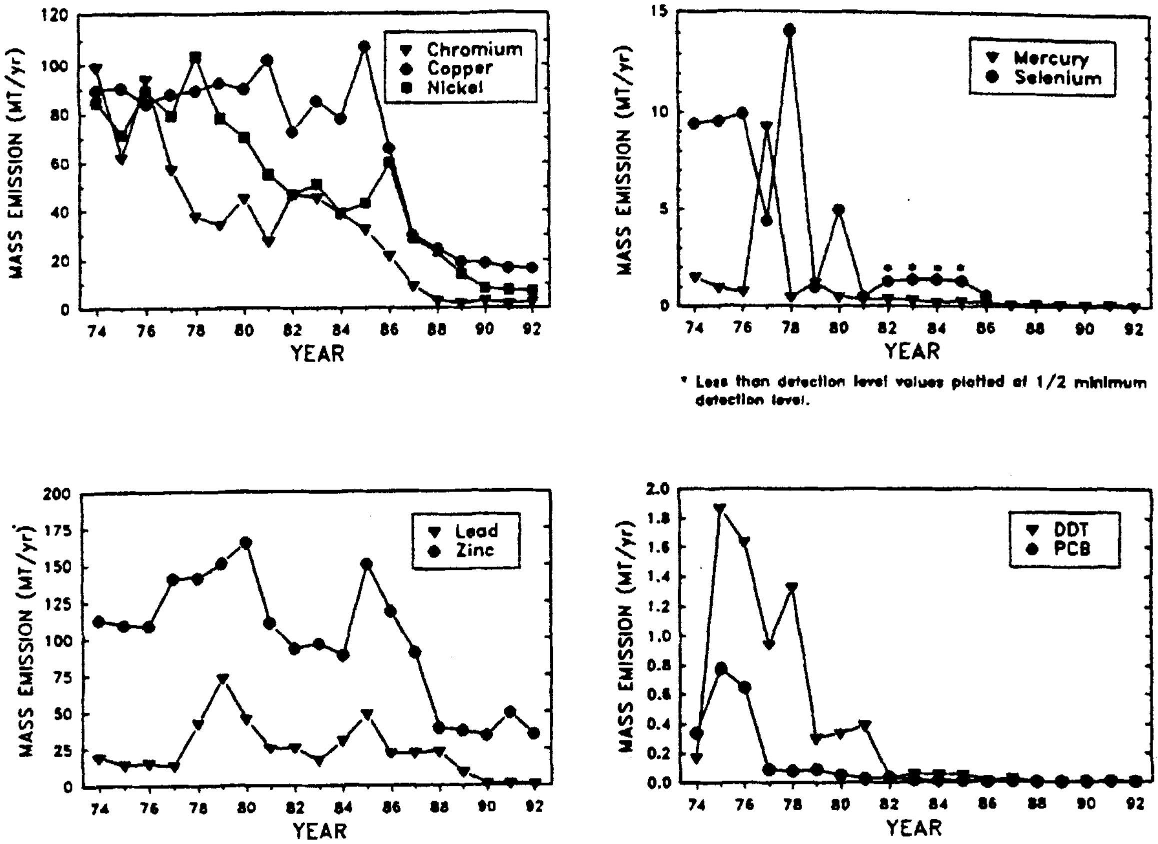


Figure 5-4 Cont.

The lowest mass emission values for BOD, TSS, settleable solids, and oil and grease were recorded in the period 1987 to 1992 (Figure 5-4 and Appendix D). Peak values for these constituents reported in 1985 were caused by hydraulic overloading, increased influent flow, and construction at HTP, which resulted in a temporary reduction in the number of primary tanks in operation (SCCWRP 1986a; Dorsey 1988, pers. comm.).

Nitrate nitrogen was measured at 141 MT in 1974, however, no measurements were taken for the period 1975 through 1984. Levels for the remaining 8 year period ranged from a reported high of 273 MT in 1989 to a low of 110 MT in 1992, a decrease of approximately 60% (Figure 5-4 and Appendix D).

From 1974-1988, phenols decreased 96% from a high of 28 MT (Figure 5-4 and Appendix D). Mass emissions for phenols have remained relatively constant averaging 0.8 MT for the five year period 1988-1992. Mass emissions for cyanide have remained within a fairly consistent range from 14.0 to 6.6 MT since 1984, compared with a range of 94.2 to 25.0 MT in the preceding ten year period.

Mass emissions for organic nitrogen, total phosphorus and detergents (MBAS) remained constant from 1975 through 1987. Levels for phosphorus elevated to 6,180 MT in 1985 but declined from there to the 1992 value of 2,530 MT. MBAS stabilized at approximately 1,500 MT in 1987, the last year measurements were available. Although ammonia nitrogen levels have fluctuated since 1974, the general trend indicates a gradual increase in mass emissions for this constituent, from a low in 1974 of 6,501, to the present high of 12,203 MT (Figure 5-4 and Appendix D).

In general, from 1974 to 1992, mass emissions of trace metals from the 5-mi outfall declined, with some metals displaying periods of fluctuation (Figure 5-4 and Appendix D). Overall, discharges of trace metals declined during the 1974-1992 period by the following percentages: silver (66%), arsenic (47%), cadmium (99%), chromium (97%), copper (82%), mercury (99%), nickel (92%), lead (96%), and zinc (69%) (Appendix D).

Total DDTs and PCBs were measured by different methods from 1974 to 1979 than from methods used during 1980 to 1987, therefore, reported values for the two periods may not be comparable. During the earlier period values were generally higher; however, DDT levels dropped sharply after 1976 and PCBs after 1978 (Figure 5-4). Since 1987, mass emissions for DDTs and PCBs have remained under the detection limits with the exception of trace amounts of DDT measured in 1991 (Figure 5-4 and Appendix D). The decline of DDTs and PCBs is credited to prohibitions placed on their use and production during the 1970s.

7-mile Effluent. As described in State-of-the-Bay report: Assessment of Conditions and Pollution Impacts (MBC 1988), between 1974 and its discontinuation in November 1987, the 7-mi pipe discharged an average of 4.4 mgd of a mix of secondary effluent and digested sewage sludge. Annual mass emissions and concentrations of total suspended solids (TSS) averaged 50,030 MT from 1974 to 1985 while those of oil and grease averaged 2,687 MT (CLA,DPW 1988). TSS and oil and grease levels peaked in 1975 and were relatively constant since 1979 (Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; CLA,DPW 1988). BOD was not reported because no limits were set, but levels in sludge were generally high (Dorsey 1988, pers. comm.).

A complete scan of EPA priority pollutants in sludge from the 7-mi outfall in 1978 identified three volatile organics (1,2-trans-dichloroethylene; ethylbenzene; toluene) and two extractable organics (4-nitrophenol; phenol) which exceeded 10 ppb, the EPA mandated quantification limit (Young 1978).

Sludge Removal. Since the termination of the 7-mi sludge outfall in 1987, sludge wastes have been relegated to land disposal locations, for land applications, nonconsumption agriculture, chemical fixation for cover material at landfills, HERS, or landfill. All sludge is anaerobically digested and dewatered by centrifuge with polymer conditioning to 20% solids (CLA,DPW 1988). Quality assurance measures have been implemented by HTP to regulate and monitor contamination levels of sludge. Materials found hazardous must be disposed at an alternate disposal site that meets with California State codes regarding the disposal of contaminated material.

In November of 1987, all sludge was hauled to landfill sites for disposal, the most economical and flexible method of disposal at the time. By 1988, alternatives for sludge (biosolids) disposal resulted in 181 metric tons per day (MT/d) used for land application, 181 MT/d for cover material, (chemical fixation), 181 MT/d for HERS, and 590 MT/d relegated to landfill disposal, for a total of 1,134 MT/d. By 1989 biosolids disposal at landfills was halted. Disposal at alternative sites in 1992 accounted for 100% of all material with 31% for land applications, 39% for city composting, 16% for chemical solidification, and 14% for use by HERS, accounting for approximately 1,100-1,200 wet tons per day (Dorsey 1993, pers. comm.).

1-mile Effluent. Power outages or mechanical failures (which are usually associated with periods of heavy storm flow) occasionally cause effluent pumps to malfunction. When pump failure occurs, part of the 5-mi effluent is diverted to the 1-mi outfall. Since 1988 overflows into the 1-mi outfall have occurred 25 times, ranging from a high of eight in 1988 to none in

1992 with an average of 5 bypasses per year (CLA,DPW 1988-1991). Such diversions to the 1-mi outfall are now rare, but when the need to divert occurs, the flow is split between the 1- and 5-mi outfalls with primary/secondary blend discharging to the 5-mi, and chlorinated secondary to the 1-mi (Dorsey 1993, pers. comm.).

Storm Overflows. Increased inflow and infiltration into the North Outfall Treatment Facility during rainstorms occasionally necessitates discharges into Ballona Creek, although the facility can store about 1.1 million gallon before this occurs. Such overflows presently receive primary sedimentation, two stages of screening, and chlorination at 40 mg/l (Crosse 1988, pers. comm.). The chlorination results in at least a four-order of magnitude bacterial kill (Crosse 1988, pers. comm.; Dorsey 1988, pers. comm.). However, there have been overflows in the past consisting of raw sewage (Sowby 1988, pers. comm.).

Ninety-four incidents of overflow discharges into Ballona Creek (and other storm drains) were recorded between 1965 and 1992 (Appendix H); none occurred in 1968, 1972, 1973, 1975, 1976, 1989, or 1991. Between 1965 and 1987, the average overflow lasted approximately 5.8 hours and discharged average of 4.6 million gallons (Crosse 1988, pers. comm.). Between the years 1988 and 1991, three wastewater overflows entered Ballona Creek discharging an average of 3.4 million gallons (Appendix H). On three consecutive days of heavy rain in February 1992, overflow discharges totaled 66 million gallons with the average overflow lasting 9.2 hours (CLA,DPW unpubl. data).

The primary reason for these overflows is the inability of the old NOS line to handle excessive water during storms. The new NORS line, completed in 1992 and due on-line in 1993, will be able to handle a total system flow to HTP of approximately 850 mgd (Figure 5-2). Presently HTP is unable to handle flows over 680 mgd, but interim projects scheduled for completion by spring of 1993 will enable the plant to receive system-wide flows to 850 mgd (Dorsey 1993, pers. comm.)

Permit Requirements. From 1979 to 1987, HTP discharges were subject to the requirements of an NPDES permit issued in 1979 that had expired in 1984. In 1987, a new permit was issued which established discharge limitations for 27 constituents in the 5- and 1-mi effluent and the 7-mi sludge discharge, which was terminated in 1987. Because the EPA could not sanction the discharge of sludge, standards specific to sludge were not set in the NPDES permit; therefore, the sludge discharge was subjected to full secondary treatment standards (Dorsey 1988, pers. comm.). The constituents included BOD (five day), suspended solids, oil and grease, settleable solids, turbidity, toxicity concentration (chronic and acute), arsenic, cadmium, chromium (hexavalent), copper, lead, mercury, nickel, silver, zinc, cyanide, total chlorine (residual), ammonia (N), nonchlorinated phenolic compounds, chlorinated phenolic compounds, aldrin and dieldrin, chlordane and related compounds, DDT and derivatives, endrin, HCH, PCBs, and toxaphene. These limitations generally included six month median values and daily maximum values. The same limitations were set on gross constituents (total suspended solids, settleable solids, BOD, oil and grease, turbidity, and toxicity) as well as limitations on residual chlorine for all three outfalls (RWQCB,LAR 1987).

In 1991, limitations on BOD, suspended solids, oil and grease, and settleable solids for the 5-mi pipe were revised to comply with a consent decree between the EPA, Region IX, and the RWQCB, LAR. HTP is currently in compliance with the permit scheduling to reach full secondary treatment by 1998.

Compliance with standards. During the past eight years, noncompliance for 1-mi effluent limit has decreased. In 1985, the effluent exceeded the daily maximum discharge limits on occasion for five parameters: fecal coliform, residual chlorine, beta-radiation, chromium, and toxicity. The seven day mean limits on fecal coliform were also exceeded. In 1986, the daily discharge limits were exceeded for three constituents. Beta-radiation levels were too high for the year, residual chlorine during five months, and fecal coliform during one month. In 1987, the daily limits of residual chlorine were exceeded in two months and the six-month median for beta-radiation was exceeded for the year (RWQCB,LAR 1988). From 1988 to 1992, compliance with NPDES permit requirements were met for all overflows through the 1-mi effluent outfall (Dorsey 1993, pers. comm.).

The 5-mi effluent has been well within compliance with all standards established in HTP's NPDES permit since 1987. Presently all heavy metals are meeting the standards for full secondary effluent that will be required in 1998, at which time BOD and TSS are also expected to meet standards (Dorsey 1993, pers. comm.).

Proposed Improvements. By 1998, HTP must be at full secondary treatment to comply with current NPDES regulations. In 1986, in order to comply with these regulations, HTP began the Interim Improvement Program to ensure that the highest quality of effluent was being discharged by the time the secondary treatment program was operational (CLA,DPW 1991). Recent improvements include a fifth pump in the effluent pumping plant and new maintenance facilities. Current construction includes a fully enclosed truck loading station to control odors, an intermediate pump station between primary and secondary systems, a cryogenic oxygen system and new secondary reactors and clarifiers for phase 1, and new headworks now in start-up (CLA,DPW 1991; Dorsey 1993, pers. comm.).

Proposed projects that will help HTP reach full secondary treatment by 1998 and increase the amount of effluent flow include a dewatering centrifuge and anaerobic digester expansion for phase 1 and 1a respectively, medium and high pressure gas compressors, steam dryer for sludge dehydration, waste activated sludge thickening, and the expansion of cogeneration facilities to remain completely self sufficient. With current projects in construction and the proposal of future work HTP expects to be in full compliances of the 1987 consent decree to discharge full secondary treatment effluent.

JOINT WATER POLLUTION CONTROL PLANT

Until the 1920s, most of the communities in Los Angeles County not serviced by HTP used cesspools and septic tanks. In the late 1920s the County Sanitation Districts were formed and White Point on the Palos Verdes Peninsula was selected as an ocean outfall site, partly because of its distance from the popular beaches of Santa Monica Bay.

The first Joint Disposal Plant was completed in 1928 and effluent was discharged into Dominguez Slough which flowed into Los Angeles Harbor. The ocean disposal of wastewater onto the Palos Verdes Shelf began in 1937 through a 5-ft diameter pipe; a 6-ft diameter pipe was added in 1947 (Rawn 1965). These outfalls discharged at water depths of 110 and 160 ft, respectively, and the initial flows were about 14 mgd each. A 7.5-ft diameter outfall, ending in a Y-shaped multiport diffuser at a water depth of 200 ft, was completed in 1956; in 1966 a 10-ft diameter pipe with a dog-legged, multi-port diffuser discharging at a 200 ft depth was added. The two diffusers are approximately 1.9 mi offshore (RWQCB,LAR 1977; Stull *et al.* 1986a).

Influent Waters. The Los Angeles County Sanitation Districts Joint Outfall System (LACSD,JOS) presently treats the wastewater of five million people and more than 70,000 businesses and industries in a service area of approximately 583 mi^2, as well as processes solids from five upstream treatment plants (Figure 5-5) (Stull 1993, pers. comm.). Approximately 30% of the influent sewage is treated to tertiary standards in upstream water

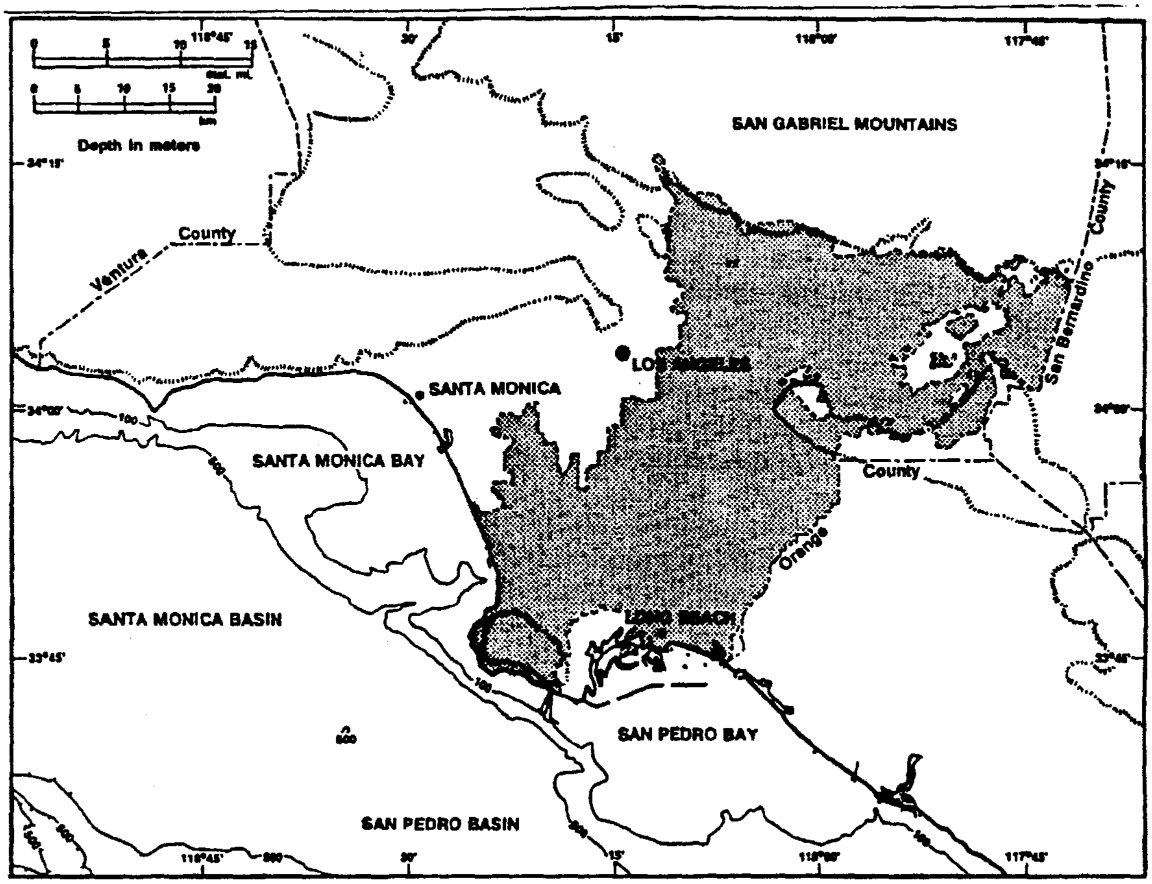


Figure 5-5. JWPCP watershed (modified from LACSD map G-m-450).

reclamation plants and 70% is treated at the JWPCP in Carson (Horvath 1988, pers. comm.). The JWPCP provides advanced primary and partial secondary treatment for about 330 mgd of wastewater (Stull 1993, pers. comm.). About 15% of the influent sewage is industrial and about 85% domestic (Horvath 1988, pers. comm.).

Treatment. In 1983, the JWPCP began operating new secondary treatment facilities and by 1985 was treating an average of 179 mgd (SCCWRP 1986a). Currently the wastewater is screened and grit removed prior to receiving advanced primary treatment, which includes the addition of a polymer to remove suspended solids. Sixty percent of the effluent receives pure oxygen secondary treatment while the rest is screened to remove grease and floatables. The combined flow is chlorinated and discharged. About 50% of the resulting sludge is sold as a soil amendment or land spread and the rest is hauled to the Puente Hills landfill (Horvath 1993). Air disposal (via anaerobic digestion of sludge and subsequent combustion of the gas for energy production) increased from 26 to 35% between 1973 and 1985 (Horvath 1988, pers. comm.; Stull and Haydock 1988).

Volumes Discharged. From 1937 to 1970, the volume of municipal waste discharged from the JWPCP increased in approximate proportion to the population growth in its service area; it has remained relatively constant since 1970 (Figure 5-6 and Appendix D) (Stull *et al.* 1986b; Stull and Haydock 1988). From 1974 to 1987 JWPCP discharged an average of 356 mgd of effluent, with a peak flow of 382 mgd in 1989. In 1991 and 1992, flow dropped by 12% to 330 and 333 mgd, respectively, the lowest recorded since 1977. This decline coincided with water conservation measures in response to the drought, as well as the economic recession (Stull 1993, pers. comm.).

Treated wastewaters are discharged through two outfalls: a 120-in. diameter "L" shaped outfall which carries 65% of the flow, and a 90-in. diameter "Y" shaped outfall, which transports 35% of the flow. Both discharge in approximately 200 ft of water. The 72-in. diameter outfall, which discharges at 160 ft depth, is on standby and may be used during heavy rains to provide hydraulic relief. The 60-in. diameter outfall which discharges at 110 ft depth is also on stand-by for extreme emergencies, although it has not been used in years (Stull 1993, pers. comm.).

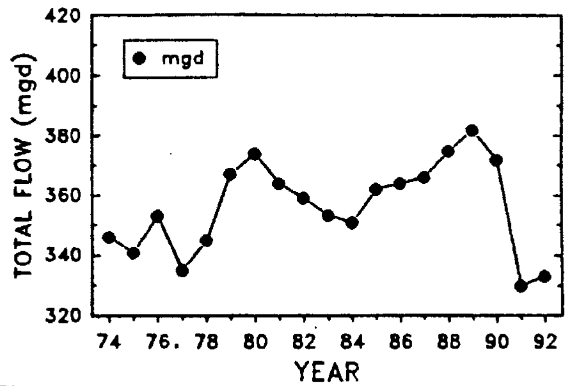


Figure 5-6. Average flow from JWPCP outfall, 1974-1992. (Data from Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; Stull 1988, pers. comm.; Horvatyh 1992, pers. comm.).

In addition to the two main and two emergency ocean outfalls, JWPCP has 11 other discharge points; Harbor Lake, Dominguez Channel, Los Angeles River, and the Pacific Ocean nearshore zone, which may be used for extreme emergency relief (RWQCB,LAR 1991).

Effluent. The JWPCP improved effluent quality substantially between 1971 and 1981, partly through better source control and partly as a result of advanced technology — the use of polymers to help settle particulates, better sludge dewatering, and better screening techniques (Stull *et al.* 1986b).

Mass emissions recorded in the period 1987 to 1992 for BOD, TSS, settleable solids, and oil and grease were the lowest reported since 1974 (Figure 5-7 and Appendix D). From 1974-1992, phenols declined to 300 MT, a decrease of more than 80%. Cyanide levels declined 98% from a high of 206 in 1974 to 3 MT 1992. Although detergents (MBAS) fluctuated over the 19 year period, the overall trend declined (Figure 5-7 and Appendix D).

Mass emissions of organic nitrogen, total phosphorus, and ammonia nitrogen remained constant from 1974 to 1992, displaying little variability between years with 1992 values slightly lower than those in 1974 (Figure 5-7 and Appendix D).

In general, from 1974 to 1992 mass emissions of trace metals from the JWPCP outfall declined. Few metals displayed periods of high fluctuation; e.g., silver peaked in 1979 at 9.6, compared with a current value in 1992 of less than 2 MT; arsenic levels rose to 9.7 in 1984 before dropping to 1.9 MT in 1992 (Figure 5-7 and Appendix D). Overall, discharges of trace metals declined during the 1974-1992 period by the following percentages: silver (68%), arsenic (84%), cadmium (98%), chromium (98%), copper (95%), mercury (80%), nickel (87%), lead (98%), and zinc (95%) (Appendix D).

Total DDTs and PCBs were measured by different methods during 1974 to 1979 than from methods used 1980 to 1987, therefore, reported values for the two periods may not be comparable. During the earlier period values were generally higher; however, PCB levels dropped sharply after 1974 and to non detectable levels by 1987 where they have remained

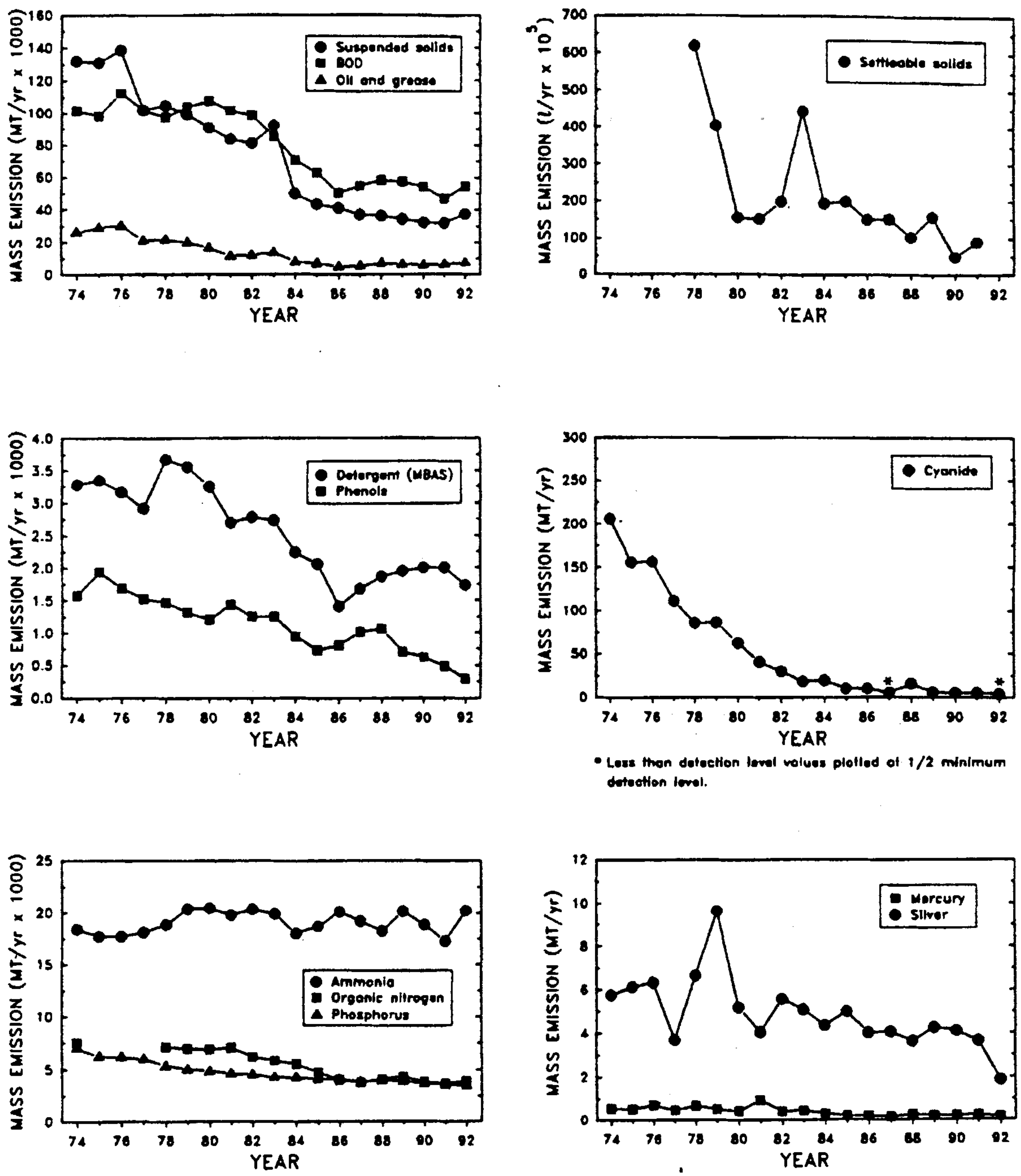


Figure 5-7. Annual mass emission rates of selected contaminants from JWPCP outfall, 1974-1992. (Data from Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; Stull 1988, pers. comm.; Horvatyh 1992, pers. comm.).

through 1992 (Figure 5-7 and Appendix D). A precipitous decline in DDT emissions occurred in 1970-1971, following termination of inputs from the primary industrial source, the Montrose Chemical Corporation, which was prohibited from discharging processing wastes into the JWPCP system (Chartrand 1988) (Figure 5-7 and Appendix D).

Permit Requirements. In 1991, the Regional Water Quality Control Board, Los Angeles Region (RWQCB,LAR), adopted a new NPDES permit for JWPCP which established discharge limitations (in concentrations) for 86 constituents. These include all of the major wastewater constituents, aquatic life toxicants, non-carcinogens, and carcinogens included in

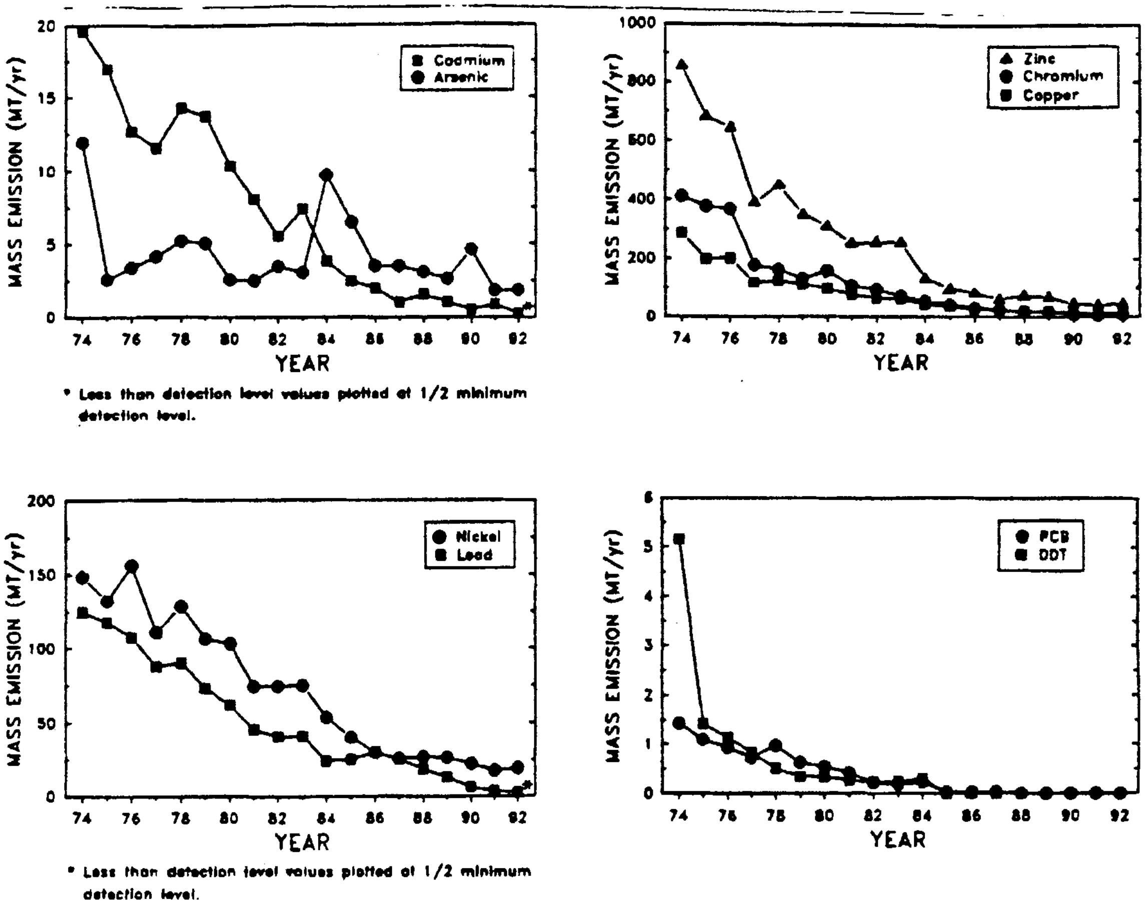


Figure 5-7 Cont.

the 1990 California Ocean Plan, plus BOD. Many of the limits are more stringent than the Ocean Plan, and are based on either previous performance or practical quantitative limits. Limits for major constituents and aquatic life toxicants are provided for both concentrations and mass emissions, and are expressed for various time periods (e.g., 30-day, 7-day, daily, instantaneous, in various combinations) (Stull 1993, pers. comm.). The permit also includes limits and provisions for receiving waters established by the 1990 California Ocean Plan.

Compliance with Standards. In the period 1983-1987, JWPCP effluent was in compliance with the California Ocean Plan limits except that daily concentration limits for suspended solids and chlorine were exceeded in 1983 and pH and turbidity in 1984. Each of these constituents were found in noncompliance during just one month (RWQCB,LAR 1988). Presently JWPCP is unable to comply with limitations regarding secondary treatment of effluent and until the 301(h) variance is resolved, or full secondary treatment is reached, must operate on interim limits set in a 1988 cease and desist order issued by the Board for secondary treatment. JWPCP's application for a variance to section 301(h) was denied in 1990 by the EPA Region IX. Subsequently, JWPCP requested and was granted a challenge to the denial. Dates for the challenge hearing are still pending (RWQCB,LAR 1991; Stull 1993, pers. comm.). A lawsuit was also filed in District Court by EPA seeking resolution of the secondary treatment issue (Stull 1993, pers. comm.).

Proposed Improvements. By 1995, LACSD will have finished construction of their sludge dehydration and thermal processing facilities (RWQCB,LAR 1988). Expansion is estimated to handle all sludge currently hauled off site to landfills, approximately 240 dry tons per day, and will be used for the energy recovery facility to generate electricity.

TAPIA WATER RECLAMATION FACILITY

The Las Virgenes Municipal Water District (LVMWD) was formed in 1958 and by 1965 construction of TWRF was completed with up to 500,000 gpd capacity. TWRF's capacity was expanded to 2 mgd after construction of sewer trunk lines were completed. Expansion in 1972 increased capacity to 8 mgd of effluent with solids handling capabilities of 4 mgd and at this time TWRF installed facilities to allow for water reclamation. Between 1972 and 1982, TWRF underwent area-wide facility upgrades, from the expansion to 8 mgd of hydraulic capacity, to the design and completion in 1982 of Rancho Las Virgenes with a capacity to handle 8 mgd of dewatered sludge. In 1984, filtration systems were installed and 1989 expansions allowed TWRF to increase capacity to 10 mgd. In 1991 construction began at TWRF and Rancho Las Virgenes that will allow for the handling of 16.1 mgd of influent and dewatered sludge (Gamble 1992, pers. comm.).

In the past discharge of effluent to Malibu Creek was through percolation beds. The beds were removed from service after the installation of on site filters, however, periodic discharge to the percolation beds is required in summer months by CDFG to maintain the creek flow necessary to sustain fish populations in (RWQCB,LAR 1989).

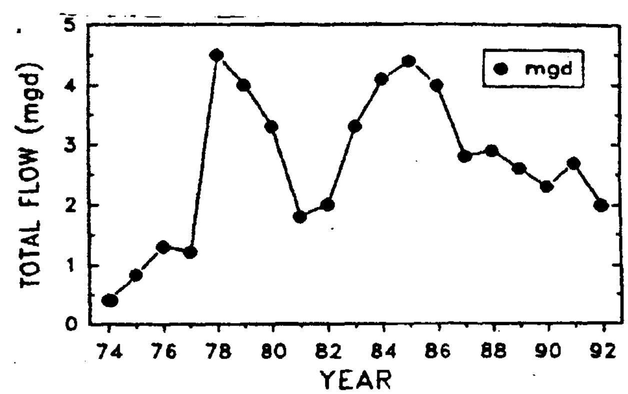


Figure 5-8. Average flow from TWRF, 1974-1992 (Whitbeck 1992, pers comm.).

Treatment. TWRF currently provides primary, secondary, and tertiary treatment of wastewater. Primary treatment includes coarse screening, grit removal, and primary sedimentation using rectangular clarifiers. Secondary treatment employs activated sludge with single-stage nitrification followed by secondary clarification. For tertiary treatment, coagulation chemicals are added and the water is flocculated, filtered, chlorinated and dechlorinated (RWQCB,LAR 1989). Tertiary treated wastewater is reclaimed and used for irrigation, dust control and fire suppression.

Sludge is currently being treated by aerobic digestion, screened, and either pumped to land injection farms, or dewatered in belt presses and hauled to landfills. Solids collected from coarse screening, grit removal, and sludge screening are hauled to landfills. Additional sludge incurred from expansion will undergo composting for use in landscape related activities.

Volumes Discharged. Flow from TWRF has averaged 2.7 mgd since 1974 with a maximum of 4.5 mgd discharged in 1978 (Figure 5-8, Appendix D). Over the last five years, flow has averaged 2.5 mgd. The trend of the previous five years has been fairly stable, though declining. This decline coincides with drought periods and subsequent water conservation measures.

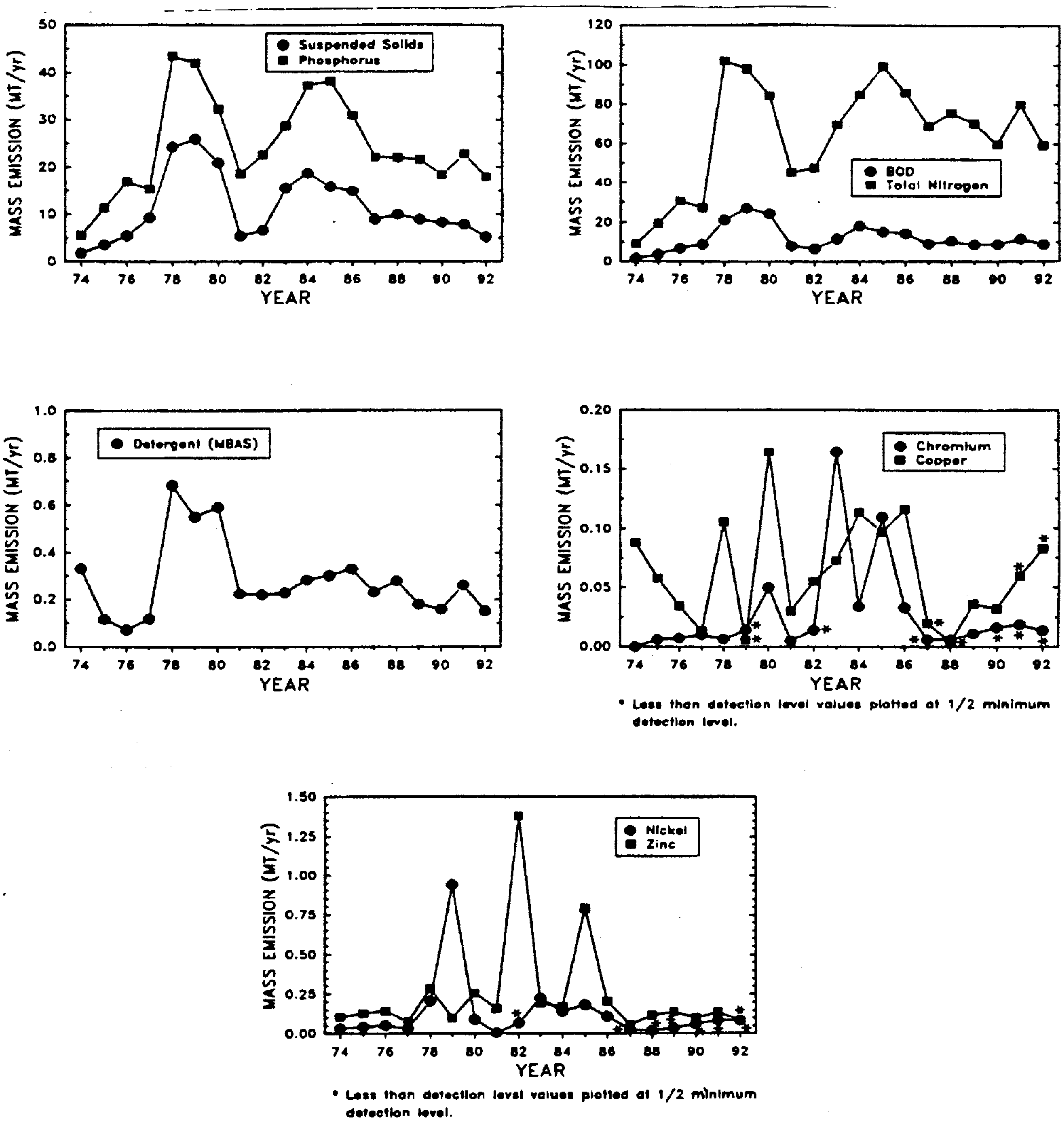


Figure 5-9. Annual mass emission rates of selected contaminants from TWRF, 1974-1992 (Whitbeck 1992, pers. comm.)

Effluent. Emissions of total suspended solids, phosphorus, BOD, total nitrogen, detergent, chromium, copper, nickel, and zinc have generally been low but have erratic variation (Figure 5-9 and Appendix D). Copper emissions have increased slightly in recent years but appears to be part of this variation.

Permit Requirements. TWRF is subject to discharge requirements established in a 1985 NPDES permit, revised in 1989.

Wastewater discharge is limited to tertiary treated water with 30-day mean and daily maximum limits set for six constituents: BOD, suspended solids, oil and grease, residual chlorine, settleable solids, and turbidity. Eighteen other constituents, as well as EPA priority pollutants, are monitored and reported on a regular basis. Because Malibu Creek has relatively low dilution and is subject to human contact, discharged wastewater must be completely pathogen free (RWQCB,LAR 1989).

Proposed Improvements. By 1993-1994, TWRF is projected to be complete, with the capabilities to treat and discharge 16.1 mgd. Improvements in the plant consist primarily of expansion and upgrades to the current facility.

INDUSTRIAL DISCHARGERS

Industrial dischargers include three power generating stations; Scattergood, El Segundo, and Redondo, and the El Segundo Refinery.

The power generating stations use seawater from Santa Monica Bay to cool steam condensers. Cool seawater is pumped into the station, circulated through noncontact heat exchangers, and discharged at elevated temperatures. In addition to increased temperatures, the once-through cooling water may include treated wastewater which is nonhazardous as defined by state and federal regulations. The wastewater may include water-side boiler tube cleaning wastes, cooling water blowdown, and various low-volume wastes consisting of fireside boiler tube wash water, water purification wastes, boiler and evaporator blowdown, in-plant floor drainage, and rainfall runoff. Chlorine is also injected into the once-through cooling system (condensers) periodically to control biological growth (RWQCB,LAR 1985a,b,c; Karapetian 1988, pers. comm.).

In addition, the following wastes could be discharged along with the once-through cooling water: wastewater from laboratory drains, metal cleaning wastes, treated wastewater from fuel pipeline hydrostatic testing, treated sanitary wastes, treated oil wastes, and groundwater. These wastes are held in settling basins before they are discharged to the ocean; residues from the basins are land disposed (RWQCB,LAR 1985a,b,c; Karapetian 1988, pers. comm.).

The growth of marine biofouling organisms in the discharge and intake conduits is periodically removed by recirculating a portion of the cooling water to achieve higher temperatures. These "heat treatments" kill fouling organisms as well as some fish and other nekton resident in the cooling water structures. Heat treatments are conducted every five to eight weeks and last two to four hours (RWQCB,LAR 1985a; Karapetian 1988, pers. comm.). Routine operation of generating station cooling systems may impinge and entrain a variety of marine organisms.

NPDES permits for generating stations limit constituents, as instantaneous and daily maximum or minimum levels or six-month median values. The regulated constituents include physical characteristics, metals, nonmetallic inorganics, toxicity, and radioactivity (RWQCB,LAR 1985a,b,c; 1991).

Concentration levels are measured in the discharged cooling water. However, because this water is unfiltered seawater, the same constituents are also found in the seawater entering the intake conduit. Calculations of mass emissions using cooling water flow and final discharge concentrations give unrealistically high values for these constituents. Therefore, the mass emissions given in the following sections are based on concentrations and flow from the retention basin discharge before it enters the cooling water effluent and reflects the mass emissions actually discharged by the plant itself. Chlorine is the only constituent added directly to the cooling water at another site in the system (Alcaino 1988, pers. comm.;

Schumann 1988, pers. comm.). An earlier study of the cooling water discharge of power generating stations in Southern California indicated that the transit through the plant increased intake (background) levels of trace metals by 0.21 ppb or less for each metal examined (Young *et al.* 1977). Thus the contribution of the cooling water discharge alone to trace metal concentrations appears to be very low.

SCATTERGOOD GENERATING STATION

The Scattergood Generating Station (SGS) in Playa del Rey is owned and operated by the City of Los Angeles, Department of Water and Power. It consists of three fossil-fueled, steam-electric generating units and has been in operation since 1958 (LCMR,IRC 1979; RWQCB,LAR 1985a). The cooling water intake is located about 1,600 ft offshore, at a depth of 18 feet below the surface. The discharge to Santa Monica Bay is 1,200 ft offshore at a depth of 15 feet below the water surface (LCMR,IRC 1979; RWQCB,LAR 1985a; Karapetian 1988, pers. comm.).

Effluent. The maximum flow from Scattergood is about 500 mgd with the average flow about 322 mgd (RWQCB,LAR 1985a). For the last five years the flow from the retention basins to the cooling water averaged 0.16 mgd (CLA,DWP unpubl. data). The temperature of the discharge averages 80.7°F in winter and 82.4°F in summer. During normal operations the temperature differential is approximately 20°F. The maximum allowable discharge temperature during a heat treatment is 135°F, and averages approximately 120°F. Flow during heat treatments is about 75% of that during normal operations, with 50% being recirculated within the station. The difference between intake and discharge temperatures can range from 35 to 85°F. The flow from other in-plant waste streams accounts for less than 0.05% of the total discharge (RWQCB,LAR 1985a; Karapetian 1988, pers. comm.).

Since 1987, Scattergood discharged an average of 1.6 MT of total suspended solids, and 0.32 MT of oil and grease to the once-through cooling water. Mass emissions of chromium and zinc have been measured in trace amounts during the 1988-1992 period (CLA,DWP unpubl. data). Emissions over the past five years have remained fairly consistent.

Permit Requirements. The NPDES permit for the SGS discharge no longer includes limits for suspended solids, oil and grease, or BOD. Based on five years of monitoring data, limits for these constituents were determined by the RWQCB to be unnecessary (Karapetian 1988, pers. comm.).

EL SEGUNDO GENERATING STATION

The El Segundo Generating Station in El Segundo is operated by the Southern California Edison Company (SCE) and consists of four stem-electric generating units. Units 1 and 2 have been in operation since 1955-1956 and Units 3 and 4 since 1963-1964 (LCMR and IRC 1979). Cooling waters for the two pairs of units have separate intake and discharge structures. Water for Units 1 and 2 is drawn from a water depth of 20 feet at the end of a conduit which extends 2,600 feet offshore and is discharged 1,900 ft offshore at a depth of 16 feet. Cooling water for Units 3 and 4 is drawn at a depth of 16 feet at the end of a conduit which extends 2,600 feet offshore and is discharged 2,100 feet offshore at a depth of 16 feet (LCMR,IRC 1979).

Effluent. From 1985 to 1987 the average flow through all units was 370 mgd; the flow through Units 1 and 2 averaged 106 mgd and through Units 3 and 4, 264 mgd. Discharge temperatures averaged 80°F for Units 1 and 2 and 85°F for Units 3 and 4 (Hertel 1988, pers. comm.). The average flow from the retention basins to the cooling water of all units was about 0.16 mgd in 1987 (Alcaino 1988, pers. comm.). The maximum temperature during a heat treatment is 125°F with the maximum difference between intake and discharge temperature during a heat treatment is 73.2°F (RWQCB,LAR 1985b).

Since 1989, emissions have averaged 3.4 MT of TSS and 1.7 MT of oil and grease. In 1991, the El Segundo Generating Station discharged about 4.8 MT of TSS, and 1.6 MT of oil and grease from the retention basin to the cooling water. Total flow from the El Segundo wastewater treatment plant in 1992 averaged less than 1 mgd, discharging approximately .07 MT of BOD, .09 MT of TSS, .03 MT of oil and grease, and 4,527 l/yr. of settleable solids (SCE unpubl. data).

Permit Requirements. Southern California Edison operates the El Segundo generating station under a NPDES permit issued in 1984, amended in 1985, and amended again in 1990 to include the objectives stated in the revised California Ocean Plan of 1988. Discharge limits for metal cleaning wastes, low volume wastes, and wastewater from treatment facilities must meet 30-day mean and daily maximum for: BOD, suspended solids, oil and grease, settleable solids, total copper, and total iron (RWQCB,LAR 1990).

REDONDO GENERATING STATION

The Redondo Generating Station, located in King Harbor, is operated by SCE and consists at present of four steam-electric generating units. Units 5 and 6 have been in operation since the early 1950s, and Units 7 and 8 since mid-1960. Units 1 to 4 went on-line in 1940 but were withdrawn from service in November 1986 (Curtis 1988, pers. comm.).

Cooling water for the two pairs of units are drawn and discharged in separate cooling water systems. Cooling water for Units 5 and 6 is drawn into two intake conduits at a water depth of 20 ft within King Harbor and discharged at a depth of 25 ft, north of the Harbor and 1,600 ft offshore. Cooling water for Units 7 and 8 is drawn at a depth of 20 ft from a conduit extending 1,000 ft offshore at the entrance to King Harbor and discharged within the Harbor at a depth of 20 ft (RWQCB,LAR 1985c).

Effluent. From 1985 through 1987 the average flow through Units 5 and 6 was 227 mgd and through Units 7 and 8, 530 mgd. The average flow in 1987 from the retention basins to the cooling water of all units was about 1.2 mgd (Alcaino 1988, pers. comm.). The average discharge temperature for Units 5 and 6 was 85.7°F and that for Units 7 and 8, 83°F (Hertel 1988, pers. comm.). The maximum temperature during a heat treatment is 125°F, which represents an increase of 68.5°F, over intake temperatures (RWQCB,LAR 1985c).

In 1992, the Redondo Generating Station discharged about 3.4 MT of oil and grease, and 6.7 MT of total suspended solids to the cooling water from the on site retention basin, a decrease of 85-90% from 1990. An average of 74 MT of suspended solids and 32.8 MT of oil and grease have been discharged during the period 1988-1992 (SCE unpubl. data).

Permit Requirements. Redondo Beach Generating Station is currently operating under an NPDES permit issued in 1984, amended in 1985, and amended again in 1990 to include the objectives stated in the revised California Ocean Plan of 1988. Limits on effluent constituents for metal cleaning, and low volume wastes are set with a 30-day mean and daily maximum for suspended solids, oil and grease, total copper, and total iron (RWQCB,LAR 1990).

EL SEGUNDO REFINERY

Chevron USA's El Segundo Refinery has been in operation since 1911 and now manufactures various petroleum products, including gasoline, jet fuel, kerosene, solvent, coke, fuel oil, liquefied petroleum gases, and propylene polymer. The refinery occasionally uses benzene and toluene in its processes, but these petroleum derivatives are manufactured else where. Manufacturing processes used at the refinery include distillation, catalytic cracking, alkylation, isomerization, coking, catalytic reforming, hydrogenation, sulfur recovery, and blending. The refinery has a maximum production capacity of about 405,000 barrels per day, although the average production is about 240,000-290,000 barrels per day (RWQCB,LAR 1984; Chevron USA 1988, pers. comm.).

Since the early 1970s ,the El Segundo Refinery has discharged treated wastewater through an outfall 500 ft offshore of the beach at Grand Avenue at a depth of approximately 20 ft (RWQCB,LAR 1984; Chevron USA 1988, pers. comm.). This discharge consisted of non-contact cooling water bleed-off, petroleum processing wastewater, treated boiler water, shallow recovery well groundwater, and stormwater runoff. All petroleum processing wastewater and shallow recovery well groundwater had been treated at an Effluent Treatment Plant (ETP) on the facility before being discharged.

In early 1993, Chevron announced plans to extend its wastewater pipeline two-thirds of a mile from the beach, effectively removing the last industrial discharger from the nearshore environment. The construction, which involves revamping an unused series of pipelines that stretch from the refinery to a tanker mooring, is expected to be completed within a year (LA Times 1993). The discharged effluent will still be processed through the ETP with treatment consisting of both primary and secondary processes including dissolved air flotation units, an equalization basin, and activated sludge (biological) units. Stormwater runoff is discharged after treatment in oil/water separators and induced air flotation units; if necessary, this can also be routed to the ETP for biological treatment. About 90% of this runoff may contain oil or other spilled contaminants (RWQCB,LAR 1984; Coonan 1993, pers. comm.).

Three tanks and an induced air floatation unit were constructed in 1988 as part of the Effluent Diversion Project to increase the residence time of the effluent during treatment. Two of the tanks have 7,140,000 gallons capacities and one has a capacity of 2,940,000 gallons (Chevron USA 1988, pers. comm.; Coonan 1993, pers. comm.).

Effluent. The refinery discharges 6 to 7 mgd of treated wastewater, with maximum discharges of up to 20 mgd and dry-weather flows of about 6.2 mgd (RWQCB,LAR 1984; Chevron USA 1988, pers. comm.; Dorsey 1988; Coonan 1993, pers. comm.). The most abundant constituents in the discharge are COD, BOD, and TSS, with average annual mass emissions of 1,760, 123, and 105 MT, respectively.

Permit Requirements. Chevron's NPDES permit limits a number of effluent constituents and includes six month medians, 30 day averages, and daily maximums for both dry and wet weather discharges. The regulated constituents include physical characteristics, metals, nonmetallic inorganics, organics, and toxicity (RWQCB,LAR 1984; Coonan 1993, pers. comm.). Settleable solids and turbidity do not have permit limitations but are monitored nevertheless (Chevron USA 1987; Coonan 1993, pers. comm.).

6 NONPOINT SOURCES OF CONTAMINATION

CHAPTER 6
NONPOINT SOURCES OF CONTAMINATION

While most of the contaminants found in Santa Monica Bay probably came from point sources and urban runoff (a nonpoint source), other nonpoint sources may also be a major factor. These include marine vessel activities, oil and hazardous material spills, dredging, ocean dumpsites, historically deposited sediments, advection, and aerial fallout.

MARINE VESSEL ACTIVITY

SMALL CRAFT BOATING AND HARBOR

Although boats berthed elsewhere use Santa Monica Bay, most small boat traffic is concentrated in Marina del Rey and King Harbor. Marinas act as collecting basins for a variety of substances, including raw and chemically treated sewage, fish wastes, antifouling paint additives, oil and grease, wash water, and trash as well as surface runoff. During ebb tides or storms these contaminants enter the Bay through harbor entrances and porous breakwater-sand jetties.

MARINA DEL REY

Marina del Rey was constructed between 1958 and 1962, from Ballona Wetlands. It includes about 403 acres of waterways (navigation channels and small craft berthing basins) and a similar amount of land-based support facilities. About one-third of the land is used by the Los Angeles County Department of Small Craft Harbors and two-thirds is leased to private entities (Soule and Oguri 1977).

About 6,000 boats can be harbored at Marina del Rey and hundreds more are in dry storage nearby: the number of boats berthed there increased from 5,500 in 1973 to 5,800 (SCCWRP 1973, Soule and Oguri 1992). The Marina includes four dry docks and two fuel docks (LACHP 1988, pers. comm.; MDRHMI 1988, pers. comm.). In addition to storm drains which empty directly into the Marina, tidal action carries storm water from Ballona Creek and Ballona Lagoon into Marina del Rey.

KING HARBOR

King Harbor was constructed between 1962 and 1968 (CCC 1987; Pitzer 1988, pers. comm.) and lies along the open coast between Hermosa Beach and the head of Redondo Canyon. It is surrounded by a porous breakwater which parallels the coast.

King Harbor includes about 110 acres of waterways and three small craft berthing basins. It has one fuel dock, two fishing piers, and berths for about 1,600 small boats (Straughan 1977a; Clemens 1988, pers. comm.; Pitzer 1988, pers. comm.). In 1973 there were about 1,400 boats in the harbor (SCCWRP 1973). Contaminants also enter King Harbor from surface runoff and the cooling water discharge of the Redondo Generating Station.

COMMERCIAL/NAVAL SHIPPING ACTIVITIES

During the late 1800s Santa Monica served as the City of Los Angeles' deep water port. At present most commercial and naval shipping activities occur outside Santa Monica Bay, in the shipping lanes offshore, and in nearby Los Angeles and Long Beach Harbors (Figure 6-1).

The entrance to Los Angeles Harbor is about 2.5 miles east of Point Fermin. In 1990, 7,013 vessels arrived at the Los Angeles-Long Beach Harbors, with over 1,000 of these tankers. Over 10,000 are expected to arrive in the year 2000 (USACOE/LAHD 1992). It is not known how many of these vessels pass by Santa Monica Bay, but it can be assumed that

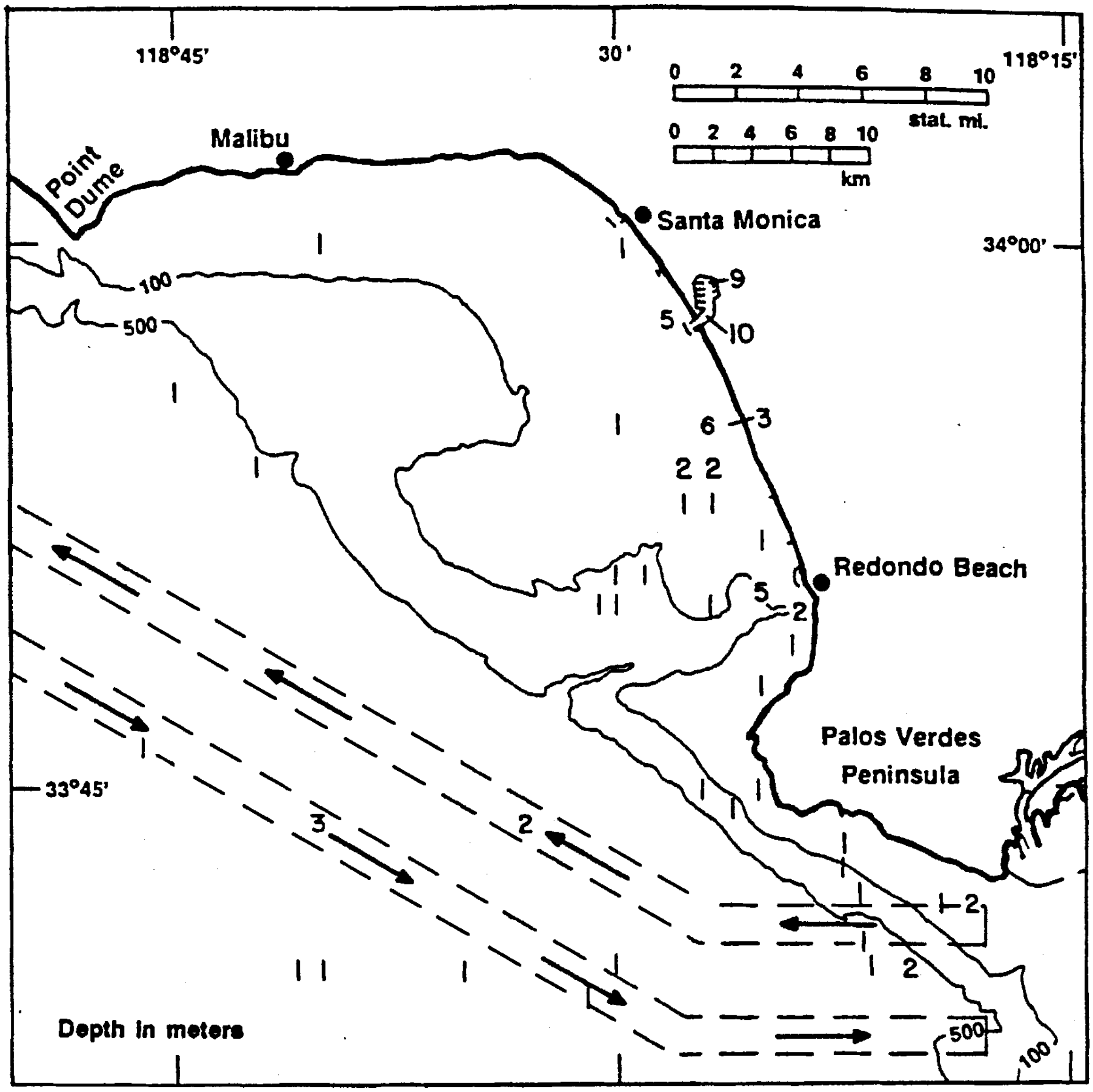


Figure 6-1. Shipping lanes and reported vessel spills (1973-1987 and 1991) in or near Santa Monica Bay area. (Numbers indicate number of spills; U.S. Coast Guard, Dept. Trans., unpubl. data).

several thousand pass the Bay during the year. The coastwise shipping lane extends west of Point Fermin for 8.9 miles before turning northwest and running parallel to the 1,640-ft isobath of Santa Monica Bay; it generally lies about 3.4 miles offshore of Santa Monica Bay (Figure 6-1).

Chevron USA maintains three submerged pipelines which extend from shore to a three-berth offshore tanker mooring facility in 42 to 66 feet of water. For the most part, these pipes transport crude oil and refined products (mostly gasoline and jet fuel) to tankers moored in the area (Chevron USA 1988, pers. comm.); refined product is occasionally off-loaded to the refinery.

Oil tankers cross the Bay from the coastal shipping lane to the moorings at a frequency of ten to 20 tankers per month (O'Reilly 1988). In 1980 and 1985, about 305 and 310 vessels arrived at the moorings respectively (MMS,POCSR 1983). About 200 tankers arrived in 1986 but only 92 in 1987.

TRACE CONTAMINATION FROM MARINE VESSELS

Trace pollutants from marine vessels include antifouling bottom paints, anticorrosion anodes, and fuel residues. Formerly, antifouling paints included copper, with trace amounts of mercury, arsenic, and PCBs; primers may contain zinc, chromium, and lead (SCCWRP 1973). In recent years tributyl tin (TBT) has been used in bottom paints as an antifouling agent. TBT is lethal (especially to mollusks) at parts per trillion levels. In 1984, 50 to 75% of pleasure craft used TBT paints and this percentage was probably higher for larger vessels (Soule and Oguri 1987). TBT-based paints are now banned on vessels less than 82 ft long that are not made of aluminum (CSG,MAP 1988).

Although its use is now restricted, much of the TBT paint from earlier applications has been sloughed, sanded, or scraped off boat bottoms, and may form a reservoir in the sediments of harbors and marinas. Because recreational vessels spend more time in port than large vessels and because their hulls are often scraped while in the water, small craft harbors may represent an important source of TBT (Soule and Oguri 1987).

In 1973, 90% of the sail and power craft in Marina del Rey used sacrificial zinc anodes to control galvanic corrosion; some cadmium was also used. Each boat uses an estimated 4 to 5 kg/yr for this purpose (SCCWRP 1973). If similar usage rates occur today, the two marinas contribute about 30 to 38 MT of zinc per year to Santa Monica Bay.

Most of the fuel sold to recreational vessels is leaded gasoline (Bender 1988, pers. comm.). In 1973, it was estimated that the use of leaded fuel by vessels in Marina del Rey contributed about 0.55 MT/yr of lead to the environment (SCCWRP 1973). Spillage of oil and combustion of fuel by small craft introduced PAHs to the harbors. Higher than background levels of benzo(a)pyrene have been found in King Harbor (Puffer 1988, pers. comm.).

In 1971, the estimated mass emission of mercury to the Southern California Bight from vessel-related sources (bottom-paint) was greater than the total estimated mass emission of mercury from the municipal wastewater and surface runoff combined. The estimated PCB and copper emissions from this source were about half of the combined emission for wastewater and runoff. Hence, vessel-related contaminants may be a significant contaminant source (SCCWRP 1973). At present the concentration of PCBs in antifouling paints is low but higher levels were found in older paints. Thus, the sediments in harbors may represent a reservoir which can release PCBs during dredging operations (Young and Heesen 1976).

OIL AND HAZARDOUS MATERIALS SPILLS

POTENTIAL SOURCES OF SPILLS

The potential sources for spills and contamination from oil and other hazardous materials in the Santa Monica Bay area include small craft boating and harbors, commercial shipping activities, refinery transfer activities, offshore oil and gas operations, natural oil seeps, underground contamination at Los Angeles International Airport and El Segundo refinery, and accidents on land which could move into the Bay through its tributaries. Spills can be highly variable in size, and consist of very different substances. They are unpredictable, and are usually caused by unexpected problems or equipment failures. They can cause little or no problems to major damage, coating miles of shoreline. A spill on the order of the Exxon Valdez could impact an area from the Mexican Border to the Central coast. Spills in the watershed can move through drainage systems to reach wetlands, the intertidal communities, and finally the ocean. Spills on the ocean can evaporate into the air, coat the surface, suspend by emulsion into the water column, or sink to the bottom, depending on the properties of the substance spilled. Petroleum products may separate into different constituents, each reacting differently.

BOATING AND COMMERCIAL SHIPPING SPILLS

The U.S. Coast Guard lists at least 82 vessel spills in Santa Monica Bay between 1973 and 1987, with an average of six spills per year; the locations of 37 more spills were questionable (Appendix E) (U.S. Coast Guard, unpubl. data). The spills listed were almost exclusively of petroleum products, including automotive and aviation gasoline and jet fuel; 31% of the spills were fuel oil, 17% crude oil, and 17% miscellaneous oil products. Spills totalling just under 2,000 gallons were recorded during this period; the median amount spilled was two gallons and only two spills were greater than 100 gallons. A tanker offshore El Segundo in 1977 spilled 1,000 gallons of crude oil, most of which was recovered. In 1973, 370 gallons of clarified oil were spilled from a recreational vessel in Marina del Rey.

In 59 of the 82 instances the vessel causing the spill was identified; 51% of these were recreational vessels, 29% tankers, and 14% fishing vessels. Twenty-four spills occurred in or near Marina del Rey, 17 were off El Segundo and Hermosa Beach, and 12 were in the commercial shipping lanes (Figure 6-1). More than 50% of these spills took place from 1973 to 1979.

In the past, there have been occasional small spills and leaks at Chevron's offshore terminal, with only two larger spills. A tanker leak of crude oil in December 1980 was cleaned up and caused no apparent harm to beaches or marine life (Chevron 1988, pers. comm.).

In March 1991, a transport vessel's anchor snagged the offshore mooring complex at the Chevron El Segundo Refinery, resulting in a spill of 9,240 gallons of a diesel oil/naphthalene mixture (MBC 1991a). At the time of the accident, an approaching low pressure weather front produced strong winds from the south-southeast, driving the floating oil to the north-northeast where it contacted the shore at Malibu. Beaches were closed to swimmers for a few days at Malibu and El Segundo during this period (Appendix I).

OFFSHORE OIL AND GAS OPERATIONS

Offshore oil and gas operations generate contaminants from a variety of point and nonpoint sources. Crude oil may be leaked in small amounts during exploration and production drilling or spilled in large amounts in a blowout, a tanker accident, or a rupture of a submerged pipeline. Refined petroleum products may be leaked or spilled during routine transfer operations and in tanker accidents or pipe ruptures.

Trace metals and other synthetic compounds are found in drilling muds and a variety of metals, combustion by-products, and other substances resulting from the operation of heavy gasoline- and diesel-powered machinery on boats and platforms. Domestic wastes generated at drilling platforms and aboard work vessels are treated in self-contained treatment plants and discharged overboard. Although operators in the Federal Outer Continental Shelf (OCS) dispose of drilling muds and cuttings at sea under a general permit, those from State Lands operations must be barged ashore for land disposal.

At present the major oil and gas operation in Santa Monica Bay is tanker traffic to and from Chevron USA's refinery in El Segundo, the largest refinery in California with a capacity of 405,000 barrels/day. The refinery does not treat Federal OCS production. In the past spills or leaks occurred about once a year during offloading or onloading at the offshore terminal.

Although oil and gas reserves are believed to occur on the Santa Monica Shelf, oil and gas development in or near Santa Monica Bay has been limited. It is estimated that the 40 tracts within the Bay have about 70 million barrels of oil and 90 billion ft^3 of gas.

By 1983, several lease plans had been considered which could affect Santa Monica Bay. Several alternatives were described in the draft Environmental Impact Statement (EIS) for the Southern California lease offering, describing different drilling scenarios as well as potential risks (MMS,POCSR 1983; MBC 1988). However, by June of 1990, Federal OCS lease sale 95 was canceled. In addition, no leasing will occur in any other areas offshore of California before the year 2000. In the Santa Barbara area, 87 tracts will be offered for lease before January 1996, adjacent to areas currently in production (MMS,OCSNC 91). It is not clear what impact this new activity in the Santa Barbara area would have for the Santa Monica Bay.

NATURAL OIL SEEPS

Two natural oil seeps are known from Santa Monica Bay. One, with three seepage zones, is located about 2.3 miles off Redondo Beach, near the head of the Redondo Submarine Canyon; the other has two seepage zones and is located about 4.6 miles off Manhattan Beach. It is estimated that an average of about ten barrels (420 gallons) of oil from the seeps reach the surface each day; additional oil probably does not surface, either deteriorating or forming tar balls underwater. The daily flow (to the surface) is estimated to range from two to 18 barrels (84 to 756 gallons) per day, but may be several times this amount during and after local earthquakes.

In calm weather surface oil slicks several miles long have been observed; in windy conditions the slicks dissipate rapidly. Surface oil generally drifts northward, towards shore, reaching the beaches from Redondo Beach to Malibu in one to two days. In 1971, 18 to 836 oil globules were found in a 2,500 ft^2 area of sand along Redondo Beach and Manhattan Beach; about 86% of these deposits originated from natural oil seeps (Marconsult 1971). More recent studies suggest that about 75% of the tar on Santa Monica beaches is from the Santa Barbara Channel (Hartman and Hammond 1981).

Natural oil from the vicinity of the La Brea Tar Pits also seeps into the Ballona Creek drainage system, contributing to contamination of the Creek and the Bay, especially during periods of low flow (Mitchell 1988, pers. comm.).

At least two accumulations of refined petroleum products have been identified adjacent to the shores of Santa Monica Bay. Although there is no evidence that any of these products have seeped into the Bay, their proximity to it has raised concern by the general public and regulatory agencies.

EL SEGUNDO REFINERY

During its first 77 years of operation, a variety of oil and refined products had leaked into the ground beneath the El Segundo Refinery (Chevron USA), from surface spills, storage tanks, and leaking pipes. The refinery is located atop sand dunes, under which three aquifers or subterranean layers of groundwater are located in sand beds separated by relatively impervious layers of clay. The removal of drinking water from the aquifers has caused seawater intrusion (Waters 1988).

For several years, Chevron contractors drilled numerous delineation wells to identify the size and nature of the contaminated pool located in the aquifers. The results indicated that the pool contained about 252 million gallons, primarily crude oil, gasoline, and jet fuel. Most of the petroleum contaminants had accumulated in the uppermost of three aquifers. Trace amounts had been found in the middle aquifer while the lowermost aquifers (the only one from which drinking water is extracted) appeared uncontaminated. Having identified the nature of the pool, Chevron began a program to recover as much of the pool as possible. 1988 estimates indicated that 50 to 70% of the materials could be recovered over the next 20 years (Waters 1988).

LOS ANGELES INTERNATIONAL AIRPORT (LAX)

During the years LAX has been operating, jet fuel has leaked into the ground beneath the airport from underground pipes or from the 500,000 gal storage tanks. Initial investigations indicated that the contamination extended to a depth of 60 ft and included the uppermost aquifer (which is brackish from saltwater intrusion), but the full extent of contamination is unknown (Kelley 1988).

Since the initial reports, LAXFUEL, a nonprofit consortium of 50 commercial airlines serving 98% of airline operations at LAX, has initiated investigations to characterize the extent of contamination. Phase I and II groundwater investigations were completed between 1989 and 1991. A free-hydrocarbon recovery system was approved by the RWQCB and installed in September of 1991. Since that time, approximately 10,000 gals of free-hydrocarbon product has been recovered. LAXFUEL is currently modernizing and upgrading its bulk storage facility, and conducting Phase III groundwater contamination investigations (Speelmans 1992, pers. comm.).

IMPACTS OF SPILLS

Impacts of oil or other hazardous material spills can reach all areas of the environment. Birds and marine mammals can be affected by a surface oil slick, by bioaccumulation in the food chain, or by direct toxicity from chemical spills. As spilled contaminants disperse through the water column, they can affect plankton, both plant and animal, as well as fish. They can also have toxic effects on kelp and other algal species which provide habitat for many animals in the Bay. When an oil spill sinks it coats the bottom and it can smother benthic communities that live in the sand and mud. Oil that washes up on the beaches or the intertidal zone can coat and smother species that dominate those areas. The California grunion, a fish that spawns on sandy beaches could be heavily impacted if a spill occurred during spawning season. Land spills, as well as ocean spills, could move into biologically sensitive wetlands, which are nursery areas for many species. Many of these areas do not have adequate baseline (pre-spill) information to determine the impacts on the communities and populations if a spill did occur (Lees 1992).

Following the 1991 spill at the Chevron USA offshore terminal, there were no observed impacts to California grunion spawning, sand crab populations, and the Santa Monica Bay artificial reef at Malibu (where the spill contacted the shore) nor were petroleum hydrocarbons found in beach sand; however, there was some mortality of mussels, spiny mole crabs, and possibly smooth turban snails (MBC 1991a).

In addition to the biological effects, there are aesthetic and economic effects for the human population. Large areas could be closed for recreational activities such as fishing, swimming, surfing, diving and sunbathing. This has an extended effect on businesses that depend on these activities. The fumes of a spill occurring, or moving ashore, in a heavily populated area could also result in health effects. Toxic materials could accumulate in sportfish species, and also cause residual health problems.

RISK OF FUTURE SPILLS

Current plans for oil and gas lease activity appear not to add any increased risk for future spills. However, if exploration and drilling resume, the risk will increase.

Commercial shipping is expected to increase for the near future. Los Angeles/Long Beach Harbors are expanding berthing facilities in their 2020 Plan to meet expected increases. In 1990, 7,013 vessels arrived at both ports, with over 1,000 of these tankers. Over 10,000 are expected to arrive in the year 2000 (USACOE/LAHD 1992). This will mean more traffic in the shipping lanes, with potential spills or accidents more frequent. It is not clear what number of these vessels transit the shipping lanes offshore of Santa Monica Bay.

The number of tankers loading and unloading at the El Segundo refinery has been steady for a number of years, however, Chevron recently received a permit to tanker from Santa Barbara to Santa Monica Bay. Currently none of these tankers has had a major spill, but should one occur, it could have a significant impact in the bay as evidenced by the Huntington Beach spill in 1990.

PREVENTION AND RESPONSE TO OIL & HAZARDOUS MATERIALS SPILLS

In 1990, the State of California passed the Lempert/Keene/Seastrand Oil Act (SB2040) in response to the Exxon Valdez and American Trader oil spills. The result of this law was to create an Oil Spill Prevention and Response (OSPR) group in the California Department of Fish and Game (CDFG). The goal of the Act is to protect the marine ecosystem, sensitive habitats, and marine biota from the effects of petroleum while the objectives of the Act include the prevention and rapid response to petroleum spills. The Office of Oil Spill and Prevention and Response meets the objectives of this Act through inspection of facilities, development and promulgation of regulations pertaining to contingency plans, rapid response to petroleum spills, and the oversight of response tasks including containment, treatment, removal, cleanup and abatement. Wildlife rescue and rehabilitation, evidence collection, natural damage assessment and post-impact recovery monitoring are also ways in which the Office of Oil Spill and Prevention and Response meets the Act's objectives (Sowby 1993, pers. comm.).

The law states that every oil facility, transporter, and vessel in state waters have contingency plans, preventative methodology, and containment equipment on hand in case of a spill. This must include a list of contacts for reporting and assistance and identification of rescue and rehabilitation groups. A Response Unit must be created to assist in a spill, if needed. OSPR provides for Natural Resources Damage Assessment methodology to be applied to determine what impacts occur during a spill, and to provide help with remediation efforts after the event. One function of OSPR is to identify sensitive biological areas that would be most affected by a spill, and provide this information to maximize efforts to keep these areas from being impacted.

The Santa Monica Bay is within two of the OSPR response areas. One extends from San Luis Obispo to Point Dume, with the OSPR Coordinator stationed in Santa Barbara. The other extends from Point Dume to Dana Point, with the OSPR Coordinator stationed in Long Beach (Grant 1992, pers. comm.).

In addition to California legislation, the U.S. government passed the Oil Pollution Act of 1990 (OPA 90), which addresses spill prevention and response and contains requirements similar to California's SB2240. In addition, federal regulations are also being written to cover marine transfer facilities, bulk cargo carriers for oil landings in the ocean and mobile facilities, e.g., pipelines, railroad transport, and tank trucks. These are expected to be released in 1993, and will only cover specific types of oil and facilities. The regulations covering other types of hazardous materials have not yet been written.

The U.S. Coast Guard, Long Beach, has created a Port Area Committee, which is making contingency plans for the local area. These plans are pre-designed responses to spills of any size and type, from small up to the worst case scenario (Exxon Valdez size). The plans designate response actions and responsibilities for management, so implementation can be as rapid as possible.

A more general set of regulations exist under MARPOL, issued by the International Maritime Organization of the United Nations, effective in 1983. Regulation 26, Annex 1, MARPOL requires response plans for all ships of 400 Gross Tons (GT) or greater and bulk oil carriers of 150 GT or greater, and will be in effect in 1995 for existing ships. The regulation is presently in effect for ships under construction (Panagakos 1992, pers. comm.).

Local agencies, primarily fire departments, respond to spills occurring on land. They are trained in containment and response procedures and maintain a list of agencies to notify in case of storm drain contamination. Local laws are in effect requiring businesses to provide hazardous material inventories to response agencies, and also require containment methodology and response plans to be present on site. A regular inspection program provides enforcement of this legislation. Inspection and response programs are also undertaken by interested groups, e.g., Ballona Creek Task Force.

DREDGING

Dredged sediments are the only materials that may be dumped into the Southern California Bight in large quantities, however, they must meet Ocean Dumping Act requirements (USEPA 1988). The Army Corp of Engineers, RWQCB,LAR and the EPA regulate and manage all dredging and oceanic dumping.

Dredging is necessitated by the accumulation of sediments around harbor entrances which pose potential navigation hazards to vessels. Removal of this material has typically been done by hopper dredges, clam shell dredges or dragging. Dredged material can be used for beach replenishment, landfill in harbors, dumped at oceanic dumpsites, or disposed in sanitary landfill sites. Disposal of dredge material must meet specific criteria for each disposal type. Beach replenishment material must undergo chemical analysis and meet grain size limitations for the location of disposal. Ocean dump site material has to undergo chronic and acute toxicity analysis as well as chemical analysis for trace constituents and heavy metals (USEPA 1988).

HISTORICAL DREDGING IN SANTA MONICA BAY

Net sediment transport in Santa Monica Bay is to the south in the northern part of the Bay and to the north in the southern portion of the Bay with the accumulation of the majority of materials at the head of the Redondo Submarine Canyon (Woodel and Holler 1991). Two areas of concern in sediment buildup are the Marina del Rey entrance channel and King Harbor.

King Harbor is uniquely situated along the coast at the head of the Redondo Submarine Canyon. Sediment transport and accumulation around King Harbor varies with seasonal, tidal and long shore current patterns. In general, transport of sediments is downcoast with accumulation on the upcoast side of the Redondo breakwater. Sediments transported around the breakwater are deposited at the head of the Redondo Submarine Canyon where they move down and off the nearshore shelf (Terry *et al.* 1956).

Between 1960 and 1963, the original Ballona Wetlands was dredged to create Marina del Rey Harbor and was, at that time, the largest dredging project on the West Coast removing approximately 10.1 million yds^3 of dredged material. Since that time, occasional dredging is necessary due to sediment deposition in the entrance channel of Marina del Rey. This deposition is partially due to the position of a breakwater off shore and parallel to the coast which creates an area of calm water inside the breakwater that facilitates the build up of sediment. Urban run-off from Ballona Creek also deposits material at the mouth of the harbor entrance. Dredge activities since 1969 have produced 684,080 yds^3 of material, ranging from 298,000 yds^3 in 1969, to 17,000 yds^3 in 1992 (Woodel and Hollar 1991; Chang 1992, pers. comm.). Dredge spoils from 1969 to 1987 dredge operations were disposed on the beach directly down coast of the Harbor entrance. Records were not available to determine if any chemical analyses were done for the 1981 and 1987 activities.

PRESENT DREDGE SITES

King Harbor was dredged in 1990 for the removal of accumulated sediments inside the Harbor following storm activities. In 1990, 156,000 yds^3 of material was dredged and used for beach replenishment 0.5 miles south of the Harbor. No chemistry data are available for this project because it was deemed clean and met all grain size criteria for disposal (Chow 1992, pers. comm.). All earlier dredging activities at King Harbor were similar to the 1990 dredging operations (Chow 1992, pers. comm.).

In 1992, approximately 17,000 yds^3 were dragged from the entrance of Marina del Rey Harbor to downcoast of the entrance, where long shore currents transported the material downcoast. Beach and LA-2 dumpsite disposal were not viable alternatives due to high levels of lead and heavy metal contamination which probably originated in run-off from Ballona Creek (Chang 1992, pers. comm.). Future dredging activities will be handled by dragging, as needed, until appropriate disposal sites can be found or measured contamination levels are below EPA regulations (Chang 1992, pers. comm.).

OCEAN DUMP SITES

The dumping of unwanted material at sea has been practiced for centuries and has been regulated by federal law since 1886, originally to prevent navigational obstructions. EPA permitted ocean dumpsites are point sources in the sense that only specified amounts of specific materials can be disposed in a prescribed area. In practice, however, every load is not carefully monitored, and the kind and amount of material dumped may differ from what is permitted. In addition, "short-dumping" (i.e., dumping before the vessel reaches the designated site to save vessel time and money) of materials may be common. Accurate records of dumping activities at dumpsites are generally lacking.

Illegal dumping has occurred in the study area, but quantification of the kinds and amounts of materials dumped is almost impossible. The California Salvage Company illegally dumped industrial wastes off White Point on the Palos Verdes Peninsula on two occasions in 1968, but it is not known what or how much waste was dumped in the area (Chartrand *et al.* 1985).

HISTORICAL DUMPING

Industrial wastes have been dumped into San Pedro Channel since the 1930s and continued more or less unregulated until 1967. Between 1967 and 1972, dredge spoils, oil refinery wastes, chemical wastes, filter cake, oil drilling wastes, refuse and garbage, radioactive wastes, and military explosives were dumped at 17 regulated dumpsites off Southern California (Figure 6-2). In 1972, the Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act) was enacted to regulate ocean dumping more closely and the disposal of hazardous materials (chemicals, munitions, bacteriological agents, etc.) at any offshore site was forbidden (Chartrand *et al.* 1985).

Prior to 1973, industrial wastes were dumped at a site (LA-1) in the San Pedro Channel, approximately ten miles northwest of Santa Catalina Island in 2,500 feet of water (Figure 5-1). Between 1947 and 1960 the California Salvage Company dumped about 125 million gallons of caustic and acid wastes from oil refineries and 2,000 to 3,000 gpd of acid sludge from the Montrose Chemical Company. This sludge contained DDT and it is estimated that

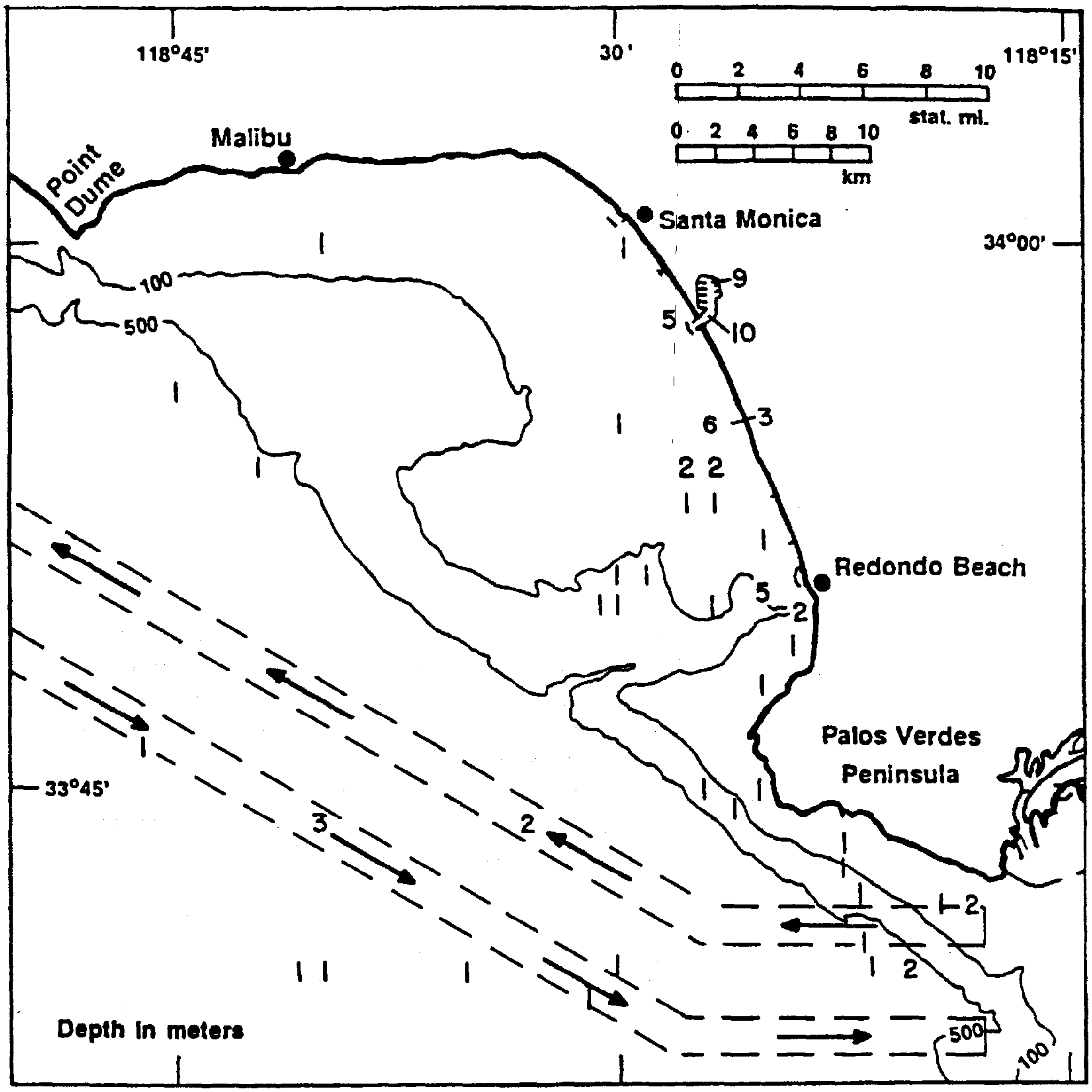


Figure 6-2. Designated ocean dumping sites in the Southern California Bight, 1931-1978 (modified from Chartrand *et al.* 1985).

over the years between 348 and 696 MT of DDT were dumped. Because of new oil refinery methods the total volume dropped from 1.2 million gallons per month to 210,000 gallons per month in 1961. Approximately three million gallons of refinery wastes were dumped between 1961 and 1972 (Chartrand *et al.* 1985).

In 1961, the RWQCB,LAR began regulating ocean dumping, requiring that wastes be in containers which were perforated just before they were dumped. Between 1965 and 1972, about 0.8 million gallons of aluminum chloride and 0.3 million gallons of cyanide were dumped in the ocean. Solvents and acid wastes, beryllium, cesium, bromine, and film-processing materials were also included (Chartrand *et al.* 1985).

Between 1961 and 1964, the Pacific Ocean Disposal Company also dumped liquid and solid wastes at LA-1. Most liquid wastes were pumped directly overboard, but some liquid and the solid wastes were in containers. About 1.6 million gallons of sodium hydroxide and 0.1 million gallons of calcium fluoride were dumped; polymer acid sludge, acid wastes, nitric-hydrofluoric acid, paint and lacquer, and hydrolyzed aluminum chloride solution were also present (Chartrand *et al.* 1985).

The Texaco Humble Union Mobile Standard (THUMS) dumpsite is a three miles diameter circular site near the center of the San Pedro Basin at a water depth of 2,910 ft (Figure 5-1). The closest edge is approximately eight miles from the study area. This site was designated by the EPA in 1985, for a period of three years, for the disposal of drilling muds and cuttings from THUMS' production operations in Long Beach Harbor. The drilling muds are similar to those approved by the EPA under a blanket permit for disposal in Outer Continental Shelf (OCS) waters (Chartrand *et al.* 1985). The THUMS dumpsite was in use for about one year (1986-1987), during which time about 50,000 barrels of drilling muds and cuttings were pumped from a barge as a slurry. THUMS did not reapply for an extension to the permit, allowing the site to become inactive (Otott 1988, 1992, pers. comm.).

LA-2 DUMPSITE

At present, there is one permitted dumpsite near, but outside of the study area (Figure 5-1) (Chartrand *et al.* 1985). This site may contribute to contamination of the Bay via advection but no estimates have been made of the amounts of material which might have moved toward shore.

The LA-2 dumpsite is a 1.1 mi diameter circle at a water depth of 600 feet, about 1.5 mi south of the study area (Figure 5-1). The site was given interim status by the EPA in 1977 for the ocean disposal of dredged materials (Rote 1985). Fine sediments which might be contaminated are tested in a laboratory bioassay before they can be dumped in the ocean, and if found to be toxic, are land-disposed.

The material dumped at LA-2 originates from maintenance and construction dredging in Los Angeles and Long Beach Harbors, which have multi-year permits for the disposal of dredged sediments. From 1978 to 1988 the U.S. Army Corps of Engineers issued permits for the disposal of 2.1 million yds^3 of dredged material at LA-2, but only 1.6 million yds^3 had been dumped. An average of about 180,000 yds^3 of material was dumped each year (USEPA 1988; Welch 1992, pers. comm.).

In 1989, SCCWRP estimated the quantity of material dumped and inputs of trace contaminants contained in disposed dredged material from 1984 to 1988. Six permit applications for dumping dredged material into LA-2, involving a total of 386,000 yds^3 were examined. Chemical data were available for only one dredge activity of 46,000 yds^3. It was assumed that the volume of dredged material discharged was equal to the amount permitted to be dumped in the application. Mass emission values were calculated from the available chemistry data and the total amount of sediments discharged. Due to the small size of the database it was difficult to determine exact mass emissions rates but a general trend can be distinguished. In general, the concentrations of contaminants in dredged materials is one-half to one-sixteenth those in municipal wastewater effluent. Although only limited chemical analysis of dredged materials has been conducted, dredge materials can reintroduce trace levels of constituents into the environment (SCCWRP 1989).

From January 1989 to March 1991, the LA-2 dumpsite was closed to dumping activities while an EIS was completed by the EPA (Cotter 1992, pers comm.). In March 1991, the LA-2 site was reopened under a new designation which allowed for continued dumping over a five year period. During this time potential environmental impacts will be monitored using current meter arrays, satellite imaging, and analysis of fisheries data. Continued use of the LA-2 dumpsite at the end of the five year period will be based on the environmental findings from this monitoring program. In the event EPA closes the LA-2 site, an alternative site must be designated within two years (Cotter 1992, pers. comm.). The EPA holds the final approval over permitting and can reassign the disposal of dredge material to land fills, beach restoration, and alternative ocean dump sites as needed (USEPA 1988).

Currently the Port of Long Beach has a five month contract ending in April 1993 for the disposal of approximately 710,000 yds^3 of dredged material at the LA-2 site. Other dredge contracts are planned for the Los Angeles and Port of Long Beach Harbors but anticipated dredged amounts are unknown at this time (Cotter 1992, pers. comm.).

ADVECTION

Advection is the transport of material by ocean currents. Prevailing currents not only disperse contaminants which are discharged into the Bay, but bring contaminants into the Bay from other areas. However, current patterns in the study area are complex and not well-known and very little effort has been expended in estimating the mass balance between contaminants entering and those leaving the Bay.

In general, water enters and exits at the seaward edge of the study area, along the 1,640-ft isobath. Surface water generally enters from off Ventura County or Redondo Canyon and leaves at the same places or to the south, offshore of the Palos Verdes Peninsula. Recent studies suggest that a clockwise gyre is dominant seaward of the 65-feet isobath (Hickey 1988, pers. comm.), but a counterclockwise gyre has been observed in Santa Monica Bay. Surface currents generally flow south off the Palos Verdes Peninsula, while below 290-ft, water enters the study area from the south.

Oil slicks, contaminants in the surface microlayer, and other floatables are likely to be transported into the Bay by wind-generated currents and waves. Tar from the Santa Monica Channel is carried into the Bay by advection (Hartman and Hammond 1981). Contaminants form the Los Angeles-Long Beach Harbor may enter the Bay from the south, in the subsurface current which flows north along the Palos Verdes Shelf.

The sediments at nearby ocean dumpsites may constitute reservoirs of contaminants which, if resuspended, could be transported into the Bay in deep currents. However, the general pattern is for fine sediments to move offshore and into basins where they are deposited. Thus, the likelihood of significant amounts of contaminants moving against that natural gradient is remote.

SEA SURFACE MICROLAYER

Many anthropogenic substances, such as trace metals, chlorinated and petroleum hydrocarbons, and plastics, accumulate in the sea surface microlayer. Little information exists on the distribution of contaminants in the microlayer in Santa Monica Bay because effective sampling methods have only recently been developed (SCCWRP 1986d, Cross *et al.* 1988).

In general, trace metal and PAH concentrations in the microlayer are higher by orders of magnitude in inshore areas of harbors than in offshore areas (SCCWRP 1986d, Cross *et al.* 1988). Chlorinated hydrocarbons were not detected in offshore areas but occurred in low levels at King Harbor. Benzo(a)pyrene, a carcinogenic and mutagenic PAH, has been found in the microlayer of King Harbor (Puffer 1988, pers. comm.).

The dominant trace metals in the particulate phase of the microlayer in King Harbor were iron, manganese, and zinc with concentrations of 1,105; 20; and 12 µg/l. The most important metals in the dissolved phase at King Harbor were copper, zinc, and manganese with concentrations of 4.14, 3.44, and 2.97 µg/l; at White Point these were iron, zinc, and copper with concentrations of 4.48, 3.93, and 2.08 µg/l (SCCWRP 1986d).

Oil and grease concentrations in the microlayer were 1.04 µ/l on the Palos Verdes Shelf at White Point. Total PAH levels were 2.65 µ/l at King Harbor and 0.59 µ/l at White Point. Total DDT occurred at 11 µ/l at White Point (SCCWRP 1986d).

WATER COLUMN

Most contaminants enter the ocean dissolved in or carried by water. However, their concentrations are affected by circulation rates and patterns and are often low; rapid dilution of point discharges makes concentrations even lower. Impacts are usually observed only in biota carried along with the water mass and exposed for longer periods.

DEBRIS

Natural and anthropogenic debris are most visible at the surface of the sea and at the shore. The distribution of debris is generally determined by wind or currents, and is not necessarily related to its origin. No estimates are available on the relative contributions of marine versus terrestrial sources, but tons of debris are removed annually from the shoreline of Santa Monica Bay. Much of this material, such as kelp, is natural and is removed for aesthetic reasons. Natural debris is eventually decomposed or consumed whereas man-made refuse, especially plastic, is persistent.

Ever increasing amounts of plastic debris are found at sea and on the shore. The average daily production of solid waste in Los Angeles County has increased from ten pounds per person in 1980 to 12 pounds per person in 1988 (MBC 1988). Although data are not available, trends in the marine environment probably parallel those of land disposal.

HEAT

In enclosed areas the addition of heated ocean water by power generating stations can cause severe impacts. In open coastal waters, waste heat seldom creates environmental problems. Waste heat from the three generating stations in Santa Monica Bay is detectable only in the nearshore surface waters between Dockweiler Beach and the Redondo Submarine Canyon (Figure 6-3).

The Thermal Plan prohibits a surface temperature elevation of more than 4°F above ambient following initial dilution and local power plants comply with this limitation (EQA/MBC 1973, IRC 1973). Areas of Santa Monica Bay which are affected by waste heat are actually smaller today than in 1973 because the availability of hydroelectric power from the Pacific Northwest has allowed most local power plants to operate below peak loadings. Two of the Redondo Generating Station's 8 units are now out of service, reducing the total potential for thermal pollution of the Bay.

TURBIDITY

Coastal waters are frequently murky, as a result of phyto- and zooplankton or of fine sediment suspended by nearshore turbulence. This natural phenomenon is often visible from the beach after a storm, when nearshore waters are brown, and offshore waters blue or blue-green. Both plankton and suspended sediments interfere with light penetration into seawater and restrict growth of seafloor plants.

Within a mile of shore, turbidity usually limits light penetration to less than 20 feet off sandy beaches and 20 to 40 feet off rocky shores (SCCWRP 1973). Off landslide areas at Portuguese Bend on the Palos Verdes Peninsula, turbidity is higher and light penetration less. Seaward of the surf-zone, turbidity declines and light penetration increases.

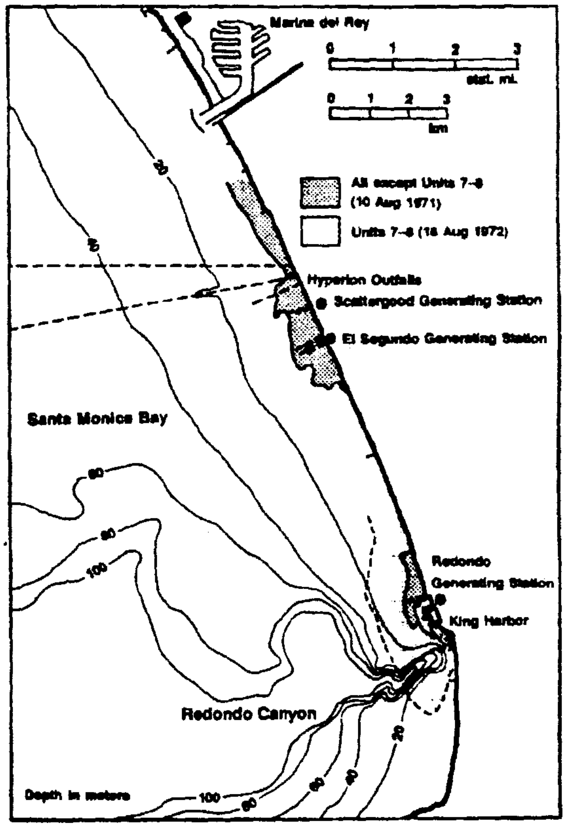


Figure 6-3. Maximum extent of 1°F above ambient thermal field from the Scattergood, El Segundo, and Redondo Generating Stations, August 1971 (Eliason and Foote 1972, EQA/MBC 1973).

Around the HTP 5-mi outfall the turbid plume caused by outfall particulates seldom reaches the surface; it usually remains below the thermocline, at depths of 65 to 100 ft (Kolpack 1979). Turbidity is highest near the ends of the outfalls but is rapidly reduced by dilution. Initially the plume moves southeast and toward shore, where it mixes with natural nearshore turbidity; it is then transported seaward by tidal currents.

Currents on the Palos Verdes Shelf are complex but primarily move along shore and toward the northwest. In the late 1970's, the turbidity plume from JWPCP outfalls rose to within 45 ft of the surface, and extended westward to Palos Verdes Point (Sweeney and Kaplan 1980). This plume most affected light transmission near-bottom, where it formed a flocculent particle layer (Meistrell and Montagne 1983). Water transparency in the study area generally increased between 1956 and 1979 (Mearns 1980); a trend which continued off Palos Verdes through 1985 (Stull *et al.* 1987).

METALS

Trace metals in the water column are found in two phases: dissolved and particulate. In the open ocean most metals are predominantly present in dissolved form, but in nearshore waters more are associated with particulates. Dissolved metals in marine waters are generally very low, even adjacent to outfalls (Katz and Kaplan 1981). Dissolved cadmium levels near the JWPCP outfall were about the same as those at control sites but chromium was elevated two-fold, nickel four-fold, and copper six-fold near the JWPCP outfalls (Young and Jan 1975).

Over 90% of the metals in wastewater of the study area associated with particles (Young and Jan 1975). Ninety percent of the particles in the HTP 5-mi effluent and 75% in the JWPCP effluent remain suspended for at least three hours, and travel six miles or more before settling (Herring and Abati 1978). Metals concentrations on suspended particulates near JWPCP were elevated 8 (cadmium) to 65 (chromium) times over background levels. The average enrichment (over background) of mercury on particulate matter near the JWPCP outfall was 36-fold. When the HTP 7-mi outfall was in operation, mercury enrichment ranged from 36 to 191 times, averaging 49.

The concentration of organotin compounds (tri-, di-, and monobutyltin) have been measured in seawater from both Marina del Rey and King Harbor. In King Harbor, total organotin levels ranged from 0.171 to 0.480 ppb, with tributyl tin (TBT) levels between 0.021 and 0.060 ppb (Stallard *et al.* 1986). TBT and total organotins were both higher in Marina del Rey water, TBT reaching 0.470 ppb (Soule and Oguri 1987). Dissolved tin compounds were not detected outside of enclosed marinas.

INORGANIC NONMETALLIC NUTRIENTS

Nutrients are introduced to the photic zone in runoff, via upwelling and destratification of the water column, and by sewage disposal. They stimulate plant growth and are generally beneficial, although excessive algal growth can have deleterious effects. Nutrients in the water column are linked with those in sediments by cyclic chemical transformations. Nitrogen is found in numerous forms including ammonia, nitrate, organic nitrogen, and nitrogen gas (Valiela 1984). After advection and upwelling, sewage was the most important source of these materials.

Nitrogen is never available for long in the open ocean. Nitrate, nitrite, and ammonia uptake by plants is swift and prevents their accumulation in surface water. Both nearshore and offshore ammonium inputs were clearly visible along the HTP 5-mi outfall in Santa Monica Bay (Figure 6-4) (Eppley *et al.* 1979). Inshore, near the El Segundo Refinery outfall, surface waters showed elevated ammonium on seven of ten cruises between 1975 and August 1977. Elevated levels have not been measured there since August 1977 and even the highest observed levels pose no hazard to exposed organisms (Eppley 1986).

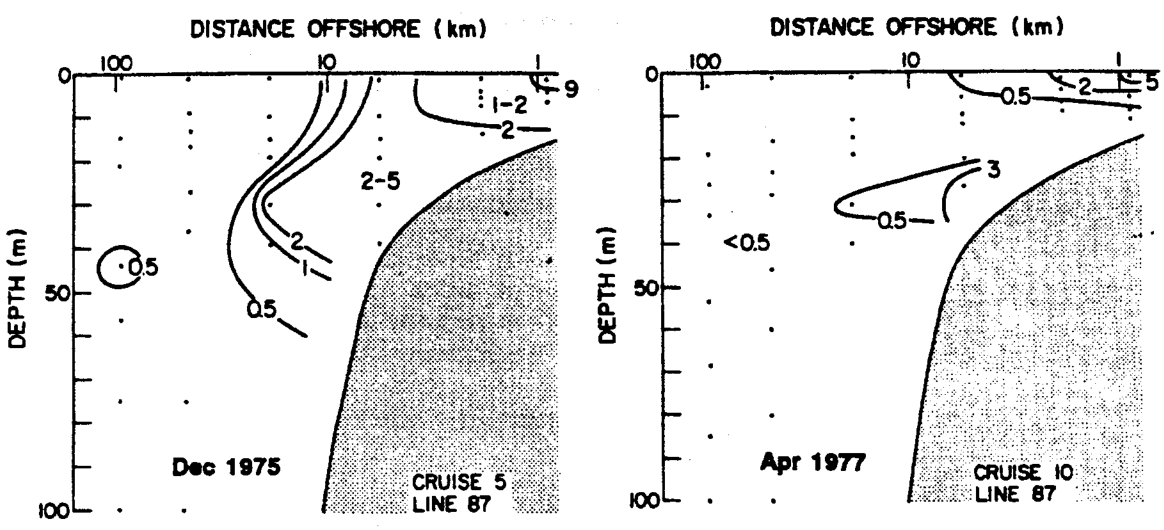


Figure 6-4. Concentrations of ammonium in ug-atoms/l from shore through mid-Santa Monica Bay parallel to the HTP outfalls in December 1975 and April 1977 (Eppley *et al.* 1979)

Toxic substances such as chlorine, sulfide, cyanide, and asbestos fibers are introduced with both sewage and runoff waters and by fallout or in solution from the air. Chlorine is generally introduced only as residual chlorine in sewage following its application as a disinfectant and is present in wastewater as chloramines. At present, HTP does not routinely chlorinate its 5-mi effluent (nor did it chlorinate its sludge), although it chlorinates overflows discharged through the 1-mi outfall. JWPCP routinely chlorinated its effluent from 1972 to 1985 during cold months when the thermocline is absent and year-round since September 1985 (Ackerman 1988, pers. comm.; Weisman 1992, pers. comm.). The discharge limit for chloramine is 0.3 mg/l - typically JWPCP effluent is <0.1 mg/l (the detection limit) (Stull 1993, pers. comm.).

The three generating stations in the Bay use chlorine to control biofouling growth in cooling systems, but under normal circumstances none is discharged into the Bay. It is not known whether significant levels of by-products of chlorination, such as chloramines and bromamines, occur in this effluent.

Data on dissolved sulfides and cyanide are not available from the study area. Asbestos has not been monitored sufficiently in the study area to establish either distribution or input levels (MBC 1988).

ORGANIC CONTAMINANTS

Contrary to popular belief, all organic materials are not contaminants. The input of natural, terrestrial organic material via rivers predates man's influence and is an essential part of the normal nutrient cycle. However, man has controlled the input of organics to the sea by diverting them to drainage channels or sewage waste streams. Basic measures of organic loading in waters and sediments include biochemical oxygen demand (BOD), chemical oxygen demand (COD), and organic carbon. These quantify organic matter in terms of oxidation demand or carbon content. In open water such as the study area, dissolved and particulate organic materials almost never depress available oxygen below levels safe for marine organisms on the continental shelf. Particulate organic material may, however, be present to excess.

BIOLOGICAL PATHOGENS

Bacteria, viruses, and protozoans are introduced into marine waters at sewage outfalls, bathing beaches, and storm drains. To minimize pathogens, sewage effluents which are discharged nearshore are treated (i.e., disinfected) with chlorine. Once introduced into the marine environment, pathogens are found both free in the water column and on particulates. Biological pathogens are discussed in more detail in Chapter 11.

AERIAL FALLOUT

Aerial fallout is a diffuse and potentially large source of contaminants which also derive from other sources. However, it is probably the least controllable source and possibly the most difficult to quantify. Relatively few studies have been conducted to assess the kinds and amounts of contaminants which enter the ocean via this path. Trace metals, chlorinated hydrocarbons, and PAHs (SCCWRP 1973, 1986a) have been identified in aerial fallout to the study area.

During the late 1960s, zinc, lead, and manganese were the most abundant trace metals in rainfall in Southern California. Bight-wide, it was estimated that the mass emissions of lead, mercury, and manganese in aerial fallout actually exceeded those from discrete sources. However, given the smaller area and the presence of two major sewage discharges, this is not likely to be true for Santa Monica Bay and the Palos Verdes Shelf. The mass emissions of copper and zinc in aerial fallout in the Bight were about the same as from discrete sources and those of iron and nickel were less (SCCWRP 1973). Levels of lead in aerial fallout were greater in the vicinity of Los Angeles than on the offshore islands.

Bight-wide, dry-weather fallout emissions of DDT and PCB in 1973-1974 were lower than those from municipal wastewater, about 1,300 and 1,500 kg/yr, respectively (SCCWRP 1973, Young and Heesen 1976). The highest fluxes of dry-weather aerial fallout of DDT in the Bight were at Santa Monica and Point Fermin where averages were estimated at 0.665 and 0.575 $\mu g/m^2$ per day, respectively. For comparison, Point Dume and Palos Verdes Point averaged 0.280 and 0.155 $\mu g/m^2$ per day, respectively (Young *et al.* 1976b). Based on the area of the present study and average fluxes at the four sites, the mass emission of DDT to Santa Monica Bay during that period was about 113 kg/yr.

Dry-weather PCB fluxes in 1974 were 0.650, 0.500, 0.190, and 0.052 $\mu g/m^2$ per day at Santa Monica, Point Fermin, Point Dume, and Palos Verdes Point, respectively (Young *et al.* 1976b). The mass emission to Santa Monica Bay during this period is estimated at 94 kg/yr.

DDT was manufactured at the Montrose Chemical Plant in Torrance; until 1972, Montrose disposed of DDT process wastes at the Palos Verdes Landfill on the Palos Verdes Peninsula. The flux of DDT from the air near the plant and landfill were 31 and 16 times higher, respectively, at Santa Monica, whereas the flux of Aroclor 1254 was about twice as great at the Montrose plant as at Santa Monica (Young *et al.* 1976b). The flux of both DDT and PCB to Santa Monica Bay was twice as high during Santa Ana wind conditions as during normal dry weather (Young and Heesen 1976). In 1986, chlorinated hydrocarbons in the sea surface microlayer were higher near Los Angeles than further offshore (SCCWRP 1986d), possibly reflecting aerial fallout.

Brush fires create pulses of trace metals to the atmosphere by mobilizing metals deposited on foliage. In 1975, smoke from a large brushfire in the Angeles National Forest was carried out over Santa Monica Bay and the aerial fallout of most metals increased. The fluxes of manganese, iron, and chromium were six to eight times higher than normal; the area directly beneath the smoke cloud had by far the highest levels (Young and Jan 1975).

Airplanes departing Los Angeles International Airport fly directly over Santa Monica Bay. The combustion of jet fuel and gasoline probably contribute to the aerial fallout in this region. PAH and other hydrocarbons may be especially high in fallout below this air corridor although this has not been quantified. In addition, airplanes experiencing difficulties have been known to dump fuel over the ocean before attempting to land.

7

URBAN RUNOFF

CHAPTER 7
URBAN RUNOFF

Urban runoff is probably the most important of nonpoint sources of contamination to Santa Monica Bay and has been the focus of much public, political, and scientific attention during the past five years. Surface runoff (consisting of stormwater and nuisance water) is transported to the Bay via the watershed's drainage channels (i.e., natural creeks and open or enclosed storm drains). Because surface runoff from urban areas generally transports more contaminants than natural creeks, surface runoff is generally called urban runoff.

In many parts of the country, the storm drain and sewer systems are combined into a single system. However, in Southern California the storm drain system is separated from the sewage system because storms are infrequent and heavy in flow. Because urban runoff is not treated it may now be the most significant source of contamination to Santa Monica Bay. Surface runoff is discharged to the ocean via about 80 storm drains. Because there are so many drains and because the flow varies with the time of year, it has been difficult to quantify the kinds and amounts of total contamination.

Surface runoff probably constitutes an important source of trace metals, pesticides, and coliform bacteria. As the quality of sewage effluent has improved over the years, the relative contribution by storm drains has increased, even if its absolute contribution has remained the same.

DRAINAGES TO THE BAY

DRAINAGE AREA

The total natural drainage area of Santa Monica Bay comprises about 414 mi^2 (SMBRP 1992). In the north part of the Bay, the natural drainage follows the crest of the Santa Monica Mountains from just west of the Los Angeles-Ventura County Line to Hollywood; a small crest separates the drainage west of Point Dume from that to the east (Figure 7-1). From the Santa Monica Mountains it extends south to Ballona Creek and the Baldwin Hills and east to downtown Los Angeles. South of Ballona Creek, the natural drainage is a narrow coastal strip from Playa del Rey to Point Fermin on the Palos Verdes Hills.

Inland, urban runoff from most of the wasteshed of Santa Monica Bay (i.e., the area with sewer lines leading to Hyperion Treatment Plant and the Joint Water Pollution Control Plant) flows into the Los Angeles River, San Gabriel River, and Dominguez Channel, all of which drain into Los Angeles and Long Beach Harbors (Figure 2-1). Hence, while most of the sewage from the metropolitan area of Los Angeles County discharges into Santa Monica Bay, most of the urban runoff from the same area discharges into Los Angeles-Long Beach Harbor in San Pedro Bay.

DRAINAGE CHANNELS

Numerous storm drains (pipes or open channels) empty onto or across the beaches of the study area (Figure 7-1). There are at least ten between the Los Angeles-Ventura County Line and Point Dume (Terry *et al.* 1956) and 68 between Big Rock Beach (east of Malibu) and Point Fermin; 37 of these are maintained by the Los Angeles County, Department of Public Works (LAC,DPW) and 31 by other organizations (LAC,DPW 1985). Along the Malibu and Palos Verdes coasts there are many small drains which collect runoff from a single street, parking lot, or small arroyo. Presently LAC,DPW is in the process of mapping drainage channels maintained by the cities in the study area (Hildebrand 1993, pers. comm.).

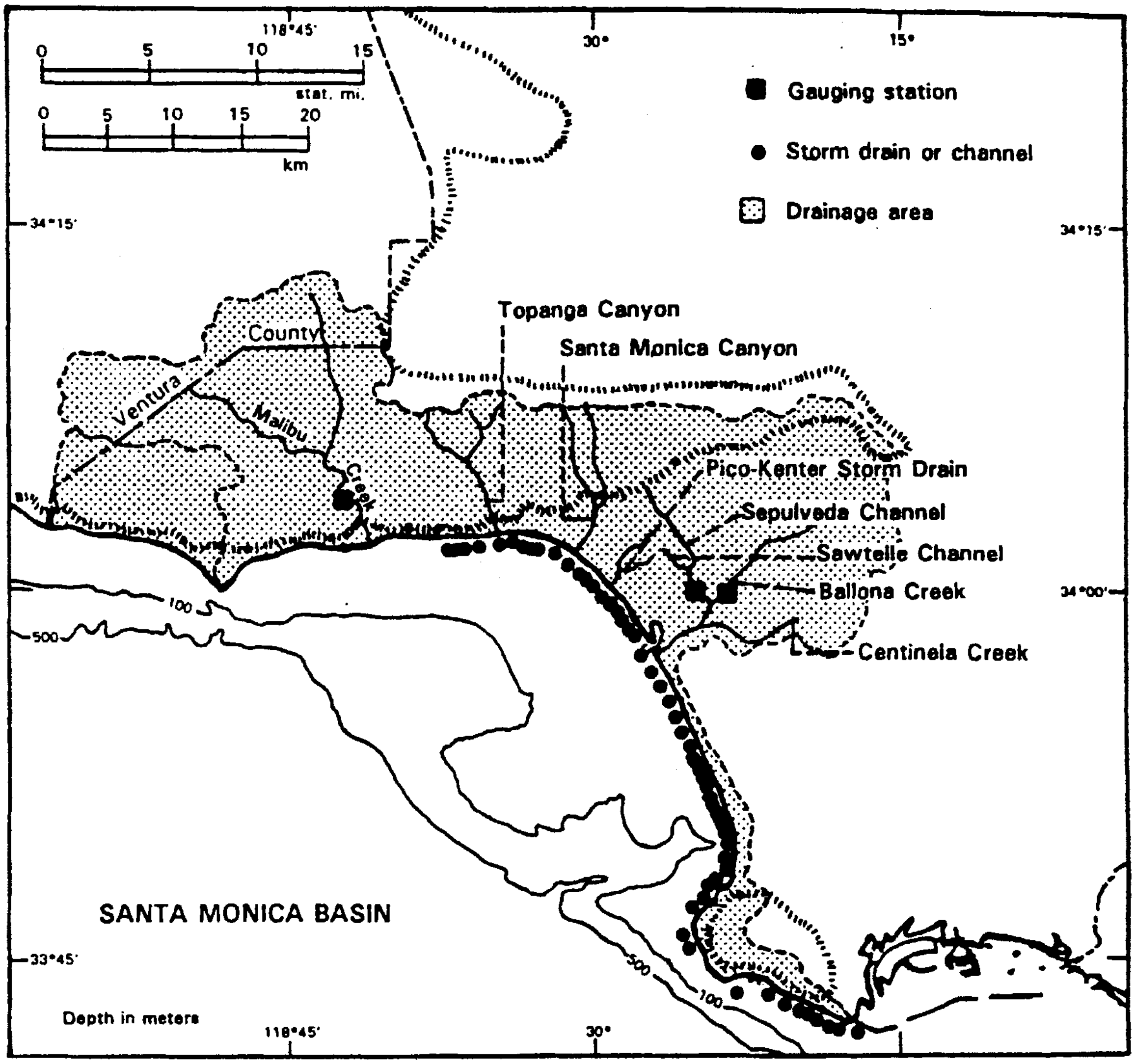


Figure 7-1. Present watershed and major drainage channels of Santa Monica Bay. Each dot represents one storm drain or channel (modified from LAC,DPW maps).

Of the major drainage channels in the area, Ballona Creek (including Centinela Creek and Sepulveda Channel) is channelized; Pico-Kenter and Santa Monica Canyon are partially enclosed storm drains; while Malibu Creek and Topanga Canyon are natural creeks. Ballona Creek drains about 130 mi^2 and Malibu Creek drains about 110 mi^2 (LAC,DPW unpubl. data).

The water quality of Marina del Rey is influenced by point source and nonpoint source discharges which enter either the Marina or adjacent contiguous waters (Soule *et al.* 1992). Ballona Creek, Ballona Lagoon, and the Oxford Flood Control Basin collect runoff from urban areas which enters the Marina as a result of tidal exchange or storm water runoff (Soule *et al.* 1992). Oxford Street flood control channel is one of the smaller drainage channels in the watershed, however, it is important because it drains into the Marina through a tide gate. Although Ballona Creek flood control channel carries a much larger volume of water from a larger area than Oxford Street basin, Ballona Creek seems to have less of an impact on the Marina (Soule *et al.* 1992). Heavy wet weather flow will carry much of the debris into Santa Monica Bay, but during dry weather low flow, debris will enter the Marina on rising tides.

RUNOFF FLOW RATES

Surface runoff has two major components: rainfall and nuisance water (street runoff from domestic activities, irrigation water, and commercial and industrial discharges). In the dry season, from May to October, surface runoff consists primarily of nuisance water. In the wet months, from November to April, most of the surface runoff is from rainfall.

ANNUAL FLOW

The average surface runoff flow to Santa Monica Bay from all storm drains and creeks has been estimated at 143 to 153 mgd (NRC,COWT 1984; Garber and Wada 1988). However, flow rates vary widely by season, by year, and during a storm due to the amount of rainfall. Ballona Creek and Malibu Creek are the major channels in the drainage with gauging stations. However, because the gauging stations are located upstream, they do not measure the entire flow from either creek (Figure 7-1). Hence, the absolute flows are actually larger than indicated below. Santa Monica Creek and Sepulveda Channel also have gauging stations (Engineering-Science 1987) but flow rates are not measured on a regular basis at these locations. The Topanga Canyon gauging station was destroyed during a storm in 1992 and at present there are no plans to replace this station (Hildebrand 1993, pers. comm.).

In normal (i.e., dry) years the annual flow in Ballona Creek is typically two to ten times greater than that in Malibu Creek whereas in wet years the two flows are more comparable (Figure 7-2). For instance, in 1984 (a dry year), the Ballona Creek mean annual flow was 19 mgd whereas that of Malibu was 12 mgd (MBC 1988). Similarly, in the dry years of 1988 to 1991, the mean annual flow from Ballona Creek was 24 mgd whereas that of Malibu Creek was 10 mgd (LAC,DPW, unpubl. data). In contrast, in 1983 (a very wet year) the flow in Ballona Creek was 81 mgd while that in Malibu Creek was 82 mgd.

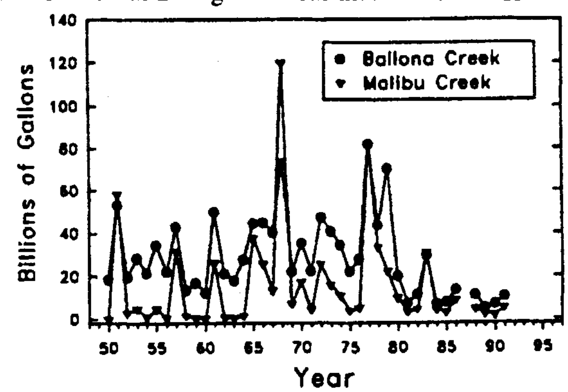


Figure 7-2. Annual flow from Ballona and Malibu Creeks for 1950-1951 (LAC,DPW unpubl. data).

However, in some wet years the flow from Malibu Creek is higher than that of Ballona Creek. For instance, in 1969 the Malibu Creek flow was about 1.5 times that of Ballona Creek. Similarly, in 1992 (January to September) the average daily flow in Malibu Creek was almost twice that of Ballona Creek (LAC,DPW unpubl. data).

Flow rates for Topanga Creek were only available for 1989 (a dry year). Flows averaged 0.2 mgd in Topanga Creek while flows averaged six mgd and 15 mgd in Malibu and Ballona, respectively (LAC,DPW unpubl. data).

SEASONAL FLOW

In addition to annual variation in flow there is seasonal variation between wet-weather (storm) and dry-weather months. In water year 1971-1972, wet- and dry-weather flows were estimated on the basis of instantaneous volumetric flows which were extrapolated to seasonal and annual flows for Ballona Creek, Pico-Kenter Storm Drain, and Malibu Creek

(SCCWRP 1973). The annual flow during that period in Ballona Creek was about ten times that of the Pico-Kenter Storm Drain or Malibu Creek, although only dry-weather flow was reported for Malibu Creek. In Ballona Creek wet-weather flow was 1.7 times greater than dry-weather flow, but in Pico-Kenter Storm Drain wet-weather flow was about 33% of dry-weather flow (SCCWRP 1973).

Based upon 1983 gauging station records, about 48% of the total flow in Ballona Creek and about 64% of it in Malibu Creek occurred during January and March. In 1984, about 39% of the total runoff in Ballona Creek was in December (LAC,DPW, unpubl. data). In 1991, 22% of the flow in Ballona Creek occurred in December and 65% occurred from January to March; however, in Malibu Creek about 15% occurred in December and 81% in January through March. Based on 1992 gauging station data for January through September, 86% of the total flow in Ballona Creek and about 88% in Malibu Creek occurred during January through March.

STORM FLOWS

Surface runoff is highest during and following storms and hence is usually highest during the winter. About 70% of the surface runoff in Southern California occurs during storms (NRC, COWT 1984). During a storm in 1986, the peak flow in Ballona Creek was 275 times the dry weather flow (Schafer and Gosset 1988a).

CONSTITUENTS OF URBAN RUNOFF

Surface runoff carries large quantities of sediment, debris, and dissolved materials to the ocean. Many of these constituents are characteristic of natural runoff and do not pose a problem to the environment. However, some contaminants are potentially a threat to human health, impact the marine habitat, or affect the aesthetic qualities of the Bay. Three categories of pollutants found in stormwater/urban runoff are of concern in Santa Monica Bay because of their potential impact on the marine environment and human health. These include toxic compounds, biological pathogens, and litter. Naturally occurring nutrients and sediment from construction activities may also impact enclosed bodies of water such as wetlands or streams.

Existing monitoring programs conducted by LAC,DPW include regular dry weather and storm sampling at Ballona Creek, Pico-Kenter Drain, Malibu Creek, Santa Monica Canyon Channel, Topanga Canyon, and Dume Creek (Hildebrand 1993, pers. comm.). Several one-time studies have also examined levels of constituents in urban runoff from the area (LAC,OCAO 1981; Schafer and Gosset 1988b; UCLA and WCC 1992).

SEDIMENT

Sediment naturally enters runoff during storms when rainwater flows over open areas. During the periods when the Los Angeles River discharged into Santa Monica Bay via Ballona Creek, storms probably transported large quantities of sediment to the Bay from the enlarged watershed area. However, even in the absence of a connection with the Los Angeles River, more sediment would have been transported in Ballona Creek prior to the construction of flood control channels during the early part of the 20th century (Terry *et al.* 1956) because the land in the drainage was less developed. Suspended sediments have not been measured in all surface runoff entering Santa Monica Bay, but aerial photographs of runoff plumes suggest that emissions are substantial, especially in natural drainages along the Malibu coast (Mitchell 1987, pers. comm.).

Mass emissions of silt are still highest in Ballona Creek. In water year 1971-1972, mass emissions of silt from Ballona Creek, Malibu Creek, and Pico-Kenter Storm Drain were estimated at 10,800, 1,000, and 700 MT, respectively. About 93% of the silt from Ballona Creek and about 71% from Pico-Kenter was discharged during storm flows (SCCWRP 1973). Sources of this silt include dust blown into the watershed by winds and sediments from upstream construction sites.

The soil in terrestrial areas adjacent to the Oxford Street flood control channel is highly contaminated with trace metals, pesticides and PCBs accumulated from earlier dumping or from World War II industrial contamination (Soule *et al.* 1992). During rainstorms, excavated soils erode and become suspended carrying pollutants into Marina del Rey harbor (Soule *et al.* 1992).

NATURALLY OCCURRING DISSOLVED CONSTITUENTS

Naturally occurring compounds and metals dominate the dissolved solids in surface runoff. These constituents are abundant in surface runoff in both developed and undeveloped areas and are not considered to be harmful. Naturally occurring dissolved solids in surface runoff include calcium carbonate, bicarbonate, sulfate, chloride, calcium, sodium, magnesium, organic carbon, potassium, nitrate, nitrite, ammonia, iron, fluoride, barium, and manganese, with traces of other metals. These constituents form the background environment to which contaminants or pollutants from human activities are added. Nevertheless some human activities in the watershed may increase concentrations and emissions of some of theses constituents.

From 1962 to 1982, the overall most abundant constituents from the five major drainage channels in the watershed were calcium carbonate, chloride, calcium, barium, and boron (Garber and Wada 1988). In 1983-1984 and 1989-1990, the major constituents of the surface runoff from Malibu Creek, Santa Monica Canyon, Pico-Kenter Storm Drain, Ballona Creek, and Centinela Creek were calcium carbonate, bicarbonate, sulfate, chloride, and calcium (Tables 7-1, 7-2) (LAC,DPW unpubl. data). The most abundant metallic ions were calcium, sodium, magnesium, and potassium. Dominant metals include iron, boron, and barium; abundant nonmetallic, inorganic constituents were chlorides and nitrates.

Constituent levels differ somewhat between drainage channels. In 1971-1972, mass emissions of most constituents were five to ten times greater in Ballona Creek than in the Pico-Kenter storm drain or Malibu Creek (SCCWRP 1973). In 1989, mass emissions of constituents in surface runoff were generally higher in Ballona Creek than in Malibu Creek (Table 7-3) (M. Stenstrom, Univ. Calif., Los Angeles, unpubl. data; LAC,DPW, unpubl. data). This was due in part to a flow in Ballona Creek that was more than twice that of Malibu Creek. Sulfate was dominant in both creeks but chloride, calcium, and sodium followed in Ballona Creek whereas in Malibu Creek, the order of the last three constituents was reversed (i.e., sodium, calcium, and chloride).

CONTAMINANTS

Constituents of concern in urban runoff are generally the same as are limited in NPDES permits for point source discharges. Toxic compounds include organic chemicals and trace metals can be directly toxic to marine organisms or can accumulate in the tissues of marine organisms and thus potentially cause adverse effects to the organisms or make them unfit for human consumption.

Contaminant levels in urban runoff are generally low, however, the more general categories of BOD and oil and grease as well as nutrients such as nitrates, ammonia, and phosphates are often abundant. For instance, in 1983-1984, mass emissions of contaminants (estimated from average concentrations in major channels) of BOD, oil and grease, ammonia, and phosphates were 1,514; 664; 277; and 201 MT/year, respectively (Table 7-4)(NRC,COWT 1984; LAC,DPW, unpubl. data). These constituents come from both natural and anthropogenic sources.

Trace metals are generally the next most abundant chemical contaminants. From 1962 to 1982 the major trace metal contaminants discharged to the Bay in urban runoff were zinc, lead, nickel, total chromium, copper, arsenic, selenium and mercury, with average mass emissions of 72.3, 17.9, 14.2, 12.4, 11.7, 2.9, 2.2, and 0.09 MT/year (Garber and Wada 1988). In 1983-1984, mass emissions of the dominant trace metals (estimated from average

Variable	Malibu Creek (n = 15)	Santa Monica Canyon (n = 15)	Pico-Kenter Stormdrain (n = 15)	Ballona Creek (n = 18)	Centinela Creek (n = 16)	Grand Mean
	Average Concentrations*					
High Concentration Constituents (mg/l)						
Total Dissolved Solids	907	764	625	664	514	695
Calcium carbonate	469	448	338	327	213	359
Bicarbonate	238	231	211	223	142	209
Sulfate	284	231	144	144	114	183
Chloride	83	61	85	89	91	82
Calcium	104	92	72	70	54	78
Sodium	89	55	66	81	80	74
COD	29	35	96	47	58	53
Magnesium	51	53	37	37	19	39
Total Organic Carbon	10	13	16	12	18	14
Low Concentration Constituents (mg/l)						
BOD	2.53	3.2	12.6	7.89	9.31	7.11
Potassium	4.41	3.97	4.87	3.66	6.91	4.76
Oil and Grease	-	-	4.54	2.16	2.65	3.12
Nitrate	3.19	2.92	2.56	1.57	1.52	2.35
Ammonia	0.42	4.33	0.64	0.84	0.27	1.3
Iron	1.05	2.03	1.56	0.31	0.82	1.16
Nitrite	0.24	0.02	5.05	0.06	0.02	1.08
Phosphate	1.71	0.61	1.03	0.73	0.64	0.94
Fluoride	0.65	0.66	0.54	0.69	0.57	0.62
Barium	0.09	0.52	0.17	0.07	0.18	0.21
Boron	-	-	0.11	0.12	0.2	0.14
Manganese	0.07	0.24	0.12	0.03	0.02	0.1
Trace Constituents (ug/l)						
Zinc	59.8	66.7	75.1	69.4	67.1	67.6
Nickel	29.5	171.6	35.6	13.5	19.8	54
Hexavalent chromium	<50.0	<50.0	<50.0	<48.1	<50.0	<49.6
Chromium	19.5	66.7	35.2	15.3	16.9	30.7
Copper	13.3	42	35	26	22.2	27.7
Lead	10	12.1	11.3	15.1	11.7	12
Silver	1.82	1.82	1.6	2.84	1.67	1.95
Cadmium	<1.3	<1.0	<1.1	<1.2	<1.0	<1.1
Mercury	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chlorinated Hydrocarbons (ug/l)						
DDT	-	-	0.341	0.028	0.065	0.144
Endosulfan	-	-	0.285	0.039	0.01	0.111
Endrin	-	-	0.212	0.013	0.03	0.085
DDE	-	-	0.108	0.052	0.07	0.077
Lindane	-	-	0.029	0.088	0.04	0.052
DDD	-	-	0.099	0.012	0.015	0.042
Heptachlorepoxide	-	-	0.019	0.031	0.015	0.022
Dieldrin	-	-	0.015	0.015	0.01	0.014
Aldrin	-	-	-	0.017	0.01	0.013
Heptachlor	-	-	0.015	0.011	0.01	0.012
Bacteria (cells/ml)						
Total coliform	72	58	781	998	394	461
Fecal streptococcus	49	174	571	180	174	230
Fecal coliform	4	7	98	72	65	49

Source: Modified from LAC,DPW, unpubl. data.

*Average concentrations of constituents from the combined years of 1983 (a wet yea.) and 1984 (a dry year). No attempt was made to specifically sample storm runoff.

Table 7-1. Average concentrations of constituents in surface runoff in creeks and storm drains entering Santa Monica Bay during 1983 and 1984.

Variable	Malibu Creek (n = 19)	Santa Monica Canyon (n = 24)	Pico-Kenter Stormdrain (n = 24)	Ballona Creek (n = 24)	Centinela Creek (n = 24)	Grand Mean
	Average Concentrations					
High Concentration Constitituents (mg/l)						
Total Dissolved Solids	1263	925	2834	726	637	1277
Chloride	149	118	1283	111	172	367
Sulphate	512	265	278	178	100	267
Sodium	156	102	741	97	123	244
Calcium	136	113	109	91	59	102
Magnesium	77	64	114	40	25	64
Potassium	10	7	44	7	12	16
Low Concentration Constituents (mg/l)						
Total Organic Carbon	3.75	3.89	9.53	7.89	9.52	6.92
Oil and Grease	1.65	1.93	4.15	2.50	3.32	2.71
Nitrate	5.43	2.73	1.79	0.95	0.56	2.29
BOD	0.92	1.21	3.07	2.09	2.95	2.05
Phosphate	2.33	0.08	0.57	0.17	0.61	0.75
Fluoride	0.67	0.55	1.18	0.46	0.39	0.65
Iron	0.13	0.99	0.85	0.13	0.23	0.46
Ammonia	0.07	0.15	1.01	0.12	0.19	0.31
Boron	0.38	0.18	0.37	0.20	0.23	0.27
Nitrite	0.14	0.18	0.34	0.21	0.19	0.21
Trace Concentration Constituents (ug/l)						
Barium	37.1	57.1	108.1	56.0	75.0	66.7
Zinc	25.3	45.4	75.0	42.5	63.8	50.4
Lead	31.6	25.6	75.6	19.0	18.3	34.0
Manganese	8.7	31.9	74.4	9.0	24.2	29.6
Copper	8.9	11.3	37.1	12.7	14.2	16.8
Chromium	13.2	11.9	17.7	15.4	12.1	14.0
Hexavalent chromium	10.5	10.0	10.0	10.0	10.8	10.3
Nickel	11.1	11.0	8.3	8.8	11.5	10.1
Cadmium	7.4	6.3	13.5	6.7	5.0	7.8
Silver	5.8	5.0	9.0	5.0	5.0	5.9
Mercury	0.5	0.5	0.5	0.5	0.5	0.5
Chlorinated Hydrocarbons (ug/l)						
Endosulfan	NA	NA	ND	ND	ND	
Endrin	NA	NA	ND	ND	ND	
Lindane	NA	NA	ND	ND	ND	
Heptachlorepoxide	NA	NA	ND	ND	ND	
Dieldrin	NA	NA	ND	ND	ND	
Aldrin	NA	NA	ND	ND	ND	
Heptachlor	NA	NA	ND	ND	ND	
Bacteria (cells/ml)						
Total Coliform	39	406	4288	389	932	1211
Fecal streptococcus	9	58	261	28	119	95
Fecal coliform	13	23	160	53	108	71

Source: Modified from LAC, DPW, unpubl. data.

NA = Not analyzed, ND = Not detected.

DDT, DDE, DDD – Data not available.

For bacteria levels, when parameter was recorded as >n for a particular month, n was used

Table 7-2. Average concentrations of constituents in surface runoff in creeks and storm drains entering Santa Monica Bay during 1989 and 1990.

	Malibu Creek				Ballona Creek				
	Total 83	Total 84	Total 89	Mean 83-84, 89	Total 83	Total 84	Total 89	Mean 83-84, 89	Grand Mean
Flow (billion l/yr)	114	16	9	46	112	27	21	53	50
Flow (mgd)	82	12	6	33	81	20	15	39	36
<u>High Emission Constituents (MT)</u>									
Calcium Carbonate	35672	9038	-	22355	31290	7376	-	19333	20844
Bicarbonate	20920	3423	-	12172	22913	4427	-	13670	12921
Sulfate	15100	6808	4091	8666	10952	4317	4076	6448	7557
COD	8500	346	-	4423	6167	1456	-	3812	4117
Chloride	7946	1484	1092	3507	8678	2118	2144	4313	3910
Calcium	8033	1945	1145	3708	6830	1520	2131	3494	3601
Sodium	6308	1802	1205	3105	7215	2048	2045	3769	3437
Magnesium	3779	1002	624	1802	3449	858	872	1726	1764
TOC*	3228	98	2	1109	1824	347	91	754	932
BOD**	478	44	-	261	1145	198	28	457	316
Potassium	354	85	94	178	358	97	162	206	192
Oil & Grease	-	-	9	9	383	-	29	206	105
Iron	544	0.5	0.5	182	71	12	2.16	28	105
Nitrate	247	101	3	117	155	24	30	70	93
Phosphate	164	40	18	74	119	6	4	43	59
Ammonia	25	1	0.4	9	221	3	1	75	42
Flouride	57	10	5	24	79	12	10	34	29
Boron	-	-	3	3	15	-	5	10	8
<u>Low Emission Constituents (MT)</u>									
Barium	25.29	0.6	0.21	8.70	8.15	2.07	1.05	3.76	6.23
Manganese	29.19	0.16	0.08	9.81	5.06	0.99	0.22	2.09	5.95
Nitrite	18.06	0.33	3.00	7.13	6.64	-	7.00	6.82	4.82
Zinc	10.04	0.13	0.09	3.42	9.33	2.62	0.51	4.15	3.79
Hexavalent chromium	5.69	0.82	0.13	2.21	5.62	1	0.21	2.28	2.25
Nickel	10.09	0.18	0.12	3.46	1.77	0.33	0.21	0.77	2.12
Chromium	5.33	0.16	0.13	1.87	1.82	0.55	0.29	0.89	1.38
Copper	2.68	0.18	0.05	0.97	3.67	0.76	0.12	1.52	1.24
Lead	1.14	0.16	0.69	0.66	1.22	1.09	0.51	0.94	0.80
Silver	0.45	0.02	0.05	0.17	0.61	0.07	0.10	0.26	0.22
Cadmium	0.23	0.02	0.04	0.10	0.15	0.05	0.11	0.10	0.10
Mercury	0.11	0.02	-	0.07	0.12	0.02	-	0.07	0.07
<u>Bacteria (trillion cells/yr (cell x 10^{12}))</u>									
Total Coliform	13991	132	146	4756	103163	84120	5295	64193	34474
Fecal Streptococcus	17747	49	19	5938	48985	-	523	24754	13465
Fecal Coliform	1384	7	13	468	16297	1800	490	6196	3332

Source: Modified from LAC, DPW, unpubl. data; M. Stenstrom, UCLA, unpubl. data

Note: Mass emissions for 1989 was calculated by adding monthly mass emissions. When parameter was not detected during a particular month, half the minimum detection level was used.
Selenium, aldrin, lindane, dieldrin, Heptachlor, heptachlorepoxide, Endosulfan, and Endrin were all not detected at Ballona Creek and not analyzed at Malibu in 1989.

BOD was not analyzed throughout 1989 at Malibu.
Data not available for DDE, DDD, and DDT in 1989.

* TOC - Total Organic Carbon
** BOD - Biochemical Oxygen Demand

Table 7-3. Mass emissions for Malibu and Ballona Creeks for 1983-1984 and 1989.

	Malibu Creek				Ballona Creek				
	Total 83	Total 84	Total 89	Mean 83-84, 89	Total 83	Total 84	Total 89	Mean 83-84, 89	Grand Mean
Flow (billion l/yr)	114	16	9	46	112	27	21	53	50
Flow (mgd)	82	12	6	33	81	20	15	39	36
High Emission Constituents (MT)									
Calcium Carbonate	35672	9038	-	22355	31290	7376	-	19333	20844
Bicarbonate	20920	3423	-	12172	22913	4427	-	13670	12921
Sulfate	15100	6808	4091	8666	10952	4317	4076	6448	7557
COD	8500	346	-	4423	6167	1456	-	3812	4117
Chloride	7946	1484	1092	3507	8678	2118	2144	4313	3910
Calcium	8033	1945	1145	3708	6830	1520	2131	3494	3601
Sodium	6308	1802	1205	3105	7215	2048	2045	3769	3437
Magnesium	3779	1002	624	1802	3449	858	872	1726	1764
TOC*	3228	98	2	1109	1824	347	91	754	932
BOD**	478	44	-	261	1145	198	28	457	316
Potassium	354	85	94	178	358	97	162	206	192
Oil & Grease	-	-	9	9	383	-	29	206	105
Iron	544	0.5	0.5	182	71	12	2.16	28	105
Nitrate	247	101	3	117	155	24	30	70	93
Phosphate	164	40	18	74	119	6	4	43	59
Ammonia	25	1	0.4	9	221	3	1	75	42
Flouride	57	10	5	24	79	12	10	34	29
Boron	-	-	3	3	15	-	5	10	8
Low Emission Constituents (MT)									
Barium	25.29	0.6	0.21	8.70	8.15	2.07	1.05	3.76	6.23
Manganese	29.19	0.16	0.08	9.81	5.06	0.99	0.22	2.09	5.95
Nitrite	18.06	0.33	3.00	7.13	6.64	-	7.00	6.82	4.82
Zinc	10.04	0.13	0.09	3.42	9.33	2.62	0.51	4.15	3.79
Hexavalent chromium	5.69	0.82	0.13	2.21	5.62	1	0.21	2.28	2.25
Nickel	10.09	0.18	0.12	3.46	1.77	0.33	0.21	0.77	2.12
Chromium	5.33	0.16	0.13	1.87	1.82	0.55	0.29	0.89	1.38
Copper	2.68	0.18	0.05	0.97	3.67	0.76	0.12	1.52	1.24
Lead	1.14	0.16	0.69	0.66	1.22	1.09	0.51	0.94	0.80
Silver	0.45	0.02	0.05	0.17	0.61	0.07	0.10	0.26	0.22
Cadmium	0.23	0.02	0.04	0.10	0.15	0.05	0.11	0.10	0.10
Mercury	0.11	0.02	-	0.07	0.12	0.02	-	0.07	0.07
Bacteria (trillion cells/yr (cell x 10^{12}))									
Total Coliform	13991	132	146	4756	103163	84120	5295	64193	34474
Fecal Streptococcus	17747	49	19	5938	48985	-	523	24754	13465
Fecal Coliform	1384	7	13	468	16297	1800	490	6196	3332

Source: Modified from LAC, DPW, unpubl. data; M. Stenstrom, UCLA, unpubl. data

Note: Mass emissions for 1989 was calculated by adding monthly mass emissions. When parameter was not detected during a particular month, half the minimum detection level was used.
Selenium, aldrin, lindane, dieldrin, Heptachlor, heptachlorepoxide, Endosulfan, and Endrin were all not detected at Ballona Creek and not analyzed at Malibu in 1989.

BOD was not analyzed throughout 1989 at Malibu.
Data not available for DDE, DDD, and DDT in 1989.

* TOC - Total Organic Carbon
** BOD - Biochemical Oxygen Demand

Table 7-4. Comparison of mass emissions for Pico-Kenter Storm Drain and major drainage channels in Santa Monica Bay in the early 1980s.

concentrations in major channels) contributed by urban runoff from major drainage channels in the watershed were 14.4, 11.5, and 10.6 MT/year for zinc, nickel, and hexavalent chromium, respectively (Table 7-4) (NRC,COWT 1984; LAC,DPW, unpubl. data). The dominant chlorinated hydrocarbons were total DDT, endosulfan, and endrin with estimated mass emissions of 31, 24, and 18 kg/year.

A previous estimate of mass emissions based on the same flow but using constituent concentrations obtained from the Pico-Kenter Storm Drain during dry weather conditions produced somewhat different values (Table 7-4). Total dissolved solids, chloride, sodium, COD, calcium, BOD, potassium, boron, zinc, lead, and cadmium had higher values while sulfates, magnesium, oil and grease, nitrates, phosphates, manganese, nickel, chromium, copper, and silver were lower (NRC,COWT 1984).

As with other constituents, contaminant levels differ between drainage channels. In 1971-1972, mass emissions of most contaminants were five to ten times greater in Ballona Creek than in the Pico-Kenter or Malibu discharges (SCCWRP 1973). In 1983-1984, Ballona Creek was higher in ammonia, oil and grease, and BOD while Malibu Creek was higher in phosphates, nitrates, and sulfates (Table 7-3) (LAC,DPW unpubl. data). In 1989, constituents that were more than ten times higher in Ballona Creek than in Malibu were TOC, nitrates (M. Stenstrom, Univ. Calif., Los Angeles, unpubl. data; LAC,DPW, unpubl. data). Levels of phosphates and lead were higher in Malibu Creek. Pesticides were only measured in Ballona Creek and these were dominated by total DDT and lindane (MBC 1988).

In 1980, dry-weather flow from Pico-Kenter Storm Drain was scanned for the presence of about 600 compounds; 250 were subjected to Ames testing for possible mutagenic properties. Although some components were mutagenic, no specific mutagen was identified. Possible mutagens found in the discharge were petroleum products; phthalate esters from thinners, lacquers, and varnishes; and automobile coolant (ethylene glycol esters and propylene glycol) (LAC,OCAO 1981; NRC,COWT 1984). Mutagenic organic substances have also been found in other stormwater samples of the Los Angeles area (Garber and Wada 1988).

BIOLOGICAL PATHOGENS

Urban runoff also contributes bacteria and viruses to the marine environment. Pathogenic (disease-causing) forms may pose potential health risks to swimmers and waders. Indicators of potential human contamination include total coliform, fecal coliform, fecal streptococcus, and enterococcus bacteria. The concentrations of these bacteria is measured to indicate possible presence of pathogens of concern to humans (Greenberg *et al.* 1985). Pathogenic agents which survive in seawater include viruses (hepatitis A and poliomyelitis), bacteria (Staphylococcus, Salmonella, and Vibrio), and a fungus (Candida albicans) (Kim 1975, Morris and Kim 1975, Dufour and Cabelli 1983).

Enteric bacteria are introduced via runoff in all drainage channels in the watershed. Enteric bacteria from Santa Monica Mountain streams (including Malibu Creek) and urban storm drains (including Ballona Creek) could pose a health risk to swimmers and waders in those areas.

In 1980, total coliform counts in dry-weather flow were highest in Centinela Creek while fecal coliform counts were highest in Pico-Kenter Storm Drain; lowest counts of both were in Ballona Creek (LAC,DPW unpubl. data). In 1983-1984, average concentrations of total coliform was highest in Ballona Creek; fecal coliform and fecal streptococcus was highest in Pico-Kenter Storm Drain.

In 1989, average concentrations of total coliform were more than 10 times higher in Ballona Creek than in Malibu Creek (Table 7-2)(LAC,DPW, unpubl. data). Average concentrations of total coliform, fecal streptococcus, and fecal coliform were highest in Pico-Kenter Storm Drain; the second highest concentrations were found in Centinela Creek.

Dry-weather coliform counts from the surf zone near storm drains during 1985-1987 were greatest near the Pico-Kenter and Pulgas Canyon Storm Drains. Elevated counts occurred throughout the surf zone of the Bay after storms but particularly near storm drains. The highest counts were off the Pico-Kenter Storm Drain and Ballona Creek (both sides); however, high counts were also found between Pulgas Canyon and HTP and off Torrance south of King Harbor (MBC 1988). Storms or extreme high tides carry fecal material washed off the jetties, such as dog, bird, and human feces, into the Marina (Soule *et al.* 1992).

LITTER

Litter enters the Bay with surface runoff, via ocean currents, and as a result deliberate or accidental disposal into the ocean or onto beaches (Pruter 1987). Most is aesthetically unpleasing and some litter may represent a physical hazard; however, some may provide food and habitat for marine life. Plastics and metals degrade slowly and may persist indefinitely.

Creeks receive a large amount of debris such as yard clippings, Christmas trees, fast food plastic containers, waste motor oil, and aluminum cans. Trash and debris significantly affect the aesthetic quality of the seashore and may cause the death of fish, birds, and marine mammals that become entangled in or attempt to consume items of litter.

INFLUENCE OF STORMS ON CONTAMINANT LEVELS

The major constituents in dry- and wet-weather flows differ considerably. In general, suspended and settleable solids are greater during storms while dissolved solids (mostly salts) are greater in dry weather. Calcium, magnesium, sodium, potassium, hexavalent chromium, calcium carbonate, bicarbonate, nitrate, chloride, fluoride, and endosulfan have greater dry-weather mass emissions. The mass emissions of most metals, ammonia, phosphates, TOC, BOD, COD, oil and grease, heptachlor epoxide, and lindane are greater in wet weather. Thus, most of the annual input of metals and organics to the ocean occurs in storm flows whereas most salts enter in dry-weather flows (LAC,DPW unpubl. data). Salts can generally dissolve in a small amount of water whereas a sizeable flow is required to suspend and carry silt and organics.

Highest concentrations generally occur in channels with the greatest flows also making them the greatest sources of mass emissions (Schafer and Gossett 1988). Highest contaminant concentrations occurred near the peak flows and not at the first increase in flow (Schafer and Gossett 1988b).

High mass emissions generally occurred in months when flows were highest (Figure 7-3). In 1991 mass emissions of lead and oil and grease were highest in March when the flow was highest in both Ballona and Malibu Creek. In 1992, flows in Malibu Creek and Ballona Creek were highest in February and decreased in March. In general, mass emissions of lead and oil and grease varied in respect to flow, with highest emissions in February and decreasing at the same rate as flow in March and April. Mass emissions of lead were extremely high in January 1989, in both Ballona Creek and Malibu Creek when flow was relatively low. This may be the result of heavy rains that occurred in December 1988, prior

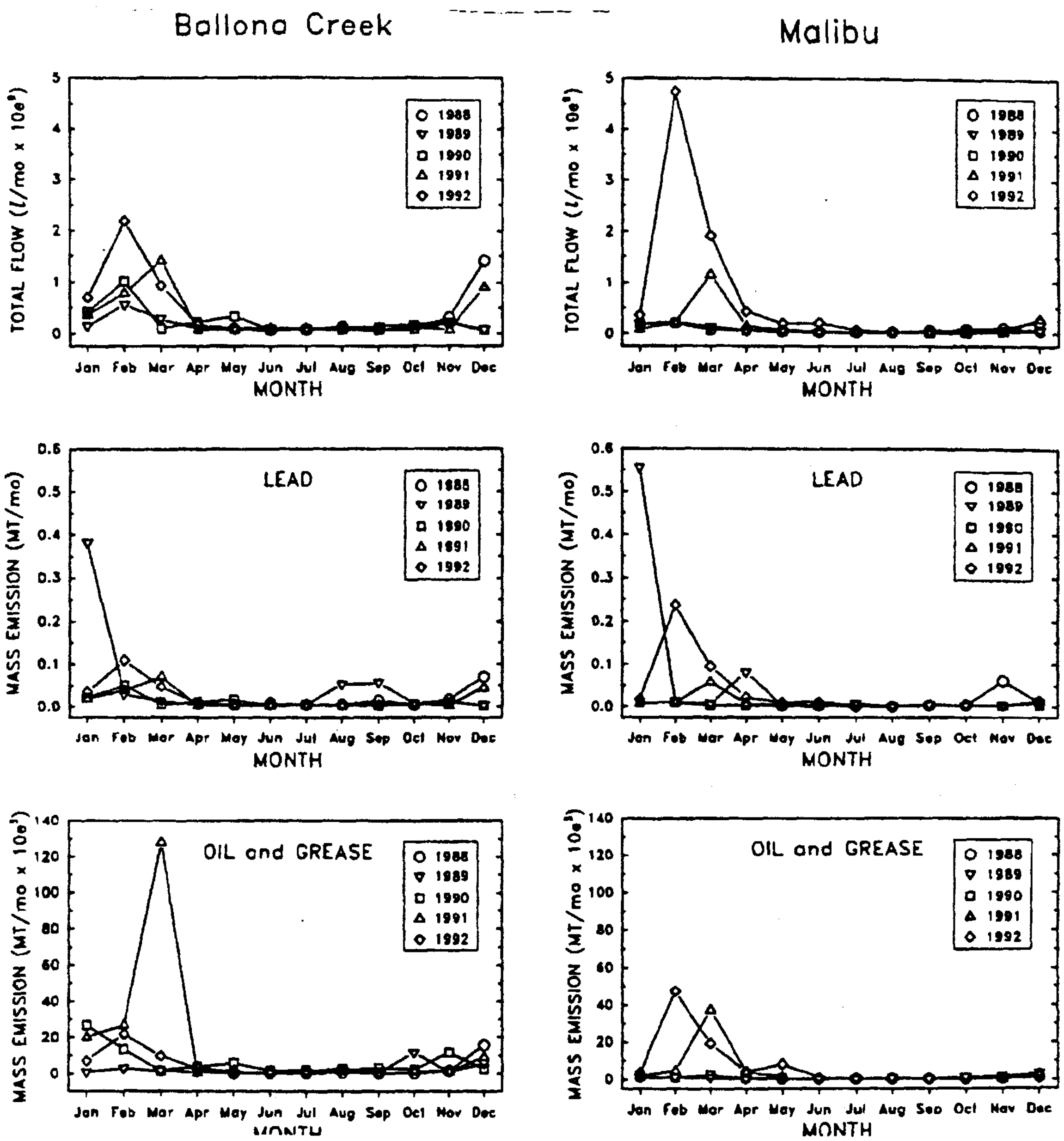


Figure 7-3. Average monthly flow and estimated mass emissions of lead and oil and grease in Ballona and Malibu Creeks, 1988-1992 (LAC,DPW, unpubl. data).

to sampling. These high values in lead may also be due to a spike or illegal discharge, or an error in sample analysis, however, concentrations were high in all drainage channels during that time. During dry periods mass emissions showed little to no variation from month to month.

RUNOFF DYNAMICS DURING A STORM

The first storm of the season (or any storm which follows a dry period of several weeks or more) that significantly increases stream flow generally creates an immediate pulse in the concentrations of contaminants which accumulated in streets, gutters, and channels during dry weather, low-flow conditions (Engineering-Science 1987, MBC 1988). The highest contaminant concentrations occur near the peak flows, not at the first increase in flow (Schafer and Gossett 1988b). During a storm in 1986, peak flows in Ballona Creek occurred 24 hours after the rainfall began but concentrations of most constituents were highest 13 hours after the beginning of the storm (when flow was 40% of the peak flow). Maximum concentrations of the constituents at 13 hours were greater than the minimum levels (which generally occurred 24-42 hours after the storm began) by the following multipliers: DDT, 1,360; lead, 261; total suspended solids, 192; total pesticides, 162; chromium, 110; cadmium, 29; zinc, 26; nickel, 19; and oil and grease, 17 (Schafer and Gossett 1988b).

COMPARISON WITH OTHER WATERSHEDS

Compared to other drainage channels in Ventura and Los Angeles Counties, Ballona Creek stormwater had the highest levels of oil and grease, DDT, and trace metals in runoff samples from the first storm after the dry season in 1986 (Schafer and Gossett 1988b). Both the Los Angeles River and Ballona Creek had the highest mass emissions of the contaminants examined; this was the result of both having the highest flow and highest mean contaminant concentrations. Ballona Creek had both higher concentrations and higher mass emissions of DDT than the Los Angeles River (Table 7-5) and other locations sampled within the Southern California bight (Schafer and Gossett 1988b). Concentrations of oil and grease and trace metals, except copper and chromium, were higher in Ballona Creek than in the Los Angeles River but the higher flow at the Los Angeles River resulted in higher mass emissions there (Schafer and Gossett 1988b).

Constituent	Station: Ballona Creek	Station: L.A. River Willow	Total	Station: Ballona Creek	Station: L.A. River Willow	Total
Total Volume ($L \times 10^9$)	4.5	11		4.5	11	
High Constituents						
	Concentrations (mg/g)			Mass Emissions (MT)		
Total Solids	2030	1410	3440	6900	10000	16900
Sus. Solids	-	-	-	3400	7100	10500
TEOs	35.3	53.5	88.8	120	380	500
Oil & Grease	19.7	15.5	35.2	67	110	177
Zinc	1.88	1.11	2.99	6.4	7.9	14.3
Lead	0.706	0.408	1.114	2.4	2.9	5.3
Copper	0.353	2.8	3.173	1.2	2.0	3.2
Nickel	0.106	0.073	0.179	0.36	0.52	0.88
Chromium	0.003	0.07	0.073	0.31	0.5	0.81
Cadmium	0.090	0.009	0.099	0.030	0.064	0.094
Low Constituents						
	Concentrations (ug/g)			Mass Emissions (kg)		
n-Alkanes	324	887	1211	1100	6300	7400
Total PAHs	32.3	56.3	88.6	110	400	510
Total PCBs	0.353	0.451	0.804	1.2	3.2	4.4
Total DDTs	0.5	0.131	0.631	1.7	0.93	2.63
Lindane	0.025	0.025	0.05	0.086	0.18	0.266
HCBs	0.004	0.006	0.01	0.015	0.044	0.059

Source: Schafer and Gossett 1988

Table 7-5. Flow and mass emissions of several runoff constituents in Ballona Creek (Santa Monica Bay Watershed) and the Los Angeles River (Los Angeles Harbor Watershed) during the September 23-25, 1986 storm.

SOURCES OF CONTAMINANTS

Potential sources of contaminants in runoff include household and industrial wastes, accidental spills, sewer overflows, septic tank leaks, illegal and illicit connections, excess runoff and chemicals from landscape irrigation, rubbish, used crankcase oil, grease, food by-products, wash water, debris discarded on the street, animal droppings, and settled air pollutants. Street runoff carries the metal, rubber, and oil residues from highways, while garden runoff carries pesticides (Soule *et al.* 1992).

Enteric bacteria in Malibu Creek may also come from the TWRF, which has discharged into the creek since the late 1970s. As of 1987, about 90% of the treated effluent is recycled and sold during the summer but in the winter, most is discharged into Malibu Creek. The effluent received advanced secondary from the late 1970s to 1984 and has received tertiary treatment since then. The effluent has been below NPDES limits for coliform about 99% of the time. However, since the effluent is dechlorinated (after disinfection with chlorine) before being discharged to the creek, it is possible that regrowth may occur (Colbaugh 1988, pers. comm.). Coliform bacteria in Malibu Lagoon and Malibu Creek may be from this source but may also be from soil, lower animal wastes, septic tanks in the drainage, or from waterfowl (Sowby 1988, pers. comm.).

Most of the residential area along the coast west of Palisades is unsewered and sewage is disposed of in septic tanks. Tanks that are in disrepair may leak and may contaminate the ocean. High coliform counts have been noted in the area after storms. Many residents in the area do not believe that a new sewer system is necessary because septic tank problems have been less common in recent years. The coliform contamination in this area may also be from pets, wildlife, and birds (Stewart 1987).

CONTRIBUTION OF CONTAMINANTS BY LAND USE

Pollutant loadings are affected by various factors such as rainfall pattern, land use, and area of the drainage basin. There are 28 separate drainage basins within the Santa Monica Bay watershed (Figure 7-4). Each drainage area is unique due to topography and land use: the largest drainage areas are Ballona and Malibu Creek. Major types of land use include residential (single-family and multi-family), commercial, public, light industrial, other urban, and open areas (Figure 7-5). Open space is the primary land use in the Santa Monica Bay watershed with 57% of the total watershed area; it is followed by single-family and multi-family residential at 26% and 7%, respectively. Commercial and light industrial uses constitute the remaining 10% of the total watershed area (UCLA and WCC 1992).

The type of land use strongly influences the pollutant load: the more impervious area, the greater the runoff (UCLA and WCC 1992). The dominant form of land use, open space, has no impervious surface area whereas commercial land use has the highest (92%) impervious surface area. Thus, more runoff per unit area will result from commercial areas than from open areas. In single-family residential areas, an average of 35% of the surface is impervious. Since more land in the Santa Monica Bay watershed is devoted to residential use than commercial, residential accounts for a greater percentage of runoff pollutants. (SMBRP 1992).

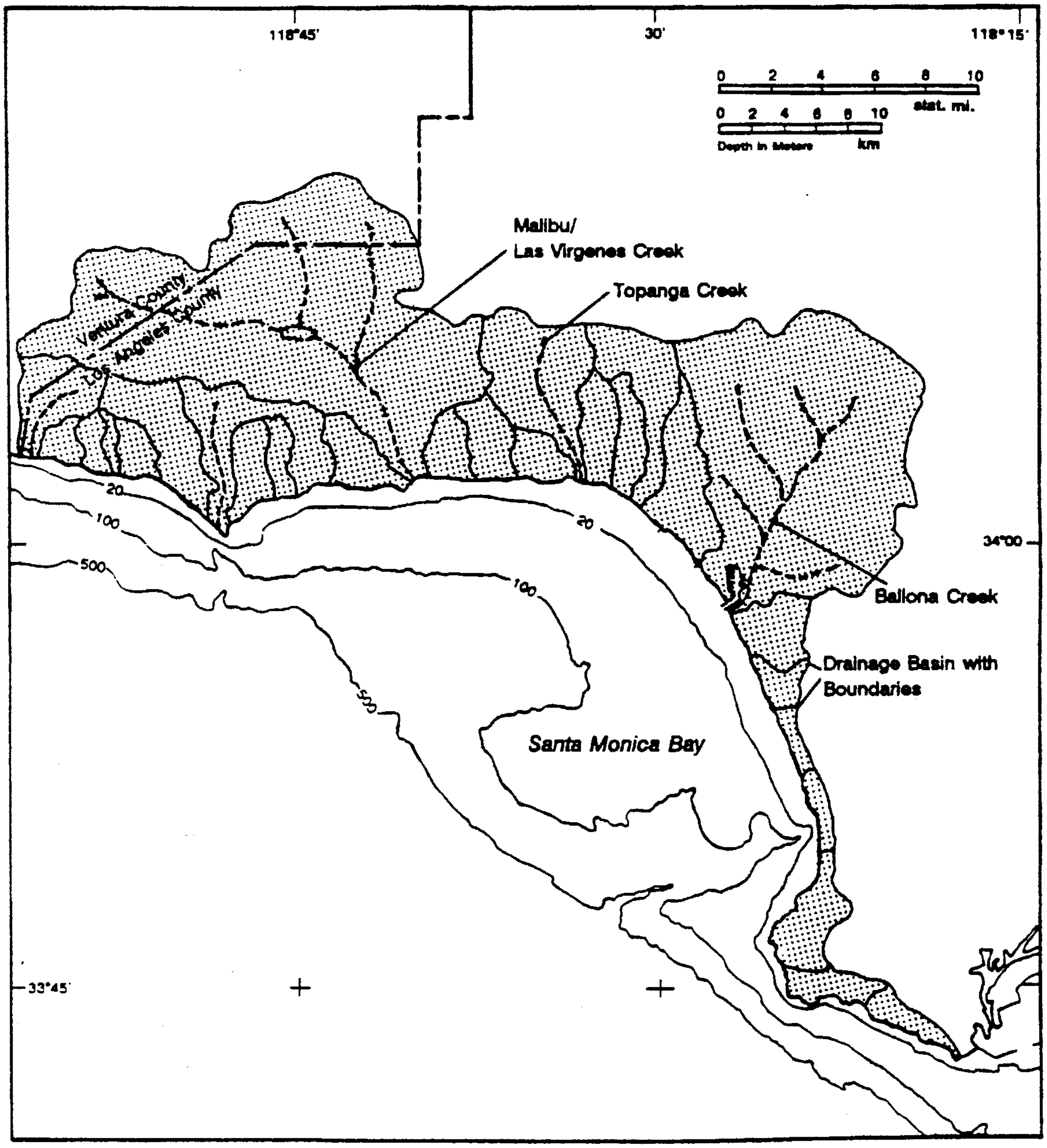


Figure 7-4. Drainage basins within the Santa Monica watershed (modified from SMBRP 1992).

Among measured attributes, oil and grease were the dominant constituent in runoff from multi-family residential, commercial, public, light industrial, and other urban areas; BOD in single-family residential areas and TKN in open areas. Single-family residential areas contribute the highest percentage of BOD, COD, total phosphorus, soluble phosphorus, TKN, nitrite and nitrate, copper, lead, and zinc. Open areas contribute the highest percentage of total suspended solids and multi-family residential areas contribute the highest percentage of oil and grease (Table 7-6) (UCLA and WCC 1992).

Single-family residential areas contributed approximately 50% of the annual load of the oxygen demand, and nutrient pollutants (Table 7-6). All other land use types contributed mostly to oil and grease; the largest contributors are from multi-family and commercial areas. The greatest percentage of copper, lead, and zinc is also from single family residential areas. TSS predominantly comes from open areas.

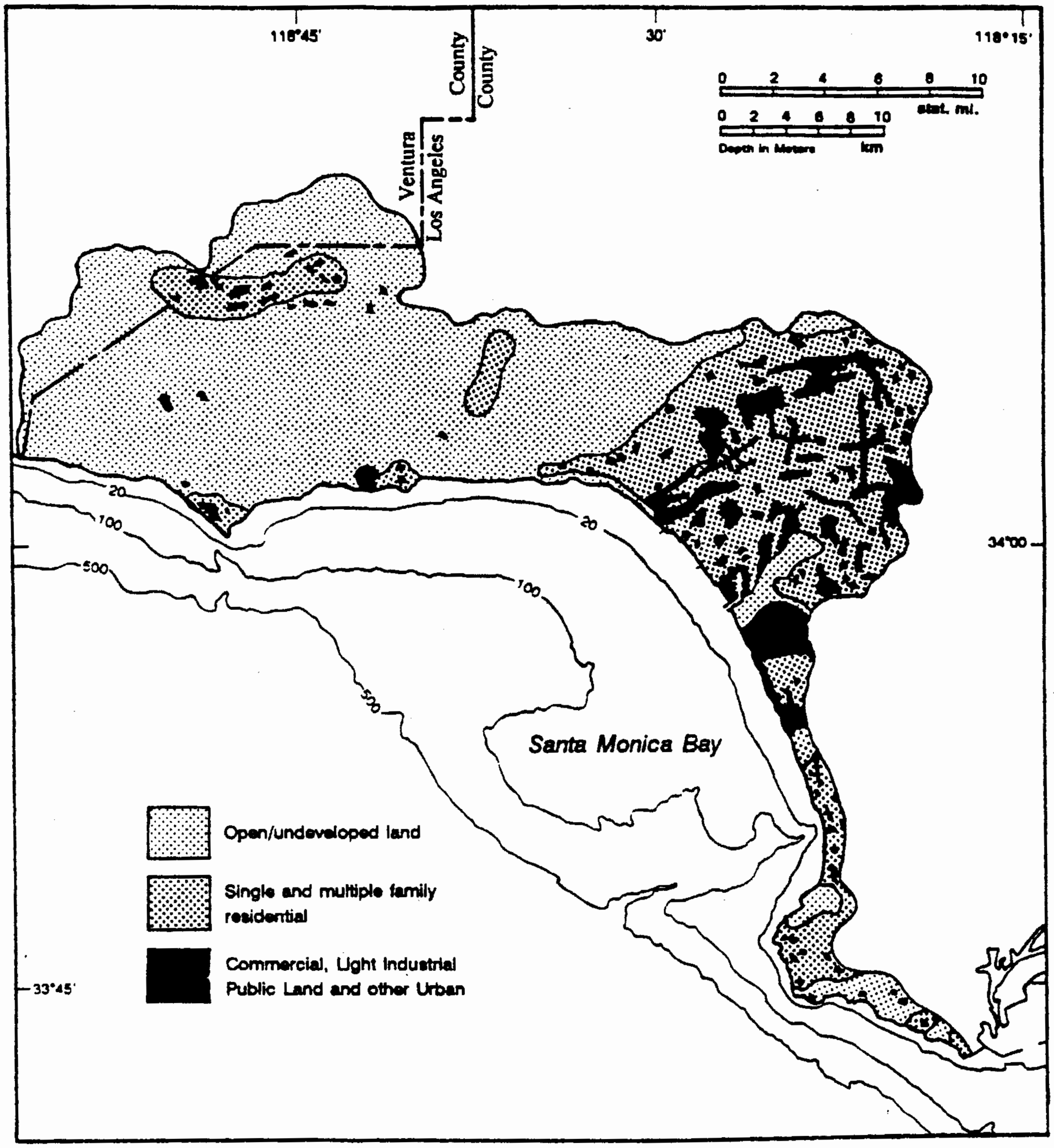


Figure 7-5. Land usage of the Santa Monica Bay study area (modified from SMBRP 1992).
General Stormwater Discharge Permits.

REGULATION OF CONTAMINANTS IN URBAN RUNOFF

Because there is no means of treating surface runoff at present, source control is the only way to reduce the levels of contamination in urban runoff.

NPDES PERMITS

In June 1990, the California Regional Water Quality Control Board, Los Angeles Region issued a NPDES permit for stormwater and urban runoff to the County of Los Angeles as principal permittee, and the cities in the Santa Monica Bay Watershed as co-permittees (Appendix F). The permit requires Los Angeles County and the 85 cities in the County to control pollution from urban runoff. To address the distinct problems associated with the control of stormwater/urban runoff pollution, a new approach has been initiated in the Santa Monica Bay watershed.

Pollutant	Residential Fam. Single	Multi	Commercial	Public	Light Industrial	Other Urban	Open	Unk.	Watershed Total
Pollutant Loadings (Metric Tons per Year)									
TSS	10,673	3,029	1,529	820	712	1,424	11,767	59	30,013
COD	5,152	1,875	765	410	356	881	2,281	37	11,757
BOD	626	216	119	64	55	102	48	4	1,234
Oil & Grease	110	317	187	100	87	149	0	6	957
TKN	158	35	17	9	8	16	67	1	311
NO2+NO3	68	14	10	5	5	7	35	0	145
Total Phosphate	31	9	4	2	2	4	12	0	64
Total Zinc	13	5	6	3	3	3	11	0	43
Total Lead	13	6	2	1	1	3	3	0	30
Soluble Phosphate	9	2	2	1	1	1	3	0	18
Total Copper	3	1	1	0	0	1	1	0	8
Percentage of Annual Pollutant Loadings									
TSS	35.6	10.1	5.1	2.7	2.4	4.7	39.2	0.2	100.0
COD	43.8	15.9	6.5	3.5	3.0	7.5	19.4	0.3	100.0
BOD	50.7	17.5	9.6	5.2	4.5	8.2	3.9	0.3	100.0
Oil & Grease	11.5	33.1	19.5	10.5	9.1	15.6	0.0	0.6	100.0
TKN	50.9	11.1	5.5	2.9	2.5	5.2	21.6	0.2	100.0
NO2+NO3	47.0	10.0	7.0	3.8	3.3	4.7	24.0	0.2	100.0
Total Phosphate	48.6	13.9	5.7	3.0	2.6	6.5	19.4	0.3	100.0
Total Zinc	29.7	12.6	13.6	7.3	6.3	5.9	24.3	0.2	100.0
Total Lead	43.6	21.5	6.5	3.5	3.0	10.1	11.4	0.4	100.0
Soluble Phosphate	50.0	10.2	8.3	4.5	3.9	4.8	18.3	0.2	100.0
Total Copper	42.7	17.6	7.5	4.0	3.5	8.3	16.1	0.3	100.0

Source: UCLA and WCC 1992.
TSS - Total Suspended Solids
COD - Chemical Oxygen Demand
BOD - Biochemical Oxygen Demand
TKN - Total Kjeldahl Nitrogen
NO2 + NO3 - Nitrite and Nitrate

Table 7-6. Estimates of annual pollutant loadings for Santa Monica Bay drainage basins by land use.

GENERAL STORMWATER DISCHARGE PERMITS

General stormwater discharge permits for industrial facilities and construction sites were issued by the State Water Resources Control Board in the summer of 1992. These stormwater/urban runoff permits provide a new regulatory framework which is considered practical and adaptable to the Los Angeles County drainage system's distinct structure. Programs developed under current stormwater permits emphasize pollution control through best management practices (BMPs) as opposed to conventional technology-driven water quality standards.

BEST MANAGEMENT PRACTICES

Studies conducted by the SMBRP have shown that land use practices are among the most identifiable causes of stormwater/urban runoff pollution. It is widely recognized that the elimination of diffuse "nonpoint" sources ultimately depends on successfully changing the long-standing habits and practices of people at work and in their communities. Therefore, among potentially effective BMPs, priority should be given to implementation of new land-use practices and to nonstructural control measures, in particular, public education and involvement programs.

OZONE TREATMENT

One potential technique for the treatment of urban runoff is to construct catch basins at the mouths of drainage channels and to treat runoff by ozone disinfection prior to discharging into the Bay. Ozone is used by the drinking water industry as an alternative to chlorine, and a pilot study demonstrating ozone disinfection was conducted for the SMBRP on the Kenter Canyon Storm Drain System in Santa Monica. Results showed that ozone was an effective dry-weather storm drain disinfectant (Greene 1992).

IMPACTS - TERRESTRIAL, INTERTIDAL, AND WETLAND HABITATS

8

CHAPTER 8
IMPACTS - TERRESTRIAL, INTERTIDAL, AND WETLANDS HABITATS

TERRESTRIAL HABITATS

The native habitats of the Santa Monica Bay watershed have been greatly modified by the arrival of humans into the area. Native Americans used the natural resources such as plants and animals for shelter and food; they even practiced some fire control vegetation management. However, the impact was small compared to that from the first Europeans. Following California's statehood, some plant communities were more impacted than others. The first to be modified were the relatively flat native grasslands and the riparian areas along streams and rivers. Changes began with cattle grazing, clearing for fields, and damming of streams. Later, residential and commercial development, channelization of rivers and streams, introduction of non-native plant and animal species and production and use of toxic chemicals for industry and agriculture have all had their impact on native habitats.

About half of the area of the Santa Monica Bay watershed has been modified from native plant communities for agricultural and urban use (Figure 7-5). The impacts of development go beyond the actual area being used, as air and water carry material into previously pristine areas, and urban populations look for recreational locations away from the everyday congestion of the urban setting.

The growth of agriculture and trade resulted in the introduction of non-native species from Europe and other parts of the Americas for use as crops, other food, or for transportation. Many introductions were accidental (e.g., rats), but some were nonagricultural but concomitant with human civilization (e.g., cats). It will never be known how many native species were driven to extinction by introduced species taking over habitats or by the destruction of small or unique habitats. It is known that most of the native perennial bunch grasses are gone, along with many other annuals, insects, birds and mammals. At present there is concern about the remaining native habitats and steps are being taken to reduce the pressure from increasing population, to protect and restore native plant communities.

In Southern California, the practice of fire suppression to prevent destruction of property has resulted in thick chaparral stands which have not burned for many years near populated areas. These stands are extremely susceptible to natural or man-induced fires, especially during Santa Ana wind conditions. Because of the accumulation of fuel, fires in these stands can burn extremely fast and hot. Urban sprawl has continued to intrude into these habitats, making control of fires necessary, but more difficult. The California Department of Parks and Recreation's policy now considers fire to be a natural element of the environment, and has begun prescribed burning in some units of the State Park System (Wells 1990). Other landholders, such as the Nature Conservancy, are taking similar steps.

Since they usually occur in the dry, hot season, large and severe fires can lead to widespread flooding, accompanied by high sediment loads in runoff from heavy winter rains. When combined with other man-made disturbances of the earth, such as road building and housing construction, flooding can result in destruction of property and loss of life.

REMEDIATION

The Conservation/Open Space Element of Los Angeles County's General Plan (revised in 1979) includes the need "to protect...watershed, streams, and riparian vegetation to minimize water pollution, soil erosion, and sedimentation, maintain natural habitats, and to aid in ground water recharge." There are 65 significant ecological items in this element that are identified in a report entitled "Land Capability/Suitability Study, Los Angeles County General Plan Revision Program 1976" (Faber *et al.* 1989).

INTERTIDAL HABITATS

IMPACTS

REDUCTION OF SAND SOURCES

Prior to the construction of flood control structures, heavy rains carried abundant sediment to the coast (Woodell and Hollar 1991). However, development in the Los Angeles basin has included measures to decrease the risk of flooding, along with water retention and diversion for agricultural and domestic use. Flood-control projects have reduced the rate and volume of flood runoff and its sediment load. As a result, some beaches downcoast of major streams or storm drains eroded; the sand which is lost offshore during high-wave events is not replenished naturally. Erosion now threatens coastal structures and beaches with less sand are less attractive for recreational activities.

Historically, the major sources of beach sand for Santa Monica Bay were bluff erosion and creeks and rivers which emptied into it: Calleguas, Malibu, Topanga and Ballona Creeks, and, occasionally, the Los Angeles River. Sand is lost to the system offshore and by longshore transport into Redondo Submarine Canyon. Estimates of transport rates vary, but in the 1960s a net transport of 246,000 yds^3/yr to the south was considered reasonable. Completion of the King Harbor North Breakwater has disrupted the loss to Redondo Submarine Canyon somewhat, although sediment still enters the Canyon from the south (Woodell and Hollar 1991). The development of housing and recreation facilities atop dunes has further reduced the amount of available sand (Casali *et al.* 1991).

Construction and beach renourishment projects have resulted in a coastal zone which is fairly stable, but which shows little resemblance to the beaches prior to man's intervention. The reduction of sand loss down Redondo Submarine Canyon, the construction of Marina del Rey and King Harbor, and the many piers and groins, have combined with beach nourishment to yield 14 miles of beaches which are now several hundred feet wider than they were previously (Woodell and Hollar 1991).

GROIN, JETTY AND PIER CONSTRUCTION

One of the fundamental problems in the coastal zone is sand management: sand often erodes from desirable locations (for recreation and storm protection) and accumulates where it is not wanted (in harbor entrances, passes and inlets). The groins and jetties which are built to protect harbor entrances or to control erosion also affect longshore sediment transport. Sand accumulates on the upcurrent side of a structure perpendicular to the shoreline and erodes on the downcurrent side (Anikouchine and Sternberg 1973).

Structural methods of shoreline protection in the past, include the construction of more than 50 groins and jetties on Santa Monica Bay beaches. Many were specifically intended to help sand accumulate (Woodell and Hollar 1991).

BEACH NOURISHMENT

The primary nonstructural method of beach protection is beach nourishment, which often has only short-term success unless other measures are taken concurrently. Beach nourishment is only feasible (i.e., cost effective) where there is a nearby sand source. Most beach nourishment projects are initiated in response to navigational requirements to dredge and remove sand from harbor entrances.

Efforts to rebuild eroding beaches was begun in 1938 when nearly 1.8 million yds^3 of material from nearby dunes was placed onto the beaches (Shaw 1980). Since then more than 30 million yds^3 of material have been placed in the littoral zone (Woodell *et al.* 1990).

Almost 17 million yds^3 of material has been placed on Dockweiler State Beach since 1938 from the construction of the original Hyperion Treatment Plant. Since 1960 Dockweiler has also received more than ten million yds^3 of material from construction and by-pass operations at Marina del Rey.

Dockweiler Beach is presently being nourished with sand from nearby dunes. In 1992, lead and other metals levels in sediments from Marina del Rey were found to be too high for beach nourishment. Materials dredged from the Marina were dumped offshore, to be distributed by longshore currents (Chang 1992, pers. comm.). More than 1.3 million yds^3 of sand from offshore sources have been deposited on Venice Beach and almost 2.6 million yds^3 on Redondo and Torrance Beaches (Woodell and Hollar 1991).

Especially large storms may even cause erosion of sand dunes. By replacing sand to the eroded dune, both beach and dune are nourished and maintained. Dune maintenance can stabilize a beach even where sand is lost to longshore transport (Walther 1991).

URBAN RUNOFF

Urban runoff is a major source of contaminants which impacts intertidal marine organisms. Contaminants in seafood organisms can be transferred to man and result in adverse health effects. Filter-feeding intertidal organisms have a particularly high potential for bioaccumulating pesticides such as DDT, complex chlorinated hydrocarbons such as PCBs, and organometallic compounds such as methylmercury. In addition, most intertidal organisms are invertebrates and are less able than vertebrates to transform organic and metal contaminants to less toxic forms. Bacteria are discharged onto beaches from storm drains during periods of high flow, necessitating beach closures for short periods of time to protect human health.

Municipal Wastewater Discharges. Intertidal habitats are not exposed directly to contaminants discharged offshore, but they are exposed indirectly with every tidal cycle. Floatable materials from municipal effluent may reach the intertidal zone during onshore winds. Of particular concern are oily materials which rise to the surface, bearing lipid soluble contaminants (Word *et al.* 1984). These accumulate at the sea surface along with contamination from spills, boat bilge pumping, storm drain runoff, and natural oil seeps.

The potential impacts of floatable materials on intertidal biota have not been examined from a community standpoint, although some air-water interface contaminant data are available (SCCWRP 1986d). The susceptibility of intertidal communities can be inferred from tissue toxicant concentrations in the California mussel; trace metals, DDT, and PCB levels were higher along the Palos Verdes Peninsula and near Marina del Rey than elsewhere in the study area.

Rocky intertidal communities in the Bay have not been well studied, although intertidal algal distributions are adequately described. Data are available from prior to (Couch 1915, Goodman 1935), during (Dawson 1959, 1965; Widdowson 1971), and after (Thom and Widdowson 1978; Harris 1980, 1983) the period of peak contaminant discharge into the Bay. Reductions in algal cover and diversity on the Palos Verdes Peninsula were attributed to effluent from the JWPCP outfalls (Tetra Tech 1984). Algal communities impacted by sewage effluent resemble early successional stages and are dominated by opportunistic species with high reproductive potential (Murray and Littler 1978). Widdowson (1971), however, indicated that exposure to treated wastewater was less damaging than either human use (trampling) or exposure to air pollution. Although the exact cause is uncertain, a decrease in intertidal algae on the Palos Verdes Peninsula may have been related to direct treated wastewater exposure (Littler and Murray 1975) because the community has recovered with declining JWPCP mass emissions.

Thermal Discharges. The rocky intertidal biota on the breakwater at King Harbor is exposed to the thermal discharge from Redondo Generating Station. Studies indicate that the main determinant of community structure is tidal height, (EQA/MBC 1973; Straughan 1977a,c) although some data suggest a slight compression of the vertical zonation with organisms being found at lower than normal tidal heights (Straughan 1977a).

Marine Vessel Spills. The effects of oil spills from marine vessel traffic in the Bay have not been well studied. However, because spills are likely to encounter the beach, they may affect the eggs and newly hatched larvae of California grunion. Benzo(a)pyrene, (a PAH found in oil spills, industrial discharges, and aerial fallout), caused decreased hatching success and larval deformities in California grunion eggs collected from Redondo Beach. Such impacts would be detrimental to the survival of the fish if they occurred (Winkler *et al.* 1983). Benzo(a)pyrene does not cause tumors in marine fishes, but it does cause stress and makes them less resistant to parasites (Puffer 1988, pers. comm.). A spill of diesel and naphthalene offshore of El Segundo in 1991 did not affect intertidal organisms at Malibu, where it came ashore (MBC 1991a), and grunion were later observed to spawn normally on the Malibu coast.

Litter. Beach litter is both an aesthetic and an ecological problem. Birds may entangle themselves or ingest harmful substances and objects, and litter may smother organisms on beaches and in tidepools. Sharp objects are also dangerous to humans engaged in recreational activities. About 2,200 MT of litter were collected from beaches between San Pedro and the Los Angeles-Ventura County line excluding Santa Monica Beach from July 1987 to June 1988 by the Los Angeles County Department of Beaches and Harbors. About 690 MT were collected from Cabrillo Beach to Manhattan Beach; 681 MT from El Segundo to Venice; and 826 MT from Will Rogers State Beach to the Ventura-Los Angeles County border (Schumaker 1988, pers. comm.). From 1987 to 1992, an annual average of 3,400 MT of litter was collected from beaches in Santa Monica Bay excluding Santa Monica Beach (Isbitsky 1992, pers. comm.). Ten to 12 MT of litter are picked up from Santa Monica Beach each year (Rogers 1992, pers. comm.).

Contaminated Sediments Used in Beach Nourishment. Dockweiler Beach received more than 0.6 million yds^3 of material dredged from Marina del Ray during its construction. Heavy metals and other contaminants are known to be high in Marina del Rey sediments (Stallard *et al.* 1986; Chang 1992, pers. comm.) and after USACE tests showed that heavy metal values were too high in Marina del Rey sediments for beach nourishment, the materials were disposed of nearshore.

Other Activities. The value of beaches for recreation and relaxation has resulted in the destruction and degradation of intertidal and dune ecosystems. Beach visitors walk on vegetation and intertidal organisms and leave litter which must be removed. Drift kelp is removed for aesthetic reasons, thus, interrupting the natural degradation of kelp and its reintroduction into the marine environment as a food for filter feeders. Beach hoppers (or sand fleas) depend on the salty dampness of the normal beach; they burrow into the sand under piles of seaweed during the day and come out at night to scavenge food. Beach isopods and kelp flies also help recycle decaying kelp and dead animals. Human foraging for edible intertidal organisms such as abalone, limpets, mussels, clams, and sea urchins may eliminate juvenile stages, leaving no individuals to grow to adulthood and reproduce.

Dunes are a fragile ecosystem which is easily disturbed by vehicle and foot traffic. Repeated disturbance kills the low-growing plants by exposing the fine root system to drying wind and sun. When vegetation is removed, the sand is exposed and becomes susceptible to transport further inland by strong winds. In addition to the direct loss of habitat, the dunes can no longer supply sand to eroding beaches or protect inland areas. Human intrusion also interrupts shorebird foraging and nesting. Inadvertent and deliberate disturbance of nesting and feeding of chicks and crushing or removal of eggs and nestlings has had a major impact on California least tern and Western snowy plover populations (Page and Stenzel 1981).

REMEDIATION

BEACH PROFILE SURVEYS

Beach profile surveys have been conducted sporadically by Los Angeles County Coastal Studies Division to study specific problem areas; they have not been used to study long-term, regional trends. However, a program is now underway to compare three recent surveys with several historical surveys, in light of the many erosion events and beach nourishments projects which have been conducted (Woodell and Hollar 1991).

CALIFORNIA STATE MUSSEL WATCH PROGRAM

The California State Mussel Watch Program has monitored contaminants in intertidal invertebrates near Santa Monica Bay beaches on an intermittent basis, a more consistent approach and thorough sampling program is needed to track patterns and trends of contaminants.

CALIFORNIA LEAST TERN HABITAT RESTORATION

California least terns nest on sandy beaches, however, they must be protected from human disturbance and introduced predators. The protected site at Venice Beach has been very successful, but additional space is needed to enhance continued population growth. An additional beach nesting site near the Ballona Wetlands complex was suggested to help the population expand by attracting first-time nesters.

In 1991, with funds from the SMBRP and USEPA, a 3.5 acre site with extant native vegetation was prepared on Dockweiler State Beach. A temporary enclosure fence was erected and plans were made for a permanent fence for the 1993 breeding season. Decoys and audio recordings of least tern calls were used to attract birds to the site. Although no terns nested on the site in 1992, there were several landings. The first year was considered to be a trial and plans now call to eventually expand the site to five acres (Baird 1992, pers. comm.). A California least tern nesting island at the west end of the Ballona Wetlands is also planned as part of the mitigation associated with the development of Playa Vista by Maguire-Thomas Partners.

WESTERN SNOWY PLOVER

The Western snowy plover is a threatened species (CDFG 1992) and restoration projects have been started. Snowy plovers have many of the same nesting habitat requirements as least terns, and restoration projects may target both species (Yoder 1993, pers. comm.).

BLACK ABALONE RECOVERY PROGRAM

The black abalone population has decreased dramatically in Santa Monica Bay, probably as a result of extensive poaching, although the increase in sea urchin (which feed on the same resource, algae) population and "withering disease" may also have contributed. A recovery program could include planting young black abalone on rocky shores.

EL SEGUNDO DUNES RESERVE

Dunes are a rapidly disappearing habitat which support a unique community of plants and animals. The remnant El Segundo Dunes are home to 11 threatened species, including the El Segundo blue, a Federal- and State-listed endangered butterfly. Restoration of the El Segundo Dunes and creation of a Dunes Habitat Preserve would halt the spread of invasive species and avoid further extinction of native species.

The dunes at the west end of Los Angeles International Airport (LAX) (most of which are owned by the airport) are the subject of a proposed El Segundo Dunes restoration program (WRA 1990). At present the vegetation is dominated by iceplant and acacia and the major goal is to reintroduce native vegetation. The area is inaccessible to the public (which should help) but an irrigation system would have to be installed and the non-native plants removed (WRA 1990).

Chevron USA maintains a 1.6-acre El Segundo blue butterfly preserve at the northwest corner of the El Segundo refinery (This site is not contiguous with the proposed El Segundo Dunes mitigation project west of LAX). The El Segundo blue recovery program involves ensuring that the butterfly's host plant, coastal wild buckwheat, is present and protecting the habitat from human intrusion.

The El Segundo Dunes fall under the jurisdiction of several entities: LAX owns 277 acres, 43 acres of which are relatively undisturbed; the Los Angeles Department of Water and Power owns 55 acres of right-of-way property; Chevron USA owns 1.6 acres, which have been set aside as a butterfly preserve; and the City of Manhattan Beach owns four acres.

WETLANDS HABITATS

IMPACTS

Wetlands in Santa Monica Bay are threatened by the proximity of the large human population and its impact on the physical, chemical and biological characteristics of the wetlands. Specific factors are stream alteration, dredging and filling, modified water flow patterns, drought, urban runoff, sewage disposal, boating and shipping, encroaching housing and commercial development, introduced species, and the increased use of natural habitats for recreation.

Wetlands have been used as waterways and have been modified by dredging and filling for harbors and marinas. In several areas, the wetlands had been diked and used for duck hunting, oil production, and reclaimed water discharge by sewage processing facilities. More recently, the margins have been developed for residential and commercial purposes.

DEVELOPMENT AND HABITAT REDUCTION

Most of the wetlands of Santa Monica Bay have already been highly modified by draining, dredging, filling, diking, and channelization to provide sites for port and harbor facilities, housing and commercial development, and farming. They have also been degraded by urban runoff, introduction of non-native species, and human disturbance, resulting in losses in biological diversity, productivity, and wetlands function. The loss of wetlands habitat is not unique to Santa Monica Bay.

Between the late 1800s and mid-1960s, much of the wetlands of Los Angeles and Orange Counties was "reclaimed," with resulting losses in biological diversity, productivity, and function. Seventy-five percent of the coastal estuaries and wetlands in Southern California have been destroyed or severely altered since 1900. Two-thirds of the 28 sizeable estuaries once found in southern California have been dredged or filled (CCZCC 1975).

Freshwater wetlands have also suffered: streams have been channelized and dammed and water appropriated to supply distant cities. Current water policy considers unused water to be a waste, thus from as far away as the San Joaquin-Sacramento River delta and the lower Colorado River water is transported to Southern California for domestic and agricultural uses. Wetlands associated with those systems have been impacted by changes in water level and seasonal flow, as well as by damming, channelization, expanded agriculture, and livestock grazing. For example, about 3,000 acres of riparian vegetation are being lost along the lower Colorado River each year (Manci 1989). Water diversions have seriously impacted the commercial and sport freshwater fisheries in central California because of water draw-downs and salinization of a large part of the formerly freshwater delta (Rozengurt and Haydock 1991).

Ballona Wetlands Complex. In 1868, the Ballona Wetlands Complex covered as much as 2,100 acres (Clark 1979). By 1894, the area had been reduced to approximately 1,535 acres, from the present-day community of Venice on the north, southwest through La Ballona, inland to Machado and south to present-day Culver Boulevard (Figure 8-1). The area consisted of a broad marsh behind a long sand spit, with a narrow, ephemeral opening to the sea. The opening probably closed to the ocean during spring and summer, leaving a brackish lagoon until high winter inflow washed out the spit and exposed the marsh to tidal waters (Swift and Frantz 1981).

By about 1930, the major lagoons of the Ballona Wetlands had been drained and converted for agricultural use, oil and gas development, and to control and abate mosquitos and black gnats (Soule and Oguri 1977). From the 1930s to the 1950s, roads and levees were built to access oil drilling pads and in the early 1960s, further reduction of the habitat resulted from dredging of Marina del Rey (Soule *et al.* 1992). Four to five feet of dredge spoils were placed on northern section of wetlands that had been previously used for agriculture (Friesen *et al.* 1981).

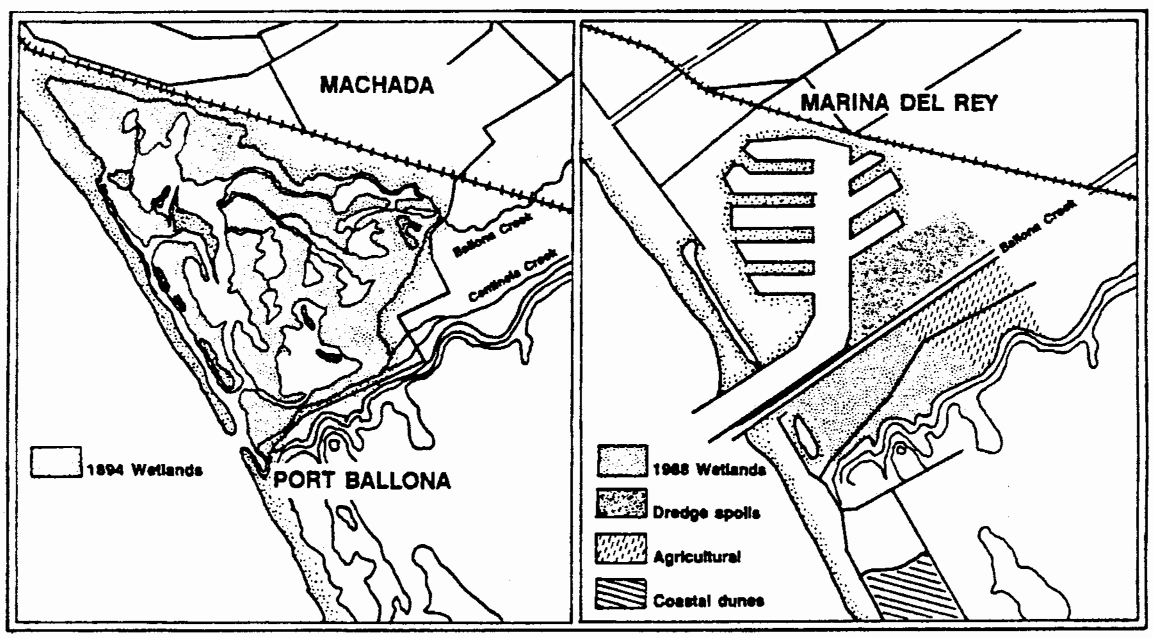


Figure 8-1. The Ballona Wetlands region in 1894 and 1988.

By 1938, Ballona Creek, which was the principal freshwater source for the Ballona Wetlands Complex, was completely channelized as a flood control measure (Clark 1979). Channelization reduced the inflow of fresh water and nutrients to the marsh ecosystem and allowed the natural inlet to be blocked by sediments within two years. It also altered the natural salinity and depth regimes of the wetlands, leading to more-saline water and a deeper and more defined channel (Swift and Frantz 1981).

Introduced plants have become established in the Complex, altering the ecological balance and use of the marsh by native biota. Introduced species account for 40% (130 of 235) of all plant species in the saltmarsh area (Gustafson 1981) and much of the terrain is vegetated by introduced species such as gum (eucalyptus) trees and iceplant which are detrimental to the habitat as a whole and out-compete native species. Because of the continued disturbance, weedy species cover approximately 15% of the saltmarsh. A restoration project in progress at Ballona Lagoon, includes planting native salt marsh vegetation and removal of introduced species (Weiss 1993, pers. comm).

Malibu Lagoon. The full extent of the historical Malibu Lagoon-marsh system is unknown (Kraft 1978), but what remains probably represents only a small portion of the original marsh (CDPR 1978). In 1978, the natural resources consisted of five acres of open water, ten acres of coastal saltmarsh, four acres of riparian habitat and mudflats (unknown). Most habitat reduction of the Malibu wetlands has resulted from the reclamation of habitat upcoast of Malibu Creek for mosquito control and houses (Kraft 1978).

The natural channel of Malibu Creek enters the ocean downcoast of Malibu Point. The sand bar which develops across the mouth is purposely breached by the Los Angeles County Department of Beaches for flood control purposes (CDPR 1978).

URBAN RUNOFF

Significant quantities of floating trash and other urban debris are carried into Santa Monica Bay by way of Ballona Creek (Metz 1978) and much of it accumulates in the Ballona Wetlands Complex (Schreiber 1981). Debris and trash can temporarily limit light availability in the water column and cover saltmarsh habitat; styrofoam and plastic bags may be ingested by fish and birds.

During dry weather the low volume "nuisance" water brings grass clippings, motor oil, household pesticides, and drainage from roadway drips and accidental spills down-channel. When this flow reaches the tidal prism, debris and contaminants are deposited inside of the Marina jetty.

During wet weather, runoff carries bacteria into the wetlands and Marina del Rey and waters are considered unsafe for body contact during and for a few days following a storm (Soule *et al.* 1992). The sand bar at the entrance to the Marina may reduce circulation and flushing within, prolonging the period of contamination. Increased flow in Ballona Creek tends to carry the debris and contaminants as well as occasional sewage overflows from the HTP North Outfall Facility into Santa Monica Bay proper (Soule and Oguri 1986, 1987). As a result, sediments at the mouth of the Ballona Creek are more contaminated than those elsewhere in the vicinity of Marina del Rey (Soule and Oguri 1987). Stagnation and high nutrient input from urban runoff periodically cause algal blooms in Ballona Lagoon (Soule and Oguri 1977).

Organic enrichment due to wastewater overflows may have accounted for the low benthic community species diversity at the mouth of Ballona Creek, where the fauna was dominated during the mid-1980s by high numbers of nematode worms and the polychaete Capitella capitata (Soule and Oguri 1987). These organisms are highly opportunistic and characteristic of unstable, stressed environments, whether natural or anthropogenic. Sampling in 1991 revealed large numbers of nematodes, indicating a disturbed or stressed environment such as would occur with the heavy freshwater rainfall runoff that impacted this area during the spring. However, also reported in this study was the largest number of species ever recorded for this site, which may be related to a reduction in contaminants (Soule *et al.* 1992).

The Oxford Flood Control Basin in Marina del Rey is are impacted by trace metals, pesticides and PCBs, apparently from sediments eroded during storms. Adjacent terrestrial areas are contaminated from earlier dumping and World War II industrial activities. Recent construction excavation may have exposed soils to erosion, as suggested by the increase in percentage of fine sediments in the Marina following heavy rainfall (Soule *et al.* 1992).

Many of the substances such as PCBs, pesticides, and heavy metals in urban runoff are toxic to marine organisms. Small amounts of several trace metals have been detected in the Marina, but these have been determined by the National Oceanographic and Atmospheric Administration (NOAA) to have low environmental effects. Concentrations of other metals (e.g., nickel and TBT) have been high in the past but are less concentrated now; concentrations of lead and zinc increase following heavy rainfall and decline during dry weather, indicating terrestrial sources. Copper concentrations have increased even during dry periods, suggesting its increased use as an antifoulant since the ban on TBT. Pesticides such as chlordane continue to be detected at high environmental effects levels (NOAA 1991b). The highest concentrations of chlordane have been at the mouth of the entrance channel, indicating that it has come from Ballona Lagoon (where there are many wooden structures which may have been treated for termite control). Levels were also high in the Oxford Flood Control Basin. Levels of DDT appear to be decreasing but still exceed the low environmental effects level at some locations in the Marina. Its metabolite DDE has increased in fish taken at the Fisherman's Village fish docks in the Marina's Main Channel (Soule *et al.* 1992).

Toxic materials may occur both in sediments and in the water column. Studies to determine levels of trace metals and organics in the marine environment are conducted by California State Mussel Watch (CSMW) primarily using California and bay (blue) mussels. Marina del Rey is the only CSMW site in northern Santa Monica Bay, but in 1981-1982, levels of PCBs in resident bay mussels from Marina del Rey were relatively high (1,000 ppb), indicating local PCB sources. Mussel transplant studies conducted in 1980 and in 1985-1986 also revealed high PCB levels (1,800 ppb in 1980 and 2,500 in 1985) in Marina del Rey (CSWRCB 1982, 1988). Marina del Rey mussels also had one of the highest lead concentrations measured in California (49 ppm), and had elevated zinc (340 ppm in 1980 and 833 ppm in 1986) and copper (13 ppm in 1980 and 112 ppm in 1986) concentrations as well. The lead concentration in Marina del Rey mussels was over 50 times those typically measured at uncontaminated coastal sites. Contaminants originating or accumulating in the Marina may flush into the Ballona Wetlands under normal conditions or from the wetlands into the Marina during wet periods.

Transplanted and resident mussel tissues also had elevated concentrations of chlordane and dieldrin; total chlordane was the highest (780 ppb in transplants and 480 ppb in resident mussels) detected in the CSMW surveys. These data suggest a local source of the pesticide, because total chlordane in mussels from Palos Verdes was generally less than 50 ppb and from reference areas less than ten ppb. The concentration of dieldrin was 91 ppb in 1980 transplant studies at Marina del Rey, although lower concentrations were measured in resident mussels from Marina del Rey (19 ppb) and the Palos Verdes Peninsula (6.5 to 11 ppb).

MARINE VESSEL ACTIVITY

Marina del Rey. The development of Marina del Rey drastically altered the original lagoon habitat. The shoreline was changed from natural muddy intertidal habitat to vertical concrete walls, although a small beach remains at the end of Basin D (Stephens *et al.* 1991). The Marina is, therefore, a wetlands only with respect to the shallow subtidal habitat which supports wetlands fish (and eelgrass in Basin D, prior to 1992). The amount of shallow bottom habitat was decreased by dredging (to 20 ft in the Main Channel and about 16 feet in the basins) and water circulation between the harbor and the ocean was increased. This alteration of habitat has no doubt decreased the abundance of lagoon species such as the arrow goby and California killifish, although this change has not been documented. It has probably also reduced the amount of nursery habitat for California halibut. Juveniles of this species generally develop in warmwater lagoons and hence the development of the Marina may have resulted in fewer adult halibut in the Bay.

The abundances of fish larvae and benthic-feeding fishes have declined in Marina del Rey since 1984. This may be the result of post El Niño cooling but may also be related to TBT concentrations in the Marina. TBT is used as a biocide in antifouling paint and is more toxic to larvae than to adults (Soule and Oguri 1987). Since the use of TBT on small boats was banned in 1988, levels of TBT in the Marina have decreased three fold (Soule *et al.* 1992). Habitat disturbance may be responsible for the disappearance of the eelgrass beds from Basin D in 1991 (Soule *et al.* 1992).

Ballona Wetlands and Lagoon. The fish fauna of the remaining natural Ballona wetlands is less speciose and less diverse than coastal embayments such as Anaheim Bay (Lane and Hill 1975) and Newport Bay (Horn and Allen 1981), probably because only the shallow tidal channel habitat is present. In addition, flood gates and the shallow Ballona Creek Flood Control Channel separate the marsh from deeper water, interrupting the continuum from shallow marsh to the Bay. The limited number of flatfish collected in the Ballona wetlands suggest that it plays a limited nursery ground role compared to other southern California wetlands (Zedler 1982). The absence of goby eggs indicated that the Ballona wetlands are not even an important nursery for resident estuarine species, although Ballona Lagoon may be important nursery habitat for California killifish and topsmelt (Ford and Collier 1976).

TBT is present at some sites in Marina del Rey and Ballona Creek at levels (i.e., above 0.05 ppb) which are potentially toxic to mollusk larvae (Alzieu 1986). The reduction in mussel populations and crustaceans in Marina del Rey may be the result of TBT. Chronic exposure to and bioaccumulation of even low levels of TBT may have lethal or sublethal effects (Soule and Oguri 1987).

The degree to which TBT may impact shorebirds which forage on mollusks, crustaceans, polychaetes, or fish is unknown. However, reduction in the quality or quantity of these food resources could indirectly impact populations of waterbirds and shorebirds in the vicinity of Marina del Rey.

In 1988, unhatched eggs of California least terns from the Venice Beach nesting site had high levels of selenium, cadmium, and lead (Collins 1992); relatively high levels of lead have also been found in least tern feathers (Boardman and Collins 1992). Potentially dangerous levels of organochlorines, including DDT and its metabolites have also been found in least tern eggs and feathers (Boardman 1988). These levels are sufficiently high to cause concern for terns and other threatened species. California least terns feed on northern anchovy and topsmelt and they may be impacted by the accumulation of chlorinated pesticides and PCBs in the same way as the brown pelican.

OTHER HUMAN ACTIVITIES

Regulation of discharge of sewage by boats in the Marina has helped to reduce the levels of bacteria which are of concern to public health. There are occasional peaks of bacterial counts during dry weather, but overall, violations of Los Angeles County Department of Health Services standards were reduced in 1992 as compared to previous years (Soule *et al.* 1992).

Horse traffic, off-road vehicles, and human foot traffic have been noted in the Ballona wetlands, and these can cause lasting impacts by impeding or accelerating drainage and by altering elevations, thus affecting species abundance and composition (Zedler 1982). Noise from off-road vehicles or humans and domestic pets (Kraft 1978, Schreiber 1981) may affect locally breeding species such as the California least tern and Belding's savannah sparrow.

Insects in the Ballona Wetlands may also be affected by horse, human, and off-road traffic which compacts the soil, crushes insects, and destroys vegetation. The spread of introduced iceplant crowds out native plants required by some insects, while pesticides may eradicate native insects (Nagano *et al.* 1981).

REMEDIATION

At present, the California Resources Agency (California Department of Fish and Game, Department of Foresty, etc.) is preparing a State Wetlands Conservation Plan (SWCP) through a cooperative, multi-organizational planning process. A draft outline was completed in 1992. The SWCP will identify and inventory wetlands and develop a state strategy for their protection and restoration. A regional wetlands agreement would take into consideration the special conditions of Santa Monica Bay wetlands resources.

The Santa Monica Bay Restoration Project funded a project to map and inventory all wetlands of the Santa Monica Bay watershed, and the report was produced in 1992 (Josselyn *et al.* 1992). The wetlands were evaluated and several sites were recommended for restoration, acquisition, creation, and/or best management practices (BMPs). Next priorities for these activities will be determined and an overall approach for protecting and enhancing wetlands resources of Santa Monica Bay will be adopted.

In 1990, the Port of Los Angeles (POLA) developed a Local Wetlands Mitigation Program, identifying 13 potential wetlands mitigation sites in the Los Angeles area (WRA 1990). Nine of the sites are in the coastal zone of Santa Monica Bay and one is in the watershed (Figure 8-2). One additional coastal site and one other watershed site were identified in the draft SMBRP Wetlands Inventory and Restoration Potential (Josselyn *et al.* 1992).

JURISDICTION AND CONCERNED GROUPS

Government. Many agencies maintain control over the wetlands in Santa Monica Bay, among them the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), California Environmental Protection Agency (CalEPA), California Resources Agency, U.S. Fish and Wildlife Service, U.S. National Marine Fisheries Service, U.S. Soil Conservation Service, California State Department of Fish and Game, California Coastal Commission, California State Water Resources Control Board, Los Angeles Regional Water Quality Control Board, City of Los Angeles, Los Angeles Department of Parks and Recreation, and Topanga-Las Virgenes Resources Conservation District (TLVRCD).

The ecologic problems of wetlands involve numerous issues (habitat protection, point and nonpoint sources of pollution, land-use planning and resource management) which are too complex for any single agency to handle. Congress has enacted several programs to deal with wetlands, but the responsibility has often been relegated to the state level. In the face of budgetary shortfalls, the emphasis has been on eliminating duplication of effort and the EPA has become a facilitator rather than a manager or administrator of water pollution policies (Imperial *et al.* 1991). Under the National Estuary Program (NEP) the EPA identifies estuaries that are threatened by pollution, development, or overuse, and facilitates the preparation of comprehensive conservation and management plans (CCMP). The plans are implemented by the states using federal Coastal Zone Management (CZM) funding and are administered by the National Oceanographic and Atmospheric Administration (NOAA).

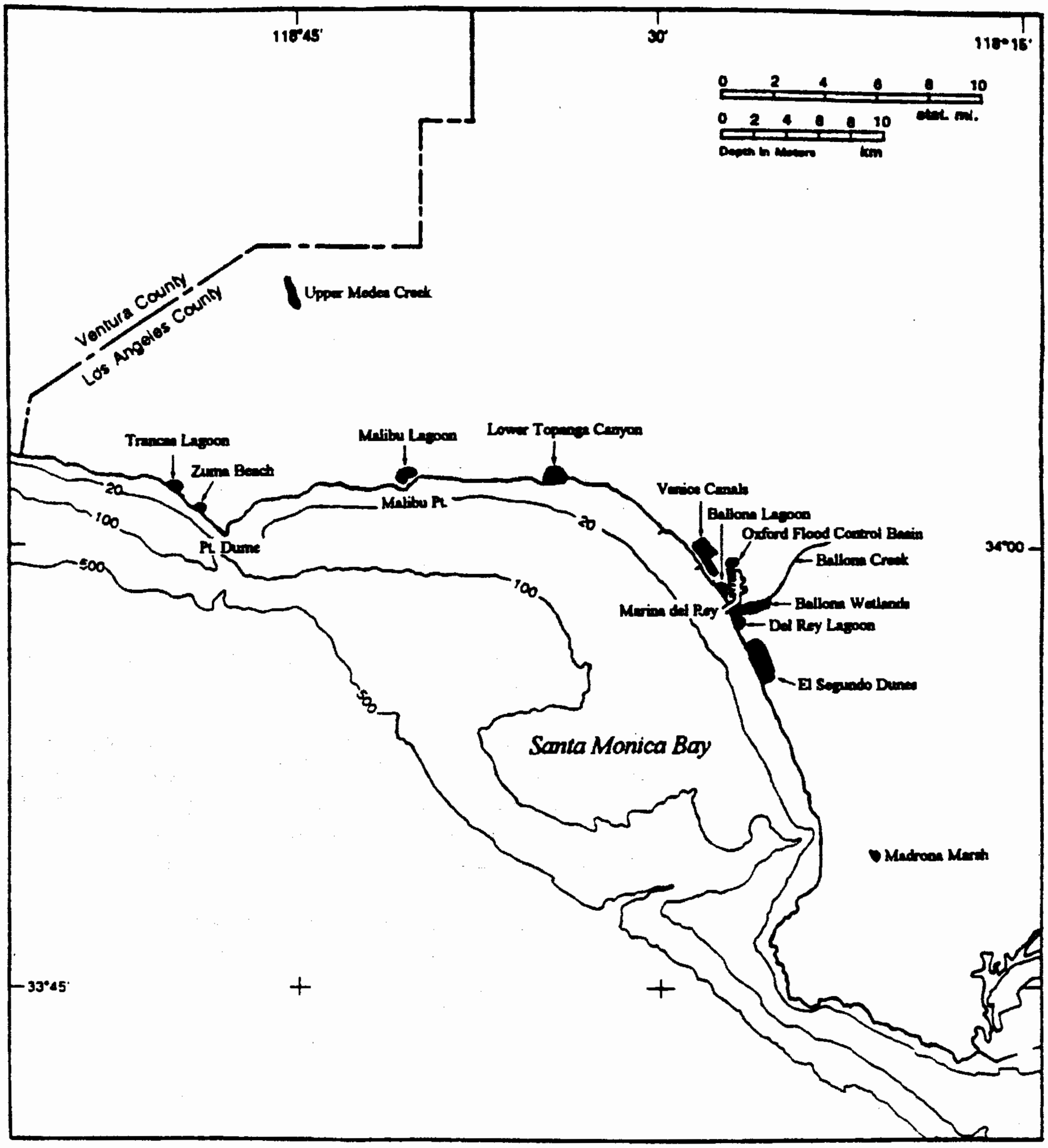


Figure 8-2. Wetlands of Santa Monica Bay study area.

Private. The 16 acres of Ballona Lagoon is owned by several private individuals but is under the jurisdiction of the City of Los Angeles. Del Rey Lagoon (1 acre) is owned by the City of Los Angeles and Summa Corporation; Venice Canals (12 acres) are owned by the City of Los Angeles; Ballona Wetlands (232 acres) are owned largely by Maguire Thomas Partners; and El Segundo Dunes Wetlands habitat (less than 1 acre) is owned by the Los Angeles International Airport. Malibu Lagoon (36.1 acres) and lower Topanga Canyon (less than one acre) are owned by the California Department of Parks and Recreation.

Responsible agencies include the Soil Conservation Service, Topanga-Las Virgenes Resources Conservation District (TLVRCD), California Coastal Conservancy, and the California Coastal Commission. Oxford Flood Control Basin (10.5 acres) is controlled by Los Angeles County, Department of Public Works and the Zuma Beach Wetlands is controlled by the Los Angeles County Department of Beaches and Harbors. Trancas Lagoon

(2 acres) is partly privately owned and restoration plans include expanding the Lagoon to the north of Pacific Coast Highway. The eight-acre Madrona Marsh has been designated as a significant ecological area by the County of Los Angeles and is owned by the City of Torrance. The proposed Upper Medea Creek restoration area (about 43 acres of riparian habitat along 2.2 miles of Medea Creek) is a tributary of Malibu Creek; much of the property along the creek is privately owned.

ON-GOING OR PROPOSED PROJECTS

Maguire Thomas Partners-Playa Vista Ballona Wetlands Project. In 1982 the California Department of Fish and Game conducted a Los Angeles County Local Coastal Plan status determination of the Ballona Wetlands pursuant to Section 30411 of the California Coastal Act 1976. Purposes of the determination were to 1) define historical wetlands and their present status; 2) identify restoration within the area; and 3) assess the feasibility of restoring and enhancing wetlands. Their study area included the major marsh area and former agricultural parcels nearby. The results indicated:

> "...that of the 510 acres within the study area, 478 acres were historically wetlands and 32 were historically uplands. Of the 478 acres of historic wetlands, 151 acres are presently viably functioning wetlands. Of these 151 acres, 65 acres are essentially non-degraded and 86 are degraded. Additionally, 327 acres of historic wetlands have been so severely degraded that they no longer function viably as wetlands. Of these 327 acres, 51 acres are feasibly restorable and 276 acres may not be feasibly restored..." (CDFG 1982).

In 1984, Friends of Ballona Wetlands successfully challenged certification of a land-use plan by the California Coastal Commission (CCC) to allow the building of a roadway across the Ballona Wetlands and building of a residential development and golf course within the Wetlands. A settlement agreement was reached with the Commission and Maguire Thomas-Playa Vista (subsequent owners of the property) which downscaled the commercial development and eliminated development in contiguous wetlands, increased wetlands acreage through restoration, and restored mid-tidal flow.

Restoration of Ballona Wetlands was proposed in the Ballona Wetlands Habitat Management Plan (NAS 1986), prepared for the City of Los Angeles as part of the Local Coastal Program for the Ballona Wetlands. The plan included wetlands restoration and an interpretive and controlled access program. Under the plan, the Audubon Society would receive ownership of the property from Howard Hughes Properties and would manage restoration efforts with funds provided by them. This plan was later dropped and the property was sold to Maguire Thomas Partners (MTP), who acquired additional acreage for development through payment of $85 million and 70 acres in a land swap with the State of California; 60 acres were set aside for the wetlands (L.A. Times, 14 Sep 1991).

MTP developed a new plan, (agreed to by the Friends of Ballona Wetlands), to develop part of the property as Playa Vista, a residential-marina complex. The plan includes restoration of the saltwater marsh south of Ballona Creek, through restoration of tidal flow (the mid-tide plan developed by the National Audubon Society), dune restoration, creation of a freshwater marsh and riparian corridor upstream, and fish habitat enhancement in the proposed marina. A second enhancement plan - to reestablish full tidal action to all areas of the salt marsh - was proposed which would require the participation of other parties interested in receiving mitigation credits for tidal wetlands. In 1990, MTP applied for a permit for the first phase of the project (creation of the freshwater wetlands) and the permit was granted in 1991. However, it has not yet been signed by MTP-PV, although the draft EIR was recently submitted.

Ballona Lagoon. The California State Coastal Conservancy (CSCC) and the Ballona Lagoon Marine Preserve have been instrumental in assembling an enhancement plan for Ballona Lagoon which emphasizes improved water quality by enhancing circulation. Planting of native vegetation, fencing, and litter clean-up, along with reduced algal growth due to increased tidal exchange, would improve the aesthetics of the area (WRA 1990, Josselyn *et al.* 1992).

The City of Los Angeles, local landowners and the CSCC have approved a plan to develop Ballona Lagoon as the Ballona Lagoon Marine Preserve. The plan includes dredging, grading, bank replanting, sediment and oil and grease traps, and provisions for public access. Dredging would enhance the habitat for marine fish which are prey for the endangered California least tern. At present, adoption and implementation of the plan depends on assignment of the CEQA documents to either the City or the CSCC.

Some small enhancement projects are underway at Ballona Lagoon. Removal of debris and bank improvement has taken place at the southeast end of the Lagoon, and several property owners have removed exotic plant species and replaced them with native vegetation (Holderman 1992, pers. comm.). The Summa Corporation (which owns about a third of the Lagoon) has agreed to create a deep pool by dredging at the north end, although the project is pending because the private owners have not agreed to the plan for the other two-thirds of the Lagoon.

Other Projects. The Port of Los Angeles has investigated the potential for restoration of Del Rey Lagoon. Increased tidal flow would improve water quality, although local residents may object to the regular exposure of tidal flats. Improved tidal flow would increase the potential for flooding in the surrounding urban area. Pet waste control measures and banning the feeding of domesticated ducks would have to be enforced.

In 1990, the Oxford Flood Control Basin Task Force determined that enhancement possibilities for the Oxford Flood Basin were limited because of poor water quality, conflict with flood control uses of the basin, and limited wildlife potential.

Rehabilitation of the Venice Canals is currently being undertaken by the City of Los Angeles and work is due to be completed in 1993 (Josselyn *et al.* 1992).

The Malibu wetlands are within Los Angeles County Significant Ecological Area No. 5. The California Department of Parks and Recreation (CDPR) and others are developing a comprehensive plan for the Malibu Creek watershed which would include recommendations for the restoration of Malibu Lagoon (Michel 1992, 1993, pers. comm.). Enhancement of Malibu Lagoon as a brackish water marsh would probably include regulation of freshwater flow by retention or release from the Tapia Water Reclamation Plant and control of biological pollutants by the elimination of point and nonpoint sources. Tidal flushing is unlikely, as the flow volume is seldom sufficiently great to keep the mouth of the creek open to the ocean (WRA 1990).

Several projects have already begun at Malibu Lagoon, with funding from the CDPR and EPA. The tidewater goby was reintroduced into Malibu Lagoon in 1990, and has survived. Under EPA's Near Coastal Waters program, with funding from CalTrans as mitigation for construction of a replacement bridge across the Lagoon, a section of stream bank in the upper reaches of the Lagoon will be recontoured and revegetated to provide more goby habitat.

The CCSC wants to investigate effects of salinity changes on resident organisms; the effects of contamination from septic tanks on both water quality and organisms; and the effects of the water level in the Lagoon on the water table. At present, the CDPR breaches the berm to allow water to escape whenever the level in the Lagoon rises above 3.5 feet to avoid possible interaction with septic systems at the Malibu Colony. The long-term fate of the tidewater goby may depend, however, on restoration of a natural pattern of opening of the berm only during high-flow periods (Manion 1992, pers. comm.).

Wetlands which were linked to Malibu Lagoon historically but are not in the jurisdiction of the CDPR are found in the City of Malibu. The City has applied for grant funding to enhance or restore several small areas along with the larger Lagoon project (Manion 1992, pers. comm.).

IMPACTS - MARINE INVERTEBRATES

9

CHAPTER 9
IMPACTS - MARINE INVERTEBRATES

PELAGIC RESOURCES

Because phytoplankton constitute the primary basis of the marine food web, impacts to the plankton populations of the Bay could seriously alter the abundance of other species.

MUNICIPAL WASTE-WATER DISCHARGES

In 1957 and 1959, the abundance of phytoplankton and zooplankton were higher within 2.2 mi of the HTP and JWPCP outfalls than at reference stations. When regular discharges ceased from the 1-mi outfall and began at the 5-mi outfall in the early 1960s, plankton abundance in Santa Monica Bay decreased in general, but the center of greatest abundance moved offshore (Figure 9-1). Because the 5-mi pipe discharges beneath the thermocline, nutrient enrichment of surface waters and phytoplankton enhancement only occurs when the wastefield surfaces (SCCWRP 1973).

In 1980, phytoplankton abundance and composition near the 5-mi outfall were not different from those at reference sites in the Bay. However, zooplankton were more abundant (the copepod Calanus pacificus was dominant) near the discharge, but it is not known whether the increased abundance was due to population growth, entrainment, or migration (Kleppel *et al.* 1982).

GENERATING STATION IMPACTS

The use of coastal water to cool electric generating stations contributes to losses of plankton (including larval stages of fish and invertebrates) and adult members of nearshore communities (Stephens *et al.* 1983). The mortality rate of plankton passing through the San Onofre Nuclear Generating Station was estimated at about 30% (USAEC 1973), that of zooplankton entrained at the Huntington Beach Generating Station was estimated at 28%. Intermittent chlorine injections (to prevent the accumulation of microbial slime inside of the pipes) temporally reduces photosynthesis by about 90%. Presumably the entrainment and chlorine treatment have a similar effect at Redondo, Scattergood, and El Segundo Generating Stations.

REFINERY IMPACTS

High concentrations of ammonium were associated with a relatively consistent dinoflagellate bloom near the El Segundo Refinery discharge from 1975 to 1977. Ammonium levels and dinoflagellate abundance both decreased after 1977, but is not certain whether effluent from the El Segundo Refinery was actually responsible for conditions leading to this bloom (Eppley 1986).

OIL SPILL IMPACTS

Oil slicks may cause a short-term reduction of light penetration and hence reduce photosyn thesis in certain areas. These effects would last for a few days (Eppley 1986).

URBAN RUNOFF IMPACTS

Storm runoff plumes can also enhance phytoplankton levels if the runoff contains elevated levels of nutrients. However, if suspended sediment concentrations are high, light penetration may be reduced, leading to low photosynthesis and phytoplankton levels (Eppley 1986). Phytoplankton abundance in Santa Monica Bay increased dramatically in 1969, a year with exceptionally high surface runoff (SCCWRP 1973).

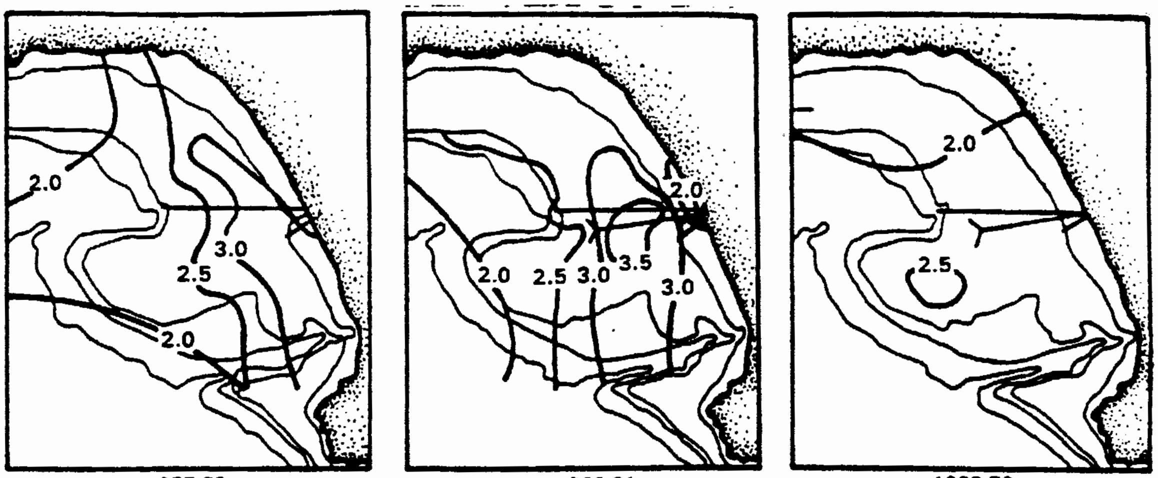


Figure 9-1. Distribution of phytoplankton and zooplankton in Santa Monica Bay during three discharge periods 1957-1959, 1960-1961, and 1962-1970 (SCCWRP 1973) Units in *ml*/1,500 *L*

SOFT BOTTOM SEDIMENTS

Most contaminants are more concentrated and more readily measured in sediments than in the water column. Because contaminants usually bind to the surface of particulates, absolute levels are generally higher in fine sediments (which have a larger surface area per unit weight). Most studies of sediment concentrations in the study area have been near the HTP and JWPCP wastewater outfalls.

Contaminants in ocean sediments generally concentrate near point sources, whereas materials entering by way of aerial fallout are evenly distributed over the entire area. Once introduced, contaminants may be moved long distances with fine particles; most materials introduced into Santa Monica Bay are ultimately moved into offshore basins. Both the spatial and temporal distribution of contaminants are important and are described below.

DISTRIBUTION BY CONTAMINANTS

Treated wastewater discharges are the major source of toxic trace metals to the Southern California Bight (Young *et al.* 1978a). Cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc are most commonly studied. To assess man's impact on levels of metals, they must be measured at a reference site far from known inputs. In 1977, SCCWRP sampled and analyzed sediments from 71 sites in the Southern California Bight at water depths of about 200 feet, the depth at which most wastewater outfalls are located. On the basis of chemical and biological measurements, 29 of these sites were selected as reference stations (Word and Mearns 1979).

In 1985, levels were reexamined (Thompson *et al.* 1987) at 13 of the 1977 references sites to evaluate changes over time. There was no consistent trend in metals concentrations at these reference stations, some increased and while others decreased, most values were in the same general range in 1985 as they were in 1977.

Analysis of undisturbed core samples has also been used to estimate background metals levels (SCCWRP 1973, Galloway 1979). In this technique, a deep core of sediments is collected and sectioned horizontally and analyzed separately. Since sediment age increases with depth in the core, levels prior to human influence can then be determined.

Trace metal levels in surface sediments near the HTP and JWPCP outfalls are higher than levels found by Galloway (1979) in core-base sediments, but have generally decreased since 1985 (Table 9-1). In 1991 trace metals from near the 5-mi outfall were 0.8 to 9.6 times higher than core-base levels; those near the 7-mi outfall were four to 120 times higher and those near the JWPCP outfall (in 1990) were 11 to 81 times higher. Cadmium was the most enriched at all outfalls.

Levels elevated above background levels are not necessarily toxic to the local organisms. Ranges of toxicity have been developed by the National Oceanographic and Atmospheric Administration (NOAA) (Long and Morgan 1990) using data from spiked sediment bioassays, sediment-water equilibrium partitioning, and the co-occurrence of adversely effected fauna and contaminant levels in the field. Chemical concentrations believed to be associated with adverse biological effects from the various independent studies were compared for each parameter and the lower ten percentile was designated as the "Effects Range-Low" (ER-L). The median of concentration levels was designated the "Effects Range-Median" (ER-M). An Apparent Effects Threshold (AET) was also determined from this data. The National Research Council has also developed threshold toxic levels based on data from USEPA, the U.S. Geological Survey, and other sources (NRC 1989).

MERCURY

In 1990, mercury levels were highest near the HTP 7-mi and JWPCP outfalls and surrounding areas (Figure 9-2). Mercury concentrations were also elevated (up to 1.2 ppm) in Marina del Rey (Soule *et al.* 1992), (Table 9-1).

In 1972, mercury levels in sediments were elevated as much as 100-fold over background levels (Eganhouse *et al.* 1976), the average enrichment on the Palos Verdes Shelf being 23-fold (Hershelman *et al.* 1981). In 1972, the highest levels in Santa Monica Bay proper were within 0.6 mi of HTP's 5-mi outfall, where they were elevated 14-fold, and near Redondo Submarine Canyon, where they were 18 times background. Concentrations in most of Santa Monica Bay were lower in 1990 than in 1970. Mercury concentrations decreased approximately 50% near the 7-mi outfall between 1990 and 1991, from almost three times the effects levels to less than twice the effects levels (Table 9-1). Concentrations are still higher near the 7-mi outfall than near the 5-mi outfall.

On the Palos Verdes Shelf sediment mercury levels declined 46% at 100-ft stations, 38% at 200-ft stations, and increased 3% at depths of 500 feet between 1973 and 1979, suggesting down-slope and offshore movement of contaminants (Stull and Baird 1985). Pre-1974 values may not be as accurate as recent values and the decrease may have been greater (Stull 1988, pers. comm.). Mercury levels on the Palos Verdes Shelf in 1990 were less than half those in 1973 except at the JWPCP outfalls. Concentrations deceased with distance north of the outfall and were below 1 ppm on most of the Palos Verdes Shelf the level at which effects are seen (Table 9-1, Figure 9-2).

CADMIUM

In 1986, cadmium concentrations exceeded 5 ppm (the level at which effects may occur) at stations close to the 5-mi outfall and in the 7-mi sludge field. They exceeded the average Bay value of 2.8 ppm in an ellipse about one mile wide and two miles long which included both outfalls. In 1990 and 1991, the ellipse of elevated levels was still centered on the 5- and 7-mi outfalls but its areal extent was smaller than in 1986 (Figure 9-3). Cadmium concentrations at the 7-mi outfall have been slowly decreasing since 1985 and were below the NRC threshold toxic level in 1991, although still above other effects levels (Table 9-1).

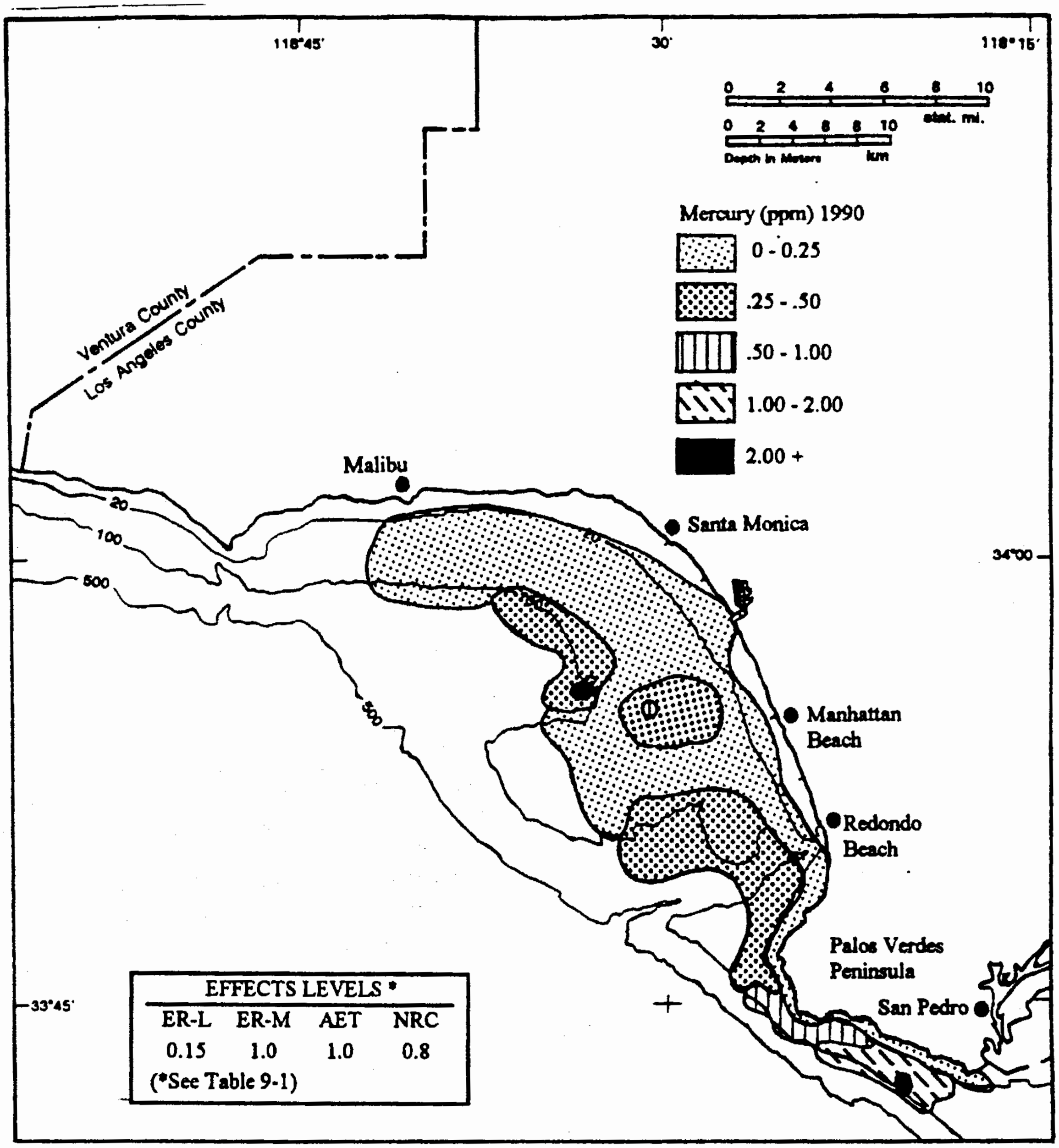


Figure 9-2. Mercury concentrations in surface sediments of Santa Monica Bay and Palos Verdes Shelf, 1990. Map contours contain areas of measurement. (Soule *et al.* 1992; CLA,DPW unpubl. data; LACSD unpubl. data).

In 1977, cadmium levels off Palos Verdes exceeded average Bight values by about 36-fold (Hershelman *et al.* 1981). Between 1974 and 1980, concentrations and the area of very high concentrations both decreased. This trend continued, with an 48% decline in sediment cadmium concentrations near the JWPCP outfalls between 1980 and 1985 (LACSD unpubl. data). The general trend of decreasing cadmium levels on the Palos Verdes Shelf appears to have continued into 1990, although at some shallow sites levels were higher in 1990 than in 1980. The highest levels on the Palos Verdes Shelf are near the JWPCP outfalls, but concentrations were above the NRC threshold toxic level of 31 ppm at only one sampling station (Figure 9-3).

Metal	Effects levels ER-L	ER-M	AET	NRC	MDR 1990	1991
Cadmium	5	9	5	31	2.1	5.5
Chromium	80	145	nd	nd	70	68
Copper	70	310	300	136	399	410
Lead	35	110	300	132	325	575
Mercury	0.15	1.0	1.0	0.8	1.1	1.2
Nickel	30	50	nd	20	41	43
Zinc	120	270	260	760	491	640
Notes	a	a	a	b	c	c

Metal	Back-ground	Core-base	JWPCP 1985	1990
Cadmium	0.4	0.42	21.0	33.9
Chromium	5-40	53	804	581
Copper	10	21	529	386
Lead	2-29	6.2	112	237
Mercury	0.05	nd	nd	2.31
Nickel	nd	nd	nd	69
Zinc	nd	75	932	1051
Notes	d	e	f	f

Metal	Back-ground	Core-base	HTP 5-mi 1985	1989	1990	1991
Cadmium	0.4	0.22	4.0	2.9	3.5	2.1
Chromium	5-40	62	20	68	84	48
Copper	10	13	63	52	50	37
Lead	2-29	7	33	24	21	11
Mercury	0.05	nd	nd	0.29	0.44	0.18
Nickel	nd	nd	nd	23	19	14
Zinc	nd	57	107	90	98	63
Notes	d	e	g	g	g	g

Metal	Back-ground	Core-base	HTP 7-mi 1985	1989	1990	1991
Cadmium	0.4	0.22	44.0	37.2	33.4	26.3
Chromium	5-40	62	217	462	298	235
Copper	10	13	657	572	531	392
Lead	2-29	7	nd	164	140	122
Mercury	0.05	nd	nd	2.38	2.89	1.57
Nickel	nd	nd	nd	89	65	52
Zinc	nd	57	829	745	612	480
Notes	d	e	h	h	h	h

Notes and sources:

a. Effects levels: ER-L, ER-M: = Effects range low and medium; AET: Apparent effects threshold (Long and Morgan 1990)
b. National Research Council EPA Threshold Toxic Levels (NRC 1989)
c. Maximum values found in Marina Del Rey in October 1990 and May or October 1991 (Soule et al. 1992)
d. NOAA 1991a
e. Means of bottoms of Phleger core samples >20 cm taken within 6 mi of the outfalls (Galloway 1979)
f. ZID station (LACSD unpubl. data)
g. Averaged of levels found at ZID Stations Z1 and Z2 (CLA, DWP unpubl. data)
h. ZID Station E6 for 7-mi (CLA, DWP unpubl. data)
nd = no data

Table 9-1. Effects levels, background, and concentrations of metals in sediment in Marina del Rey, near HTP 5 and 7 mile outfalls and near JWPCP outfalls, 1985-1991. All values are in ppm.

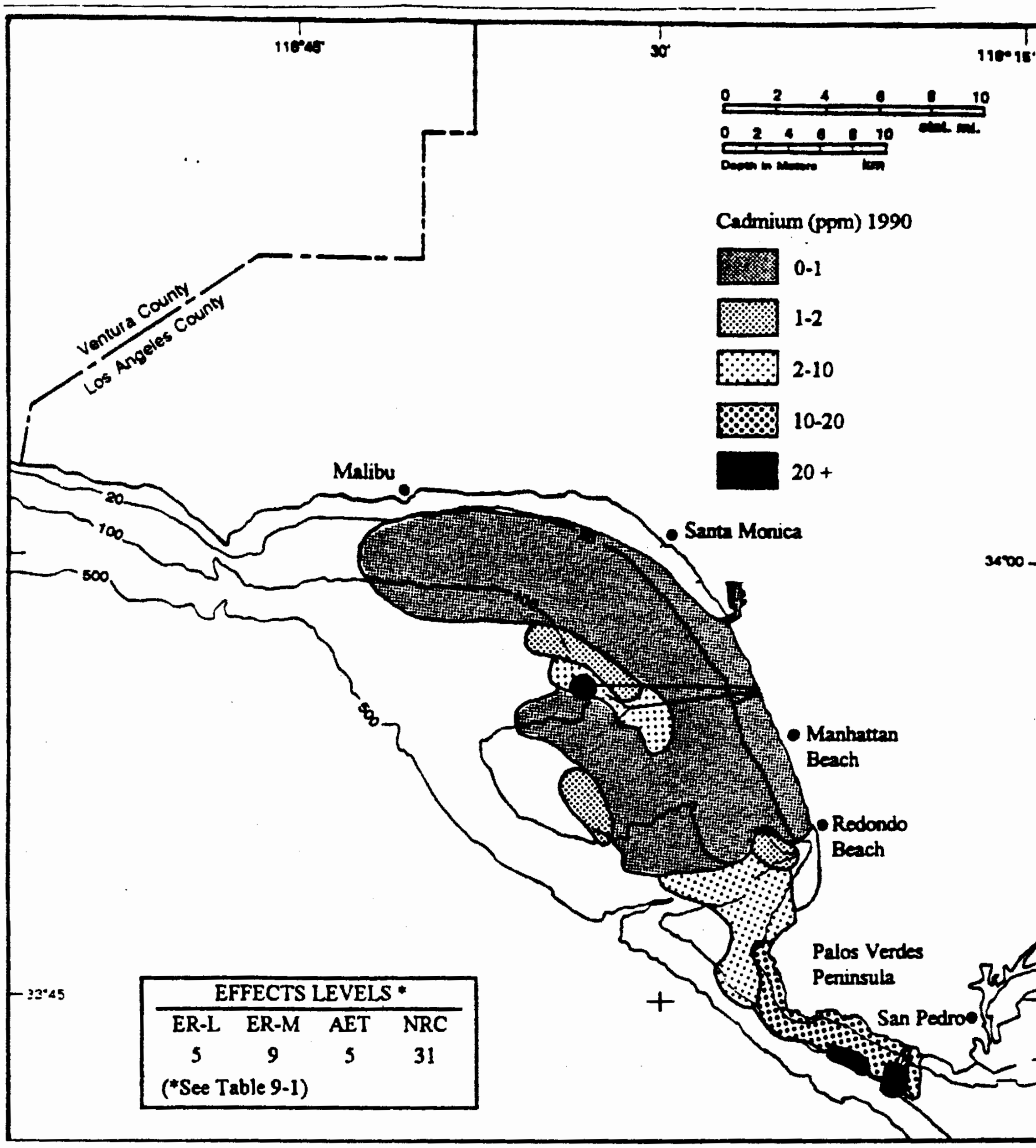


Figure 9-3. Cadmium concentrations in surface sediments of Santa Monica Bay and Palos Verdes Shelf, 1990. Map contours contain areas of measurement. (Soule *et al.* 1992; CLA,DPW unpubl. data; LACSD unpubl. data).

Cadmium concentrations in Marina del Rey in 1991 were generally below 1 ppm, although they ranged as high as 5.5 ppm (Table 9-1).

LEAD

In 1986, the concentrations of lead in sediments Bight-wide along the 200 feet isobath, averaged 32 ppm, five times background level (Word and Mearns 1979). In 1990, most levels in the Bay were below 20 ppm (Figure 9-4). In 1986 and 1990 the most concentrated lead values were in the Bay at the end of the 7-mi outfall. Elevated lead levels extended northwest of the 7-mi outfall (Figure 9-4) in both 1990 and 1991, although levels were only above effects levels near the 7-mi outfall (Table 9-1). In the Bay, levels were lower overall and the area of elevated levels was smaller than in 1986.

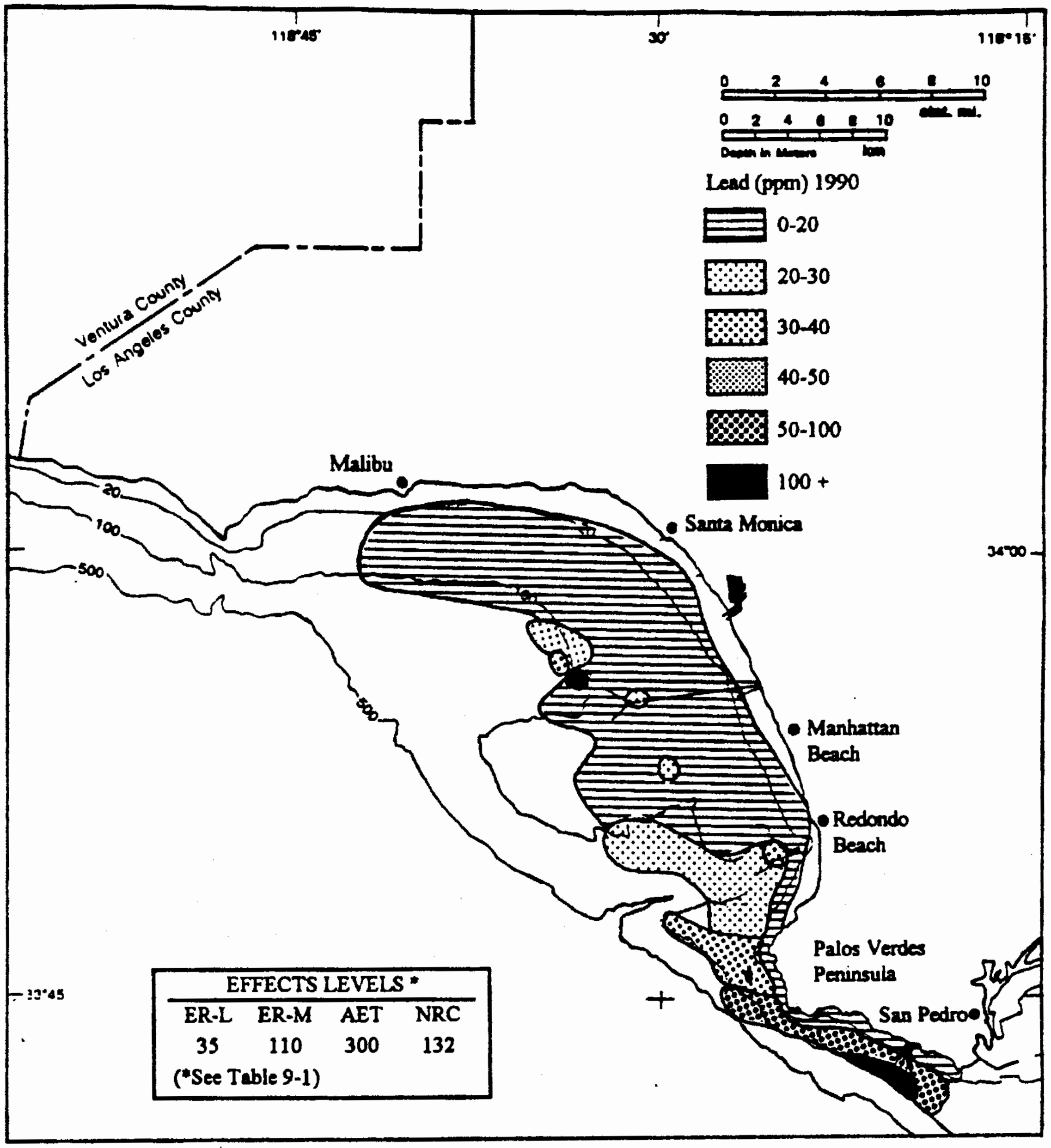


Figure 9-4. Lead concentrations in surface sediments of Santa Monica Bay and Palos Verdes Shelf, 1990. Map contours contain areas of measurement (Soule *et al.* 1992; CLA,DPW unpubl. data; LACSD unpubl. data).

Most sites in Marina del Rey in 1991, contained more than 100 ppm lead, over ten times the levels in most of Santa Monica Bay (168 ppm in May, 152 ppm in October) and the highest levels exceeded toxic thresholds (Table 9-1). The average lead concentrations in Marina del Rey in 1991 were higher than average from 1984 to 1991 (Soule *et al.* 1992). Lead levels in Marina del Rey also generally increased between 1977 and 1987, a three-fold increase in the entrance channel and a ten-fold increase at the mouth of Ballona Creek (Soule and Oguri 1987).

Lead concentrations in sediments near the JWPCP outfalls decreased by 59% between 1980 and 1985 (LACSD unpubl. data), continuing the trend from 1974 to 1980 (Stull and Baird 1985), although values were still 23 times background at stations nearest the outfalls (Swartz *et al.* 1986, LACSD unpubl. data). Vertical profiles of Palos Verdes Shelf sediments along the 200-feet isobath also show declines from earlier levels (Figure 9-5) (Stull *et al.* 1986a). Sediment lead concentrations decreased substantially on the Palos Verdes Shelf to below 100 ppm in 1990 except in sediments nearest the JWPCP outfalls (Figure 9-4). Highest concentration in 1990 was 237 ppm compared to 449 ppm in 1980 and 594 ppm in 1974. However, concentrations on much of the Palos Verdes Shelf remain above NRC theoretical effect concentrations (Table 9-1).

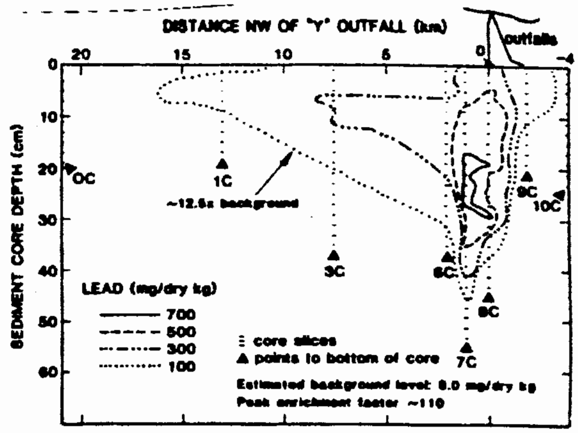


Figure 9-5. Lead stratigraphy along the 60 meter isobath on Palos Verdes Shelf. (Stull *et al.* 1986a; SDWG 1988).

The general trend over time appears to be a decline in sediment levels throughout the study area, except in Marina del Rey. This is probably a result of a decline in mass emissions from wastewater treatment plants and in aerial fallout. Nearshore sediments are gradually being cleansed of lead by resuspension and offshore transport.

OTHER METALS

Generally, the distributions of other metals are similar to those of mercury, cadmium, and lead. In 1990, copper concentrations were five to ten times higher near the JWPCP outfalls than on the rest of the Palos Verdes Shelf; arsenic, chromium, and zinc were four times higher and nickel and silver, two times higher (LACSD unpubl. data). Copper concentrations are relatively high in Marina del Rey, but appear to be decreasing near the HTP and JWPCP outfalls (Table 9-1).

A notable exception to this pattern is that of the organic forms of tin, particularly tributyl tin (TBT). TBT has been used in the production of textiles, plastics, paints, fungicides, bactericides, and rodenticides since 1925 and in anti-fouling boat paint in the 1960s (Sax and Lewis 1987, Soule and Oguri 1987). However, because TBT is toxic to marine life it has been banned from use on vessels less than 50 feet long.

Present levels of TBT are linked to historical use on pleasure craft berthed in marinas. TBT values in Marina del Rey have decreased three orders of magnitude from 1,070 ppm in 1987 to 0.53 ppm in 1991 (Soule *et al.* 1992).

INORGANIC NONMETALLIC SUBSTANCES

Sediments act as a regeneration point for water column nutrients and as a sink for water column toxicants. Elemental nutrients (nitrogen, phosphorus, silicon) and toxicants (sulphur, chlorine) undergo changes in chemical form and distribution which may be further modified by man's activities. Inorganic nonmetallic substances may be essential parts of the marine system, but may be contaminants if especially excessive.

ORGANICS INDICATORS

Total organic carbon (TOC) and organic nitrogen are measures of the amount of organic matter in sediments. In 1985, Bight-wide reference sites contained 0.2 to 1.5% TOC (Thompson *et al.* 1987), whereas in Santa Monica Bay, TOC was 6.4% at HTP's 7-mi outfall and 0.8% at the 5-mi outfall (CLA,DPW 1986). In the same year, values in Marina del Rey ranged between 1.0 and 10.1% and were highest at the mouth of Ballona Creek (Soule and Oguri 1986).

In 1990, TOC in Santa Monica Bay was again highest (4.7%) at HTP's 7-mi outfall with levels of 1.3 to 1.7% to the northwest, while most of the Bay sediments contained less than 1% (CLA,DPW unpubl. data). After the termination of sludge disposal from the 7-mi outfall, TOC in the sludge field decreased from approximately 10% in 1986 to 8.5% in 1990 (SCCWRP 1992). On the Palos Verdes Shelf, levels were highest (5 to 8%) at and offshore of the outfalls, and decreased to 1 to 2% to the north. Levels in Marina del Rey in 1991 were generally 2 to 4% (Soule *et al.* 1992).

Treated sewage is a major source of nitrogen and elevated nitrogen values in sediments can be used to trace the transport and deposition of wastewater particulates. In 1977, organic nitrogen in sediments along the 200-ft isobath in the Southern California Bight averaged 0.11%, compared to the background level of 0.08%. The highest levels were in the vicinity of the HTP 5-mi (0.11%) and the JWPCP outfalls (0.81%) (Word and Mearns 1979), but in 1990 organic nitrogen levels were half the 1977 level near the JWPCP outfalls (Stull 1993, pers. comm.).

After termination of sludge disposal, organic nitrogen in the 7-mi sludge field decreased, from approximately 1.0% in 1986 to 0.08% in 1990 (SCCWRP 1992). Sediment levels of organic nitrogen also decreased on the Palos Verdes Shelf between 1971 and 1990. The highest levels (up to 0.4%) in 1990 were near the JWPCP outfalls, while most of the Shelf had levels below 0.2%. Organic nitrogen levels in Marina del Rey in 1991 were generally 0.1 to 0.2% (Soule *et al.* 1992).

OIL AND GREASE

In 1991, the highest levels of oil and grease in Santa Monica Bay were at the 7-mi outfall (4,400 ppm) and in approximately 150 feet of water off El Segundo (4,760 ppm) (CLA,DPW unpubl. data). Levels higher than 400 ppm extended northwest and southeast of the 7-mi outfall while most sediments in the Bay contained less than 300 ppm. In 1989 and 1990, levels were even higher near the 7-mi outfall, 17,300 and 16,300 ppm, respectively.

The abundance of oil and grease near El Segundo in 1991, may have been due to a Chevron oil spill in March 1991, as levels in 1989 and 1990 were near average.

Oil and grease levels were high in Marina del Rey in 1991, as much as 8,700 ppm, although they were between 1000 and 2000 ppm in most areas (Soule *et al.* 1992). Oil and grease levels have always been high in Marina del Rey in the past, presumably from boating activities. In 1977 and 1978, values ranged from 1,000 to 7,000 ppm; in 1984 from 200 to 5,000 ppm; and in 1985 and 1987, up to 20,700 ppm. In 1987, concentrations within the Marina ranged from 1,000 to 4,250 ppm; the higher concentrations were near the mouth of Ballona Creek, suggesting runoff as the source (Soule and Oguri 1987).

In 1980, concentrations of oil and grease were 20,600 ppm at the JWPCP outfalls, but decreased to 1,020 ppm northward (Swartz *et al.* 1986). By 1983, concentrations had decreased to 6,860 ppm at the outfalls and to the north, around Palos Verdes Point, to 610 ppm. In those same years values at a reference site in northern Santa Monica Bay were 338 and 516 ppm, respectively.

PCBs

Polychlorinated biphenyls (PCBs) are among the most persistent and toxic of synthetic organic compounds. Over 200 congeners of PCB and a variety of mixtures have been produced; Aroclor 1254 was the most widely used locally. The manufacture of PCBs was limited in 1970 and their use restricted in 1972 to closed systems; manufacture of new PCBs was banned altogether in 1976.

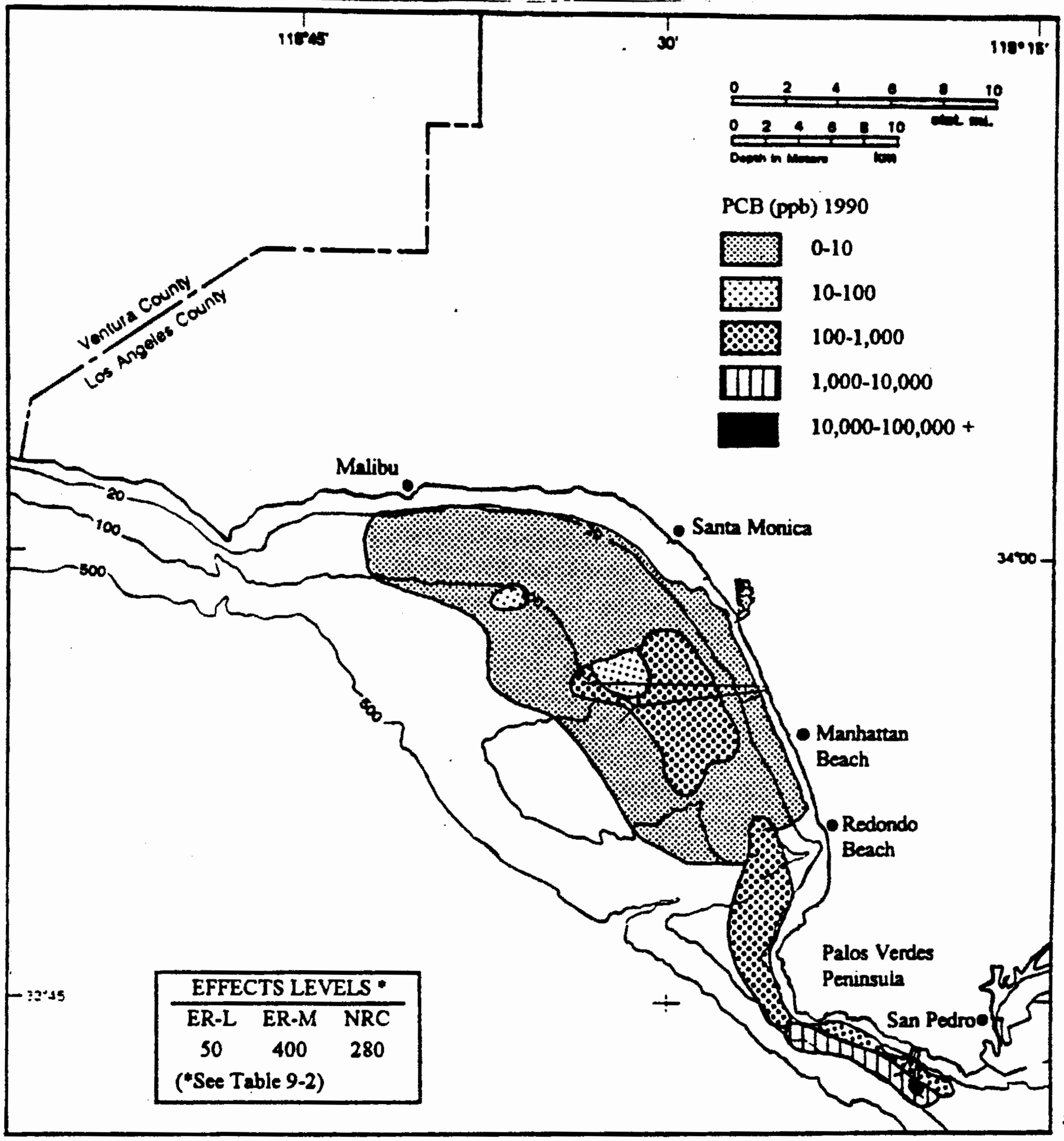


Figure 9-6. PCB concentrations in surface sediments of Santa Monica Bay and Palos Verdes Shelf, 1990. Map contours contain areas of measurement. (Soule *et al.* 1992; CLA,DPW unpubl. data; LACSD unpubl. data).

PCBs are still concentrated in the sediments near municipal outfalls and in harbors, even though input levels have decreased with time (CSWRCB 1983). In 1976, it was estimated that 6 MT of Aroclor 1254 alone occurred on the 19 mi^2 of shelf surrounding the JWPCP outfalls (Young *et al.* 1976a).

In 1985, reference areas outside the study area had an average PCB concentration of 17.5 ppb — more than twice the average of 7.2 ppb in 1977 (Thompson *et al.* 1987), although the high levels have been attributed to analytical or sampling site differences (Stull 1993, pers. comm.). In 1977, concentrations of PCBs in sediments from the 200-ft isobath of the Palos Verdes Shelf averaged 3,120 ppb, 69% which was Aroclor 1254. Concentrations of 10,890 ppb (60% 1254) were found near the JWPCP outfalls, but levels of both total and 1254 declined westward to 109 ppb (83% 1254) off Rocky Point (Word and Mearns 1979). By 1985, most of the Palos Verdes Shelf had PCB levels of less than 2,000 ppb. The highest levels (4,880 ppb) were again found offshore and to the north of the JWPCP outfalls (Stull 1988, pers. comm.). In 1990, PCB levels on most of the Palos Verdes Shelf were below 500 ppb, however, near the outfalls levels were 2,000 to 4,000 ppb, and up to 11,000 ppb in areas immediately adjacent (Figure 9-6).

In 1977, sediments contained an average of 157 ppb PCBs (81% 1254) in the vicinity of the HTP outfalls and along the 200-feet isobath. Levels were highest (up to 513 ppb, 80% 1254) near the outfalls; these values were four times the background off Point Dume (Word and Mearns 1979). In 1975, PCB concentrations as high as 10,000 ppb were measured in the sludge field below the 7-mi outfall.

By 1989 and 1990, PCB levels were below detection levels (20 ppb), in much of Santa Monica Bay, although in 1989 they were detected in a small area north and west of the 7-mi outfall. In 1990, levels were higher than in 1985 in an area near and southwest of the discharge (Figure 9-6). In 1991, the area of detected PCBs was larger than in 1990 in the same locations. Essentially all PCBs detected from 1989 to 1991 in Santa Monica Bay were Aroclor 1254.

In 1989, PCB concentrations were high (up to 330 ppb) in Marina del Rey where they previously had not been detected (Soule *et al.* 1992). Areas of high concentration varied between surveys, but were below detection levels by 1991. These PCBs may have been introduced at the result of grading projects in areas which were contaminated by industrial activity during World War II. Levels were up to six times toxic thresholds in May 1991 (Table 9-2).

	Effects levels					Hyperion	
Pesticide	R-L	ER-M	NRC	MDR	JWPCP	5-mi	7-mi
DDT	3	350	nd	136	138,000	75	146
PCB	50	400	280	300	10,913	90	125
Chlordane	0.5	6	20	436	nd	<50	<50
Notes	a	a	b	c	d	e	f

Notes and sources:
a. Effects levels: ER-L, ER-M: = Effects range low and medium (Long and Morgan 1990)
b. National Research Council EPA Threshold Toxic Levels (NRC 1989)
c. Maximum values found in Marina Del Rey in May or October 1991 (Soule et al. 1992)
d. ZID station, 1990 (LACSD unpubl. data)
e. Averaged of levels found in 1990 at ZID Stations Z1 and Z2 (CLA, DWP unpubl. data)
f. ZID Station E6 for (CLA, DWP unpubl. data)
nd = no data

Table 9-2. Effects levels and maximum concentrations (ppb dry weight) of pesticides in sediments in Marina del Rey, near HTP 5 and 7 mile outfalls and near JWPCP outfalls, 1990-1992.

The recent appearance of PCBs in Marina del Rey, and the increase in sediment concentrations from 1989 to 1990, and 1990 to 1991 indicate an upstream, historical source of PCBs.

Large amounts of DDT processing wastes were discharged through the JWPCP outfalls, resulting in especially high concentrations of DDT, DDD and DDE on the Palos Verdes Shelf. An estimated 1,700 MT of DDT were discharged between 1953 and 1970 — about 291 kg/day in 1970. The discharge of DDT processing wastes ceased in 1971, although DDT was manufactured until 1982.

In 1972, an estimated 200 MT of "total" DDT (i.e., DDT, DDD, and DDE) were contained in the upper foot of sediments in a 19 mi^2 zone around the JWPCP outfalls and 300 MT more on the surrounding shelf. In some places concentrations exceeded 200,000 ppb, the highest in shallow water northwest of the outfalls (MacGregor 1976, Young *et al.* 1976b). Between 1971 and 1973, the concentration of DDT in surface sediments near the JWPCP outfalls ranged from 50,000 to over 200,000 ppb, however, in 1982 they averaged about 19,000 ppb. By 1985, most surface sediments on the Palos Verdes Shelf contained less than 10,000 ppb, although adjacent to the JWPCP outfalls, levels were as high as 65,000 ppb (Stull 1988, pers. comm.). Peak DDT levels (375,000 ppb) in 1985, were 12 in. below the surface (Figure 9-7), indicating that the heavy loading of the late 1960s and early 1970s has been buried.

By 1990, DDT levels on the Palos Verdes Shelf (Figure 9-8) had decreased somewhat, though not substantially since 1985. The highest concentrations are near the JWPCP outfalls, (up to 138,000 ppb), ten times those on the shelf generally, and 100 times those to the north (CLA,DPW unpubl. data; LACSD unpubl. data).

In 1985, concentrations of DDT around the HTP outfalls decreased to the north and increased to the south, although levels near the 5- and 7-mi outfalls were higher than in the surrounding area. Values in Redondo Submarine Canyon are intermediate between those in Santa Monica Bay and the JWPCP area, suggesting that DDT has moved from the Palos Verdes Shelf into and across Redondo Submarine Canyon, and has mingled with inputs from HTP. In 1982, the mass emission rate from JWPCP was only 15 times that from HTP, yet the sediments off Palos Verdes contained 200 to 300 times more DDT than those around the HTP outfalls (Brown *et al.* 1984a).

DDT levels in Santa Monica Bay in 1990 and 1991 indicate that areas of high concentrations are slowly shrinking (Figure 9-8). Most of the total DDT found in Santa Monica Bay from 1988 to 1991 was DDE. DDT has only been detected twice since 1988: near the 5-mi outfall in 1988 and inshore of the 5-mi outfall in 1990, indicating that most DDT has degraded to the less toxic DDE (NRC 1989).

Total DDT in Marina del Rey is above low effects levels (Table 9-2). Maximum levels decreased between 1990 and 1991, but increased between May 1991 and October 1991 after the spring rains, indicating upstream sources of DDT. The presence of DDT as well as DDE and DDD also suggests continued input (Soule *et al.* 1992).

In 1977, background sediment DDT levels averaged 30 ppb along the Bight-wide, 200-feet isobath (Word and Mearns 1979). When these same stations were resampled in 1985, the average DDT concentration had declined to 19.4 ppb (Thompson *et al.* 1987). In 100 feet of water DDT averaged 9.1 ppb, while in 500 feet of water it averaged 30.1 ppb, suggesting that DDT has moved offshore with time. Although levels in most of Santa Monica Bay have decreased with time, they remain above background levels.

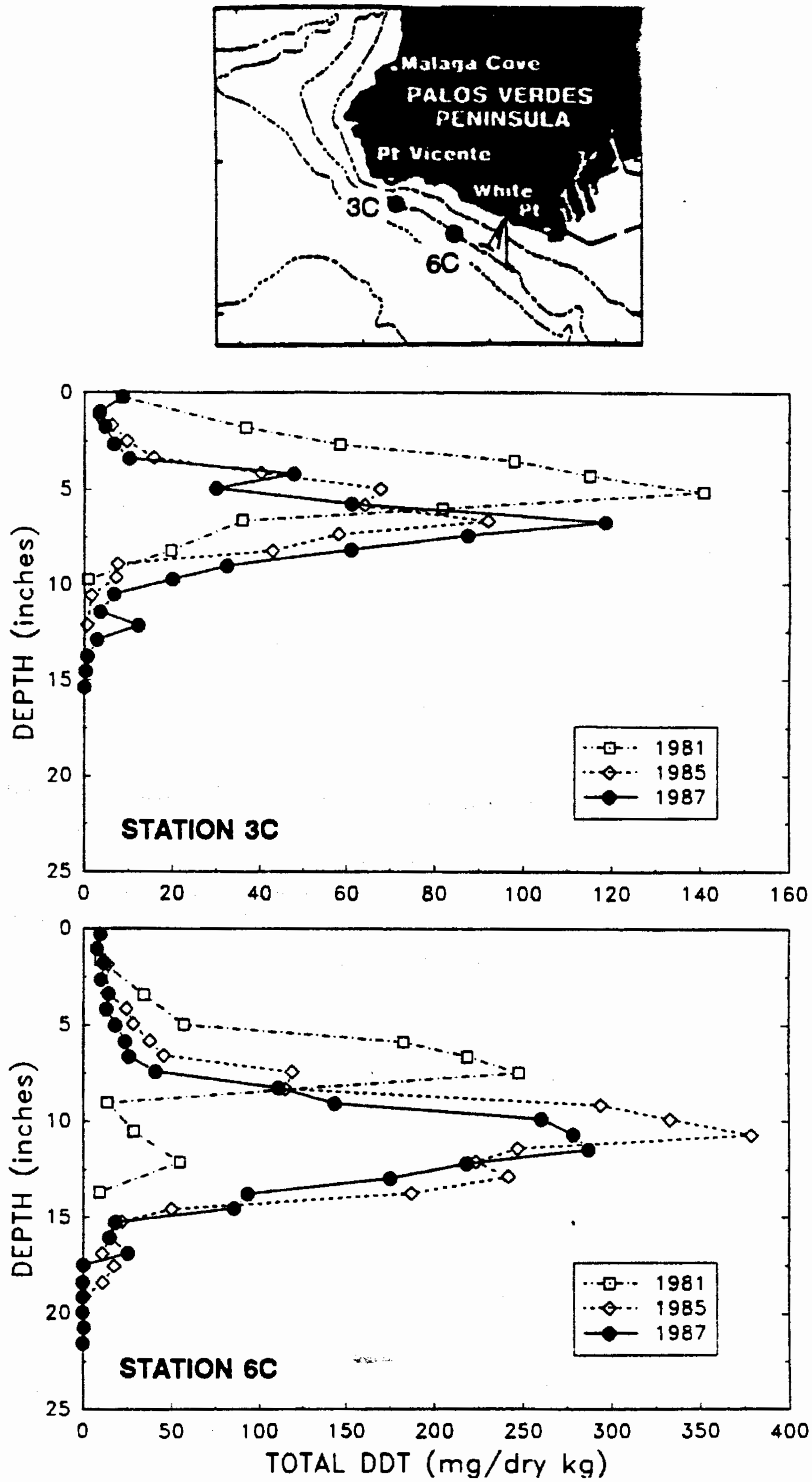


Figure 9-7. Concentration-depth profiles of total DDT at two stations along the 60 meter isobath 1982-1987 (modified from SDWG 1988).

Since 1971, mass emissions of DDT to the study area have decreased and degraded to DDD and DDE and moved offshore. Because contaminated sediments can be reexposed and resuspended by storms and bioturbation, leading to the bioaccumulation of previously buried DDT or DDE, DDT continues to be of concern.

OTHER PESTICIDES

After DDT was banned, other pesticides were used and many of these are now found in the marine environment. Among the most common are aldrin, dieldrin, endrin, endosulfan, heptachlor, and isomers of BHC. In 1986, the concentrations of most of these in the vicinity of the HTP outfalls were less than 9 ppb. Gamma BHC, heptachlor epoxide, and endosulfan were most concentrated near the HTP 5-mi outfall, alpha BHC along the shelf break off Malibu, and dieldrin in Redondo Submarine Canyon. By 1991, most of these compounds were not detected in Santa Monica Bay, although 266 to 718 ppb of Beta BHC were found along the 45-mi isobath.

Chlordane is a persistent insecticide which was used extensively in termite control until it was banned in 1988. Chlordane is high in Marina del Rey and may be increasing suggesting that it is continually being introduced (Soule *et al.* 1992). In 1991, all levels exceeded effects levels in Marina del Rey (Table 9-2).

PAHs

Polycyclic (or polynuclear) aromatic hydrocarbons (PAHs) are related compounds which are present in crude oil and refined products and are released during combustion. Some are also released during the burning of non-petroleum substances in brush and forest fires. There is concern about PAHs in the environment, however, their local abundance and distribution is not well known.

In 1984, the concentration of PAHs near the JWPCP outfalls was 560 ppb, at the HTP outfalls 370 ppb (Malins *et al.* 1987). In 1985, among sediments from 24 river mouths, harbors, and outfalls between Santa Monica Bay and San Diego, the least contaminated sample contained 150 ppb of PAHs. Sediments from the HTP 5-mi outfall contained 393 ppb PAHs, those from the 7-mi outfall 11,317 ppb, and those near the JWPCP outfalls 7,902 ppb (Anderson and Gossett 1986).

In 1985, 43 "reference" sites between Point Conception and San Diego averaged 32 ppb PAHs. Sites close to Los Angeles generally included four to six compounds, those further away only one or two compounds. A site in 100 feet of water west of Point Dume was one of the most contaminated, with 147 ppb PAHs (Thompson *et al.* 1987).

In 1987, sediment PAH at HTP 7-mi outfall were 20,000 ppb, higher than found in sites in Long Beach, Los Angeles, or San Diego harbors where values ranged from 4,700 to 12,100 ppb (SCCWRP 1989). Since the termination of sludge disposal at the 7-mi outfall, PAHs in the sludge field have decreased 50%, from approximately 10,000 to 5000 ppb (SCCWRP 1992).

In a nationwide survey, the highest levels of total PAH in California were found in San Diego Harbor (7,300 ppb) followed by San Francisco Bay (4,700 ppb) and San Pedro Bay (2,400 ppb) (NOAA 1991a). Sediment levels near Palos Verdes, in Santa Monica Bay, and in Marina del Rey were 1,100, 1,300, and 320 ppb, respectively.

CONTAMINATED SEDIMENTS AS POINT SOURCES

Areas on Palos Verdes Shelf, near HTP 5- and 7-mi outfalls and in Marina del Rey, sediments are sufficiently contaminated to be considered point sources of contamination themselves.

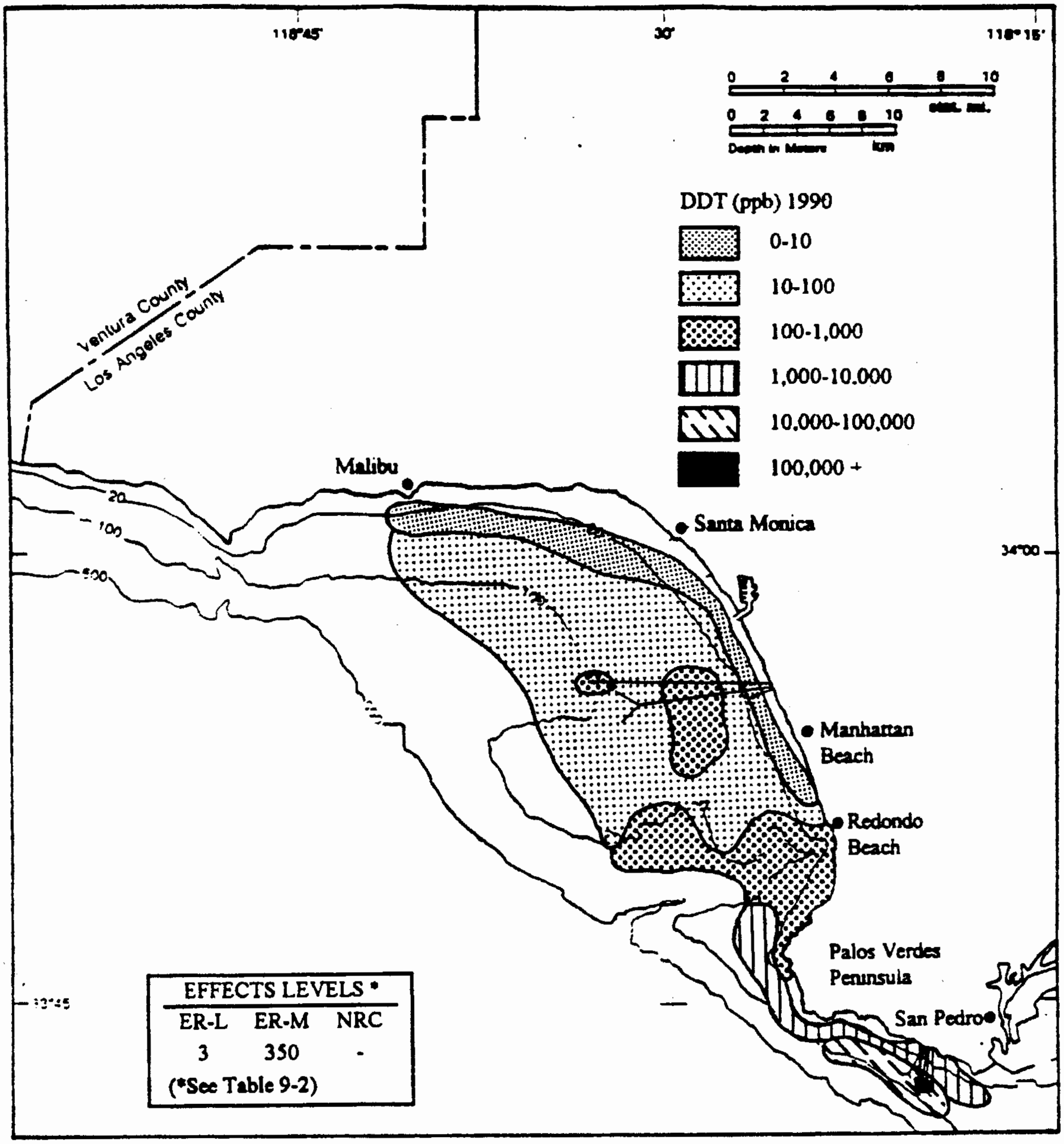


Figure 9-8. Total DDT concentrations in surface sediments of Santa Monica Bay and Palos Verdes Shelf, 1990. Map contours contain areas of measurement. (Soule et al. 1992; CLA,DPW unpubl. data; LACSD unpubl. data).

Most contaminants are more concentrated on the Palos Verdes Shelf than in Santa Monica Bay; they are especially high to the northwest and offshore of the JWPCP outfalls, and decrease with distance toward Redondo Submarine Canyon. DDT levels are decreasing in Santa Monica Bay and on the Palos Verdes Shelf, however, they remain elevated near the outfalls. Lead concentrations have decreased, but are now higher in Marina del Rey than at the JWPCP outfalls.

PALOS VERDES SHELF

Contaminated sediments deposited on the Palos Verdes Shelf in the recent past may be a primary source of contamination to Santa Monica Bay and of DDT and PCBs for the entire Southern California Bight (Mearns *et al.* 1991, SCCWRP *et al.* 1992). High levels of DDT, PCB, lead, and other trace metals accumulated near the JWPCP outfalls prior to the 1970s. The primary field of contaminated sediments in 1972 was about 19 mi^2 upcoast of the JWPCP outfalls (MacGregor 1976, Young *et al.* 1976a).

Although DDT levels were highest near the sediment surface in 1972, peak levels were about six inches below the sediment surface in 1981, and about 12 inches below the surface in 1987 (Figure 9-7) (SDWG 1988). Away from the outfalls (at Point Vicente) levels of DDT were shallower,six inches below the sediment surface in 1981 and seven inches in 1987 (SDWG 1988). Lead shows a similar pattern: peak concentrations about 12 inches below the sediment surface near the outfall and about two inches below the surface nine miles upcoast of the outfalls (Figure 9-5) (Stull *et al.* 1986a, SDWG 1988).

Despite the burial by cleaner particulates following termination of DDT inputs (1971), and PCB inputs (mid-1970s), in 1990 DDT and PCB levels in white croaker and yellow rock crab tissue were still much higher on the Palos Verdes Shelf than at other locations in Santa Monica Bay indicating that the sediments are a primary source of contamination (SCCWRP *et al.* 1992). Bioturbation (the burrowing activities of infauna) may bring some of this contamination to the surface. In addition, some of these infauna may be preyed upon by fishes and larger invertebrates, thus introducing contamination into the food chain. Erosion especially at the edges of the field, may also remobilize the contaminants (SDWG 1988).

RECOVERY AT THE 7-MILE OUTFALL

Sludge from HTP was discharged from the 7-mi outfall from 1957 to 1987 resulting in a 20 mi^2 area of elevated contaminant concentrations centered along the axis of the upper part of Santa Monica Submarine Canyon. The sludge field was 50-100 cm deep (SCCWRP 1987) during the period of active sludge disposal. Sediments in the Canyon were characterized by extremely high organics and sulfides. By August 1990, the concentrations of most contaminants in the sludge field had decreased (SCCWRP 1992). DDT levels, on the other hand, decreased considerably at a nearby site although not in the sludge field.

Sulfide levels decreased rapidly within nine months after disposal abatement but remained higher than background levels. Organic carbon levels decreased 23%, nitrogen 29%, PCBs and PAHs about 49%, and trace metals 53 to 59%. In 1990, approximately 1 cm of clean sediment was found on the surface of the accumulated sludge. Based on the evidence of 1.5 year of pre-abatement and three years of post-abatement data recovery of the sludge field is estimated to take at least ten years, except for sulfide concentrations which may approach background by the end of 1994 (SCCWRP 1992).

MARINA DEL REY

Concentrations of the insecticide chlordane in Marina del Rey Harbor are as much as 100 times the "low effects" range (Soule *et al.* 1992). Although banned, chlordane continues to enter the Marina, either from continued use or from leaching from previously treated structures. DDT levels in Marina del Rey are sufficiently high to potentially impact larval and juvenile organisms. PCBs were found in the Marina between the October 1989 and May 1991, but were not detected in October 1991 (Soule *et al.* 1992).

Nickel concentrations are below low effects levels at most stations in the Marina while copper, lead, and zinc levels have fluctuated. Lead and zinc increase after heavy rainfalls, indicating terrestrial sources (Soule *et al.* 1992), lead levels in Marina del Rey are among the highest in Southern California (Mearns *et al.* 1991). Average copper levels in Marina del Rey have increased between October 1990 and October 1991, possibly because of copper based antifouling paint (Soule *et al.* 1992).

SOFT-BOTTOM BIOTA

MUNICIPAL WASTE-WATER DISCHARGES

MACROFAUNA

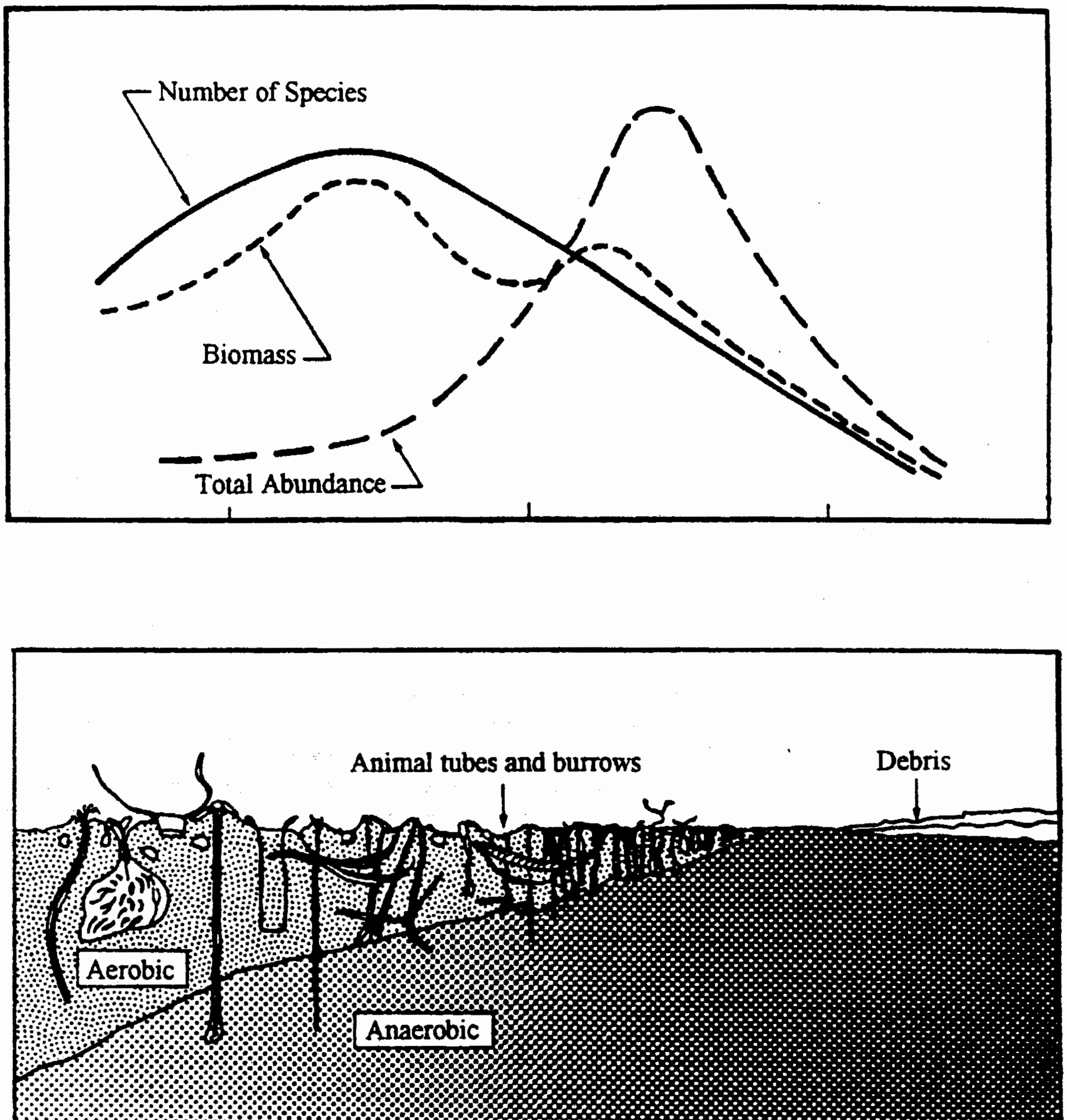
Large wastewater discharges into the sea have created "hotspots" of contamination and ecological imbalance, which generally expand with time as the discharge continues. They may contract if the discharge is stopped, its quality is improved, or if contaminated sediments are resuspended and flushed from the area. There is little evidence that wastewater effluent has approached shore in Santa Monica Bay since the discharge from HTP's 1-mi outfall was discontinued in 1960.

Early benthic investigations detected altered physical conditions in infaunal communities near outfalls in Santa Monica Bay. In 1957, the bottom near the JWPCP outfall was "foul" and lacked several important animal groups (Hartman 1959). As early as 1952, it was noted that infaunal community structure near the HTP 1-mi outfall was altered (Hartman 1956). Within 0.3 mi of the outfall was an impoverished zone, which was followed by an area of pollution-tolerant populations at 0.3 to 1.9 mi, and a zone of enrichment at 1.9 to 4.5 mi. High diversity and low density of species was noted at 4.5 to 7.9 mi and an unaffected bottom beyondeight miles. This description exemplifies the benthic enrichment gradient described by Pearson and Rosenberg (1978) (Figure 9-9).

The HTP 5-mi outfall became operational in 1961 and an area of impacted infauna began to develop around the discharge point. The 7-mi outfall became operational in 1957, and a degraded bottom community, (which corresponded to Hartman's 1952-1954 impoverished zone) developed. The affected area increased in the 1960s and 1970s, although the net trend has been downward (Hartman 1956, Tetra Tech 1981, Dorsey 1988). In 1985, an area of 11.5 mi^2 around the 5-mi and 7-mi outfalls supported an affected bottom community (Dorsey 1988), which corresponded to the first three zones observed by Hartman around the 1-mi outfall in 1952 to 1954. Thus, in the 31 years from 1954 to 1985, the area of bottom affected by the discharges declined by more than half, from 25 to 12 mi^2.

In 1977, the infaunal community in the study area was most degraded near the JWPCP outfalls and the HTP 7-mi outfall (Figure 9-10), as measured by the infaunal trophic index which evaluates the relative abundance of different infaunal assemblages (Bascom 1978). The general distribution of degraded and altered communities is very similar to that of many contaminants, including DDT and PCBs (Figures 9-6 and 9-8).

Comprehensive investigations of the infauna near the JWPCP outfalls were undertaken in 1972 and have continued to date. The infaunal community is most severely affected along a gradient of organic enrichment extending northwest of the outfalls along the Palos Verdes Shelf and slope. In 1980 to 1981, the abundance and biomass of infauna were low about 2.5 miles northwest of the outfall, although at or slightly above 1977 reference station values. Diversity and numbers of species were also very low up to 2.5 miles northwest of the outfall.



NORMAL	TRANSITION	POLLUTED	GROSSLY POLLUTED
Normal Infauna	Increased Abundance	Pollution Indicator Species	No Macrofauna

Figure 9-9. Generalized changes in fauna, sediment structure, and benthic community parameters along an organic enrichment gradient (Pearson and Rosenberg 1978).

The densities of the dominant species of infauna changed along a gradient extending 7 mi northwest of the outfalls at a depth of 200 feet (Tetra Tech 1984). The polychaete worms Capitella and Schistomeringos, which are indicators of degraded or polluted conditions, were most abundant near the outfall, while the clam Parvilucina (an indicator of mild pollution) and the polychaetes Mediomastus and Tharyx and the ostracod Euphilomedes (indicators of organically enriched, but not degraded areas) (Word *et al.* 1977) were more abundant away from the outfall.

Once the discharge of wastewater is stopped, the benthos recovers fairly quickly (Vesco and Gillard 1980). When regular discharge through the HTP 1-mi outfall was discontinued in 1961, the infauna in the area began to recover almost at once. Based on data collected between 1983 and 1987, the infauna near the 1-mi outfall can no longer be distinguished from that at similar depths elsewhere in the Bay (Dorsey 1988). HTP's 1-mi outfall was in a shallow, high-energy environment; recovery in deeper water (where most present outfalls are located) may proceed much more slowly (Smith 1988, pers. comm.).

HTP stopped disposing of sludge via the 7-mi outfall in November 1987. Quarterly sampling to determine the rate and direction of benthic recovery around the outfall was initiated in February 1986 (1.5 year prior to termination) and continued until August 1990.

In 1986, indicator taxa such as the polychaete Capitella capitata were most abundant in the contaminated area on the periphery of the sludge field, while sites in the sludge field near the outfall terminus were characterized by unusual polychaete taxa, such as Ophryotrocha spp., which are found only in highly contaminated areas (SCCWRP 1987).

After the termination of sludge discharge, the abundance of Ophryotrocha spp., initially increased, but they were nearly absent by August 1990 (SCCWRP 1992). Although Capitella capitata was only present in low abundance in the sludge field during discharge, it became the most abundance in this area within a year after discharge termination. By 1990, Capitella capitata abundance had decreased in all areas. Decreasing abundance of these two species indicates the gradual recovery of the sludge field. However, Amphiodia urtica an indicator of uncontaminated conditions and a species abundant in reference sites, to date have not become abundant in any of the contaminated areas (SCCWRP 1989).

Recovery also occurs when the discharge of pollutants is reduced, but not stopped. Between 1971 and 1981 the quality of the JWPCP effluent improved markedly and so did the infaunal community (Stull *et al.* 1986b), which is still recovering (Stull 1988, pers. comm.). Both the number of species and the Shannon Wiener diversity increased from 1972-1991, indicating general improvement in the Palos Verdes benthos. Species are recruiting on and across the Shelf forming more balanced communities. Microcrustaceans are more abundant and polychaetes and mollusks less abundant (Stull 1992, 1993, pers. comm.).

Recovery of benthic assemblages was especially apparent following the reduction in input of DDT, PCBs, solids, trace metals, and various other contaminants from the JWPCP outfalls. Since 1972 the benthic community has become less characterized by pollution indicator species, has become more diverse, and has supported increasing abundances of microcrustaceans and echinoderms (Word and Striplin 1980) which were absent previously (SCCWRP 1973).

In 1973, large numbers of spoonworm Listriolobus pelodes settled on the Palos Verdes Shelf and by 1975 the center of the population was near the outfalls. The population declined by 1977 and the worms had all but disappeared by 1980 (Stull *et al.* 1986c). Although it is not certain whether their occurrence was due to chance or to the local environmental conditions, they had an important impact on the benthic community. Spoonworms form U-shaped burrows in the sediments, and their burrowing, feeding, and respiratory activities rework and aerate the sediments. On the one hand this bioturbation may improve physical, chemical, and biological characteristics of the sediments generally but it also exposes buried contaminants to the water column.

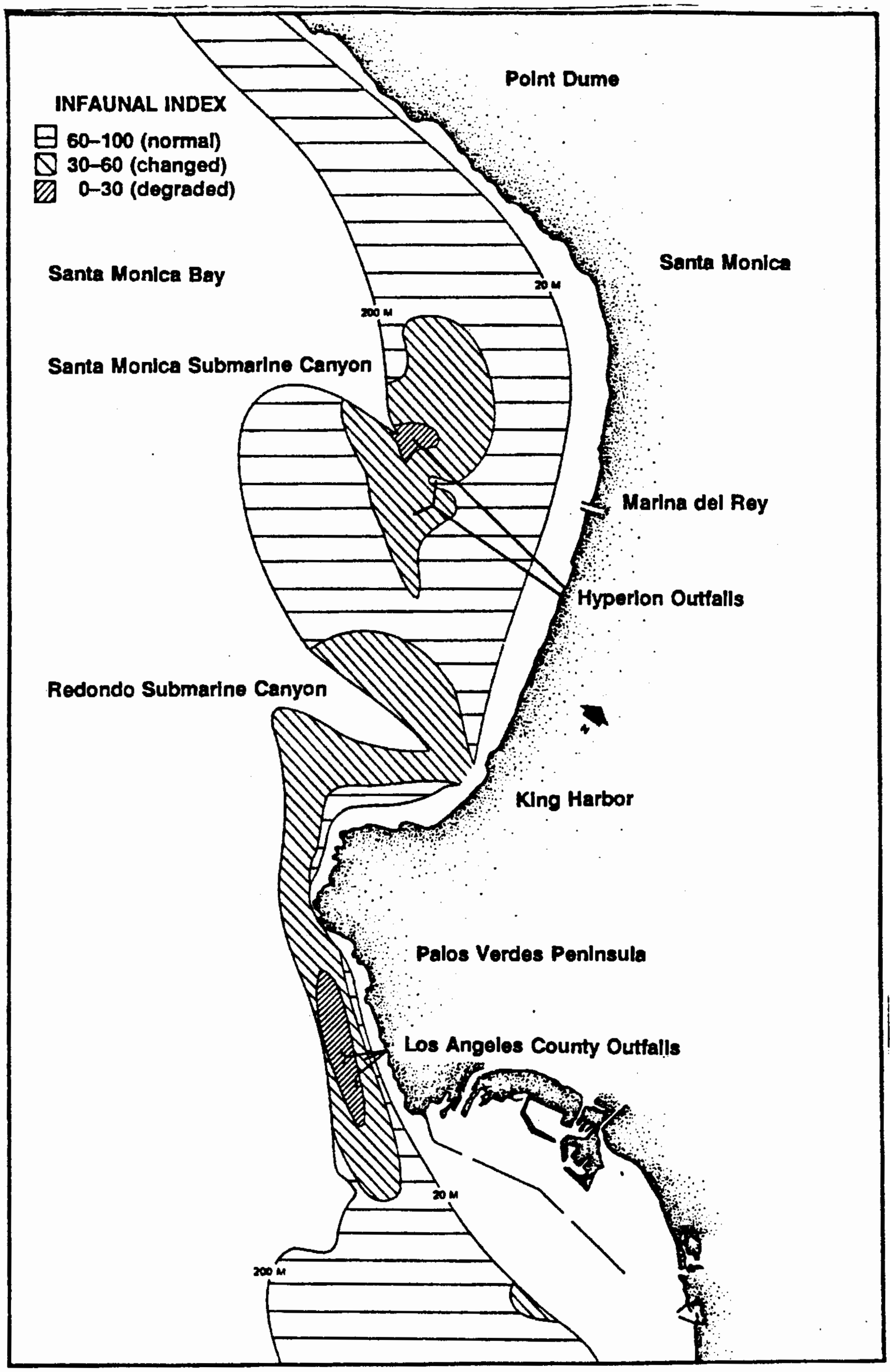


Figure 9-10. Location of normal, changed, and degraded areas in the study area as defined by changes in infaunal index, 1977 (Bascom 1978).

The areal extent of black sediments rich in hydrogen sulfide decreased during the spoonworm period, and the abundance of pollution-tolerant polychaetes, Capitella capitata and Schistomeringos, decreased as well. However, following the collapse of the spoonworm population, neither the species abundances nor the sediments returned to their previous states. The net improvement in sediment conditions during the period of high spoonworm density may have resulted from increased oxygenation of the surface sediments and a consequent decrease in free sulfide. Free sediment sulfide has been found to be the abiotic variable most strongly correlated with the infaunal community at outfall depths on the Palos Verdes Shelf (Greene and Smith 1975).

Recovery continued between 1980 and 1983; stations near the JWPCP outfall went from major degradation in 1980 to moderate degradation in 1983, changes which were attributed to improvements in the quality of the JWPCP effluent. However, natural environmental changes associated with the strong El Niño event of 1982-1983 may have also been involved (Swartz *et al.* 1986). The strong storms of that time period presumably resuspended contaminated surface sediments, especially near headlands such as the Palos Verdes Peninsula.

In 1989-1990, the numbers of species were lowest immediately adjacent to the HTP outfalls, but increased rapidly with distance from these disturbed areas; abundance was moderate around the 5-mi and high at the 7-mi outfall (CLA,DPW 1991). Diversity was lowest at the 7-mi outfall and increased with distance from the area, whereas it was moderate around the 5-mi outfall. Abundance and numbers of species were highest south of the outfalls at Short Bank, a habitat characterized by low-lying rock outcrops and heterogenous sediments.

Classification analysis of recent summer macrofauna data indicated five broad macrofaunal assemblages, which formed site groups associated with depth and proximity to the outfalls (Figure 9-11). Around the 5-mi outfall, two subgroups were delimited. One subgroup consisted of stations adjacent to the outfall, the other subgroup consisted of stations further from the outfall and represented macrofauna which are transitional between outfall and natural conditions (CLA,DPW 1991). The site group nearest the 7-mi sludge field was characterized by large numbers of individuals and low numbers of species, including several opportunistic, pollution-tolerant species.

Macrofauna assemblages also vary in composition along a strong depth gradient (from inner-shelf to upper-slope) and along natural sediment gradients, and with distance from the two outfalls, representing an environmental stress gradient (CLA,DPW 1991). Diversity and composition of the assemblages away from the outfalls were typical for Southern California shelf communities.

The fluctuations in the size of the area impacted by the outfalls may result from the increase in numbers (species and individuals) of opportunistic species which respond quickly to small physical and chemical changes in the environment (CLA,DPW 1991). There are fewer opportunistic species around the 5-mi outfall, and species that were common away from it, (e.g., Pectinaria californiensis), have become common at the outfall. Pollution sensitive species such as Amphiodia urtica, however, are still sparse near the outfall but have invaded transitional areas between the outfalls and unaffected areas. During the period of sludge disposal, the polychaete Ophytrocha dominated the field, but since about 1987, the abundance of this polychaete has diminished to nearly zero (CLA,DPW 1991).

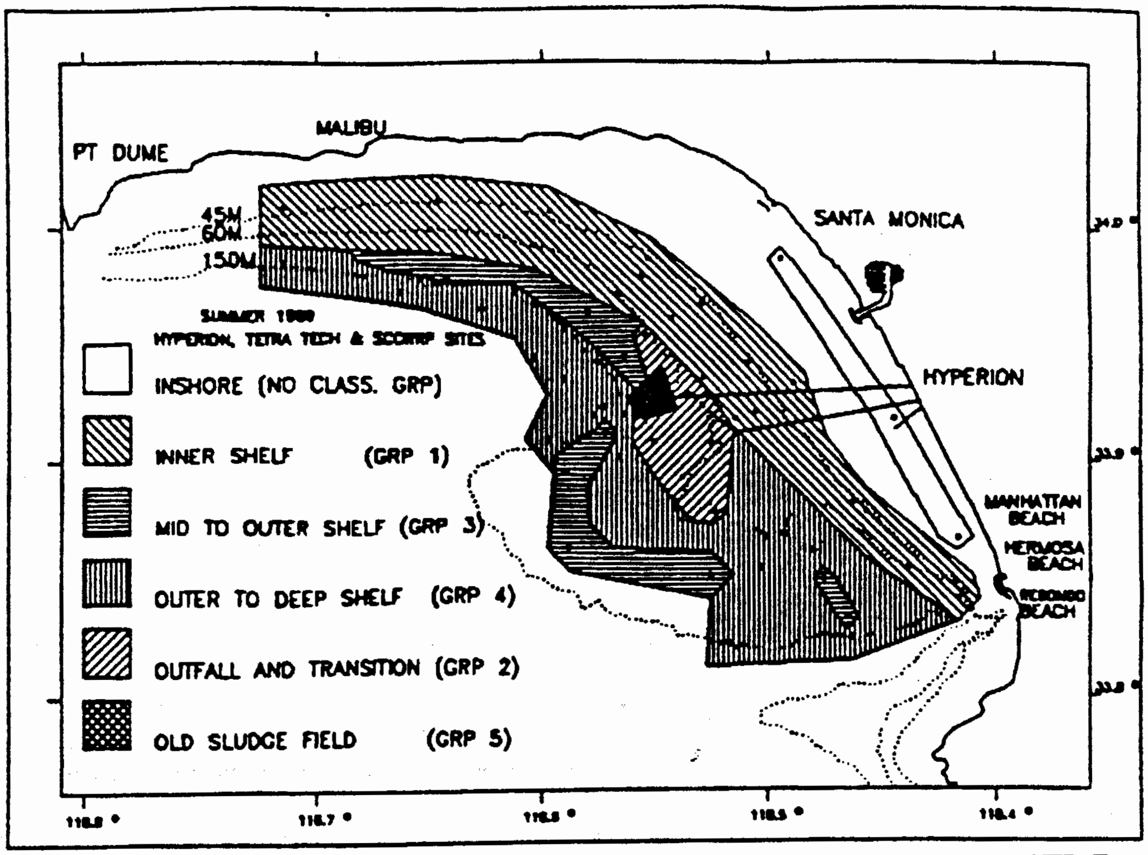


Figure 9-11. Map of site groups derived from classification of macrofaunal data from the HTP, Tetra Tech, and SCCWRP cruises in Summer 1989 in Santa Monica Bay (CLA, DPW 1991).

Thus, in general, the abundances of opportunistic species are approaching background levels and overall diversity is increasing. The area around the 5-mi outfall now supports a relatively natural composition of macrofauna, although sediments in the old sludge field are populated with a mix of "natural" and opportunistic species (CLA,DPW 1991).

The "degraded" area also persists around the JWPCP outfalls, although it is much smaller (in areal extent) than it was previously. The "changed" area has also contracted, gradually receding eastward on the Palos Verdes Shelf.

MEGAFAUNA

At water depths of 200 feet on the Palos Verdes Shelf, white sea urchins and other large echinoderms were uncommon (low population densities) between 1972 and 1979 compared to reference areas at the same depth (Word and Striplin 1980). Major megafaunal species were absent within several miles of the JWPCP outfalls in 1973, although they were present elsewhere in Santa Monica Bay (Mearns and Greene 1974). The diversity and abundance of echinoderms as a group were depressed near the JWPCP outfalls between 1971 and 1976 (Allen and Voglin 1976) and total invertebrate megafaunal biomass on the Shelf was only half that at stations in Santa Monica Bay between 1977 and 1982 (Moore *et al.* 1982). However, densities of the ridgeback rock shrimp were greatly enhanced.

Location	Number of Individuals Mean ± S.D.	Number of Species Mean ± S.D.	Biomass (kg) Mean ± S.D.	Dominant Species
Northern Santa Monica Bay Reference	1018 ± 977	12.6 ± 2.5	5.4 ± 1.3	*Lytechinus pictus* *Astropecten verrilli* *Sicyonia ingentis* *Ophiura lutkeni*
HTP Outfall	1565 ± 757	18.7 ± 7.0	19.5 ± 9.0	*Astropecten verrilli* *Lytechinus pictus* *Parastichopus californiensis* *Sicyonia ingentis*
JWPCP Outfall	669 ± 316	12.4 ± 2.3	5.9 ± 2.3	*Astropecten verrilli* *Sicyonia ingentis* *Crangon nigromaculata* *Pleurobranchaea californica*
Source: Cross 1982a				

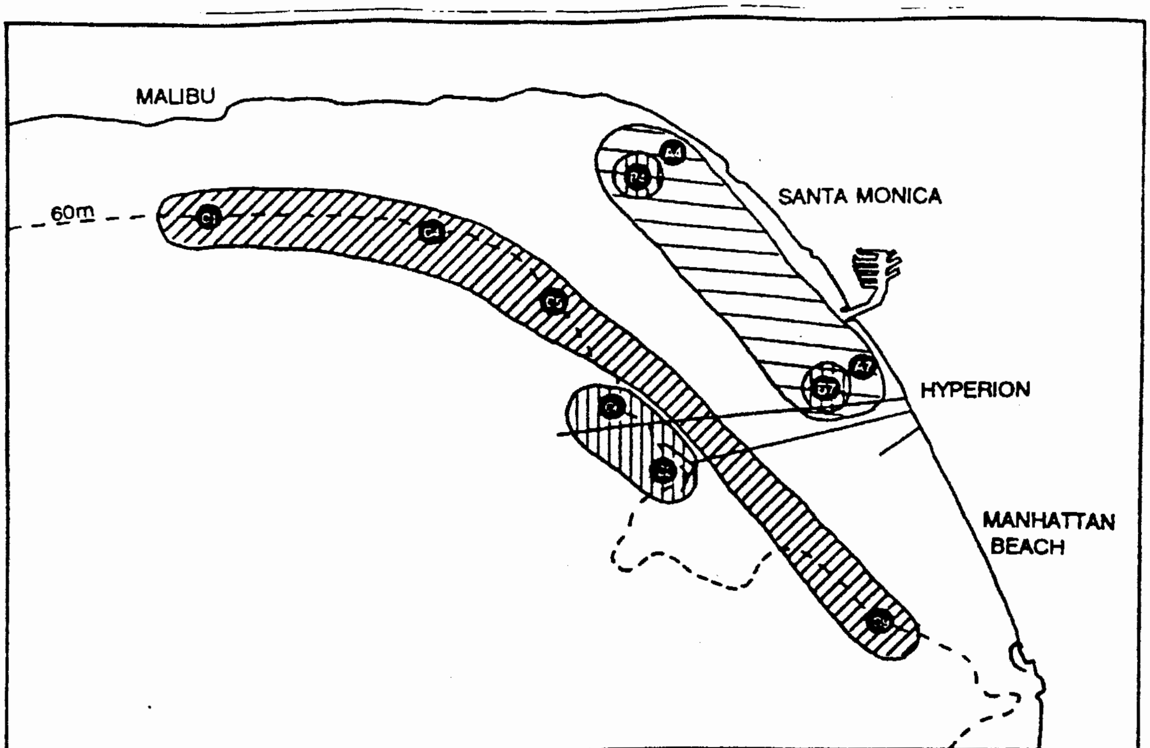
Table 9-3. Measures of megafaunal invertebrate community structures near Santa Monica Bay sewage outfalls and in northern Santa Monica Bay, 1982.

In 1982, megafaunal biomass was about equal at sites on the Palos Verdes Shelf and at control sites in northern Santa Monica Bay (Table 9-3); however, in the vicinity of the HTP outfalls it was three to four times higher than at the reference sites (Cross 1982a). Between 1984 and 1986 enhanced biomass was most apparent south of the 5-mi outfall: while at the outfall itself the biomass was slightly lower than at the northern Santa Monica Bay control site (Johnson and Roney 1988).

By 1982, echinoderms (which had previously been lacking), were collected in the vicinity of the JWPCP outfalls, indicating a major change in the community structure since the early 1970s. Classification analysis of trawl-collected megafauna from throughout the Southern California Bight between 1971 and 1985 indicated that 1980 was a turning point on the Palos Verdes Shelf (SCCWRP 1986e). Prior to 1980 samples from Palos Verdes Shelf were separated from the "normal" mainland shelf group; whereas after 1980 samples from the Palos Verdes Shelf were grouped along with "normal" samples. Samples collected from depths of 120 to 520 feet in Santa Monica Bay, including those from near the HTP outfalls, were grouped with the reference stations during all years.

In 1989 and 1990, megafaunal communities exhibited a pronounced relationship to the HTP outfalls. Near the 5-mi outfall, diversity and the mean number of species were reduced (Figure 9-12)(CLA,DPW 1991). Spiny sand stars were most abundant at the outfall sites, possibly due to the abundance of prey whose populations were enhanced by organic enrichment. White sea urchins were present at offshore sites but not in the vicinity of the outfalls; in laboratory studies, both these species prefer clean sediments over contaminated sediments (Anderson *et al.* 1988).

During pre-abatement sampling at the 7-mi outfall, ridgeback rock shrimp and white sea urchin were the most abundant megafaunal invertebrates collected (SCCWRP 1989). Megafaunal species collected at the 300 feet depth contour differed between contaminated sites and the reference sites (SCCWRP 1989). In 1986-1987, (during active sludge discharge) the most abundant megafaunal species at the contaminated sites was the California sand star (SCCWRP 1989). Following discontinuation of sludge disposal the abundance of California sand star decreased below reference levels (SCCWRP 1989). White sea urchin was formerly most abundant at the reference sites and did not usually occur at the contaminated sites, it has not returned following sludge termination (SCCWRP 1989).



SITE GROUP	MEAN SPECIES	S.D.	MEAN NO. OF INDIVIDUALS	S.D.	SPECIES NAME	PERCENT ABUNDANCE
I	4.4	2.0	10.2	9.3	*Pyromaia tuberculata*	31.0
					Podochela lobifrons	28.2
					Astropecten verrilli	11.8
					Astropecten armatus	4.8
					Heterocrypta occidentalis	4.5
II	3.9	1.9	627.0	781.7	*Astropecten verrilli*	98.7
					Luidia foliolata	0.4
					Sicyonia ingentis	0.4
					Parastichopus californicus	0.2
III	10.6	2.6	62.0	1125.0	*Lytechinus anamesus*	72.0
					Astropecten verrilli	9.8
					Ophiura lutkeni	7.1
					Ophiothrix spiculata	3.7

Figure 9-12. Trawl stations, site group locations, and community variables for invertebrate assemblages in Santa Monica Bay during 1989-1990 (CLA,DPW 1991).

INDUSTRIAL DISCHARGE IMPACTS

MACROFAUNA

The shallow, subtidal bottom between Redondo Beach and El Segundo have been surveyed in connection with NPDES permits for three generating stations and the El Segundo Refinery industrial discharge. No effluent impact on the infauna has been demonstrated around either the El Segundo or Scattergood Generating Station discharges (IRC 1979, 1981, MBC 1991b); thermal effects and NPDES monitoring studies at the Redondo Generating Station have not indicated any effects of the discharge other than increased bottom turbulence (EQA/MBC 1973, MBC 1982a).

Turbulence associated with the discharge plume results in coarser bottom material near the discharge structure, and coarse sediments are inhabited by a somewhat different benthic community. Coarsening has also been observed at the intake structure, where mussel and barnacle shell fragments are flushed out during heat treatment of the conduits. These minor changes are only noticeable within 300 feet of the structures. Metals dissolved from the condenser tubes and chlorine used to control growth of clams and barnacles within the cooling water system do not have detectable effects on bottom communities.

Infaunal sampling at El Segundo and Scattergood Generating Stations in 1991 indicated no effects from the discharge (MBC 1991b). Abundance and species richness have been greatest at stations along the 20 feet and 30 feet isobaths upcoast of the Scattergood Generating Station. Infaunal abundance and species richness patterns were closely associated with sediment grain size, suggesting that the sediments are the most important factor, but that the impact is not ecologically significant (MBC 1991b). Abundance, species richness, and diversity all generally decreased with increasing distance from the El Segundo Refinery discharge in 1990, indicating enhancement, if anything, due to the discharge (MBC 1990).

MEGAFAUNA

Diver-observed and trawl-caught megafauna along the 30 feet isobath were no different near the El Segundo Generating Station than away from it (IRC 1979, 1981). At water depths of 65 feet off Redondo Beach, white sea urchins were less abundant near the power plant discharge than in trawls taken off Manhattan Beach (MBC 1986a); however, few other species showed such a pattern.

MARINE VESSEL ACTIVITY IMPACTS

The soft benthos of Marina del Rey appears to have been impacted by marine vessel-related contaminants, in particular TBT from antifouling paints. Many mollusk species are virtually absent or are less abundant in areas where TBT levels are high than they would normally be expected (Soule and Oguri 1986, 1987).

HARD BOTTOM HABITATS

MUNICIPAL WASTEWATER DISCHARGES

Treated wastewater can affect nearby rocky habitat through sedimentation, turbidity, and the toxicity of its metal and chlorinated organic components. In 1958, algal cover in rocky areas exposed to the JWPCP effluent was fairly normal at water depths of ten and 33 feet, but almost no algae were found below 33 feet (CSWQCB 1964). In 1969, almost no algae were found at water depths of 50 to 75 feet from two miles upcoast to two miles downcoast of the outfalls and more than 0.4 inches of fine organic-rich sediment covered rock surfaces 1.3 miles upcoast of the discharge (Grigg and Kiwala 1970).

It appears that the area affected by the outfalls tripled between 1954 and 1969 and in 1966 the algal community at depths of 20 to 100 feet off Palos Verdes Point (eight miles upcoast of the JWPCP outfall) was modified as a result of exposure to wastewater (Strachan and Koski 1969). Partial recovery of the subtidal algal community (which coincided with decreases in the emission of particulates and toxicants from the JWPCP outfalls) was reported later (Grigg 1978, Meistrell and Montagne 1983), but significant increases in algal cover and diversity only occurred at sites farthest from the outfall (e.g., Palos Verdes Point). Algal populations and community structure near the outfalls were still impacted (Tetra Tech 1984).

In 1977, concentrations of metals and chlorinated hydrocarbons in the flocculent, near-bottom particulate layer off Palos Verdes Point were elevated above ambient. A concentration gradient (more metals and organics in this layer nearer the JWPCP outfalls) indicated that the outfalls were the source. Both positive and negative responses were noted: some populations apparently benefitted from outfall-derived nutrients, butoverall the richness of the fauna increased as mass emission rates decreased. Exposed epifauna may have been affected indirectly by reductions in the availability of algal food and by the floc layer directly. By 1977, significant improvements had been observed compared to conditions in 1969, the greatest recovery being at Long and Palos Verdes Points (Grigg 1978).

The mass emissions of suspended solids from JWPCP in the 1990s is less than one-fifth the 1970 level, and it is no longer the source of particulates described by Grigg and Kiwala (1970) or Grigg (1978). Since 1978, the Portuguese Bend landslide, (located 3.5 miles west of the JWPCP outfall system), has been more active than before and through the 1980s, an average of 200,000 MT per year of slide debris were dislodged (City of Rancho Palos Verdes 1986), over five times that of JWPCP (Stull 1993, pers. comm.). The landslide sediments are released at the shoreline; whereas solids from JWPCP are discharged 1.2 to 2.5 miles offshore in 200 feet of water. Thus, while the rocky subtidal community of Palos Verdes Peninsula continues to be impacted by turbidity and sedimentation, the landslide has replaced JWPCP as the source of particulates. Reductions in mass emissions of trace constituents coincided with significant recovery of eastern sites from the 1970s to the mid-1980s (Stull 1993, pers. comm.).

The HTP outfall conduit provides additional hard-bottom substrate for both plants and animals to colonize, thereby creating positive impacts. Inshore portions of the 5- and 7-mi conduits are dominated by gorgonian corals and strawberry anemones, and the ballast rock provides crevices for cryptic species (Allen *et al.* 1976). In deeper water, low-relief rocky bottom near the shelf break has been examined with remote camera (Moore and Mearns 1980) and the hard substrates of the HTP outfalls by submersible (Allen *et al.* 1976). Plumose anemone was dominant on the pipe, however, it was not seen on the deep, low-relief rock bottom, despite its presence at equal depths elsewhere. The reasons for this and other differences between the communities in the two areas are not known, but may be related to the waste discharge. Although the outfall pipe supports a diverse and abundant epifauna, it is not the same as that of nearby natural rock areas.

The conduit does provide a habitat which attracts many fish and invertebrates, thereby making them popular sport fishing locations. Many species of rockfish are common near the 5-mi outfall terminus.

INDUSTRIAL DISCHARGE IMPACTS

No effects from the Redondo Generating Station effluent have been noted on rocky subtidal invertebrates in King Harbor. The widespread distribution of open coast algae in the harbor indicates good water circulation, which is at least partially due to the generating station intake and discharge (Straughan 1977).

MARINE VESSEL ACTIVITY IMPACTS

The substrate of groins, breakwaters, and jetties in shallow water near Marina del Rey may be subjected to the toxic effects of TBT on mussels, clams, and snails (Soule and Oguri 1986, 1987). TBT has been used in boat bottom-paint and because of its toxicity to mollusks, Marina del Rey has fewer species of mollusks than other areas where there are fewer marine vessels.

FISHERY IMPACTS

Commercial fishing in the study area for California spiny lobster, rock crabs, and red sea urchin occurs primarily west of Malibu Point and south of Palos Verdes Point. Lobsters can only be fished from mid-October to mid-March (Schultze 1986), and commercial catches of lobster from the Bay have declined since 1955 (MBC 1985). However, total catch decreased in the early 1970s on the Palos Verdes Shelf and increased in the 1980s. Rock crab catches from this area were especially low in 1971, peaked in 1975, and have decreased since then. The red sea urchin fishery began on a large scale in 1976 and by 1981 had already been overharvested (Stull *et al.* 1987). It is not certain whether these fluctuations were due to natural causes, overfishing, loss of habitat (e.g., surfgrass nursery grounds for lobster), or pollution.

Recreational fishing for California spiny lobster, rock crabs, pink abalone, and rock scallop also occurs in the Bay, primarily by divers. The impact of this fishery has not been described, but the construction of artificial reefs in the Bay was intended to increase their habitat and thus fishing success.

ARTIFICIAL REEFS

A large number of unique and popular plants and animals utilize the hard-bottom, reef habitat. However, hard bottom is lacking in most of the study area and artificial reefs have been constructed to provide hard-bottom habitat. Originally, the justification for construction of artificial reefs was to enhance recreational fishing and diving, however, in recent years artificial reefs have also been used as mitigation for marine resources lost in coastal development projects (Wilson *et al.* 1990, Johnson *et al.* 1992).

Most of the nearshore area of Santa Monica Bay proper consists of sandy bottom and is devoid of natural reefs. Since 1958, the California Department of Fish and Game (CDFG) has constructed 14 artificial reefs in Santa Monica Bay. Five of the early reefs were constructed of streetcars, automobiles, and other degradable materials and have since disappeared. However, nine artificial reefs remain in the nearshore subtidal area from Malibu to Torrance Beach (Figure 9-13) (Lewis and McKee 1989). These are named as follows: Malibu, Topanga, Santa Monica, Santa Monica Bay, Marina del Rey Reef 1, Marina del Rey Reef 2, Hermosa Beach, Redondo Beach, and Palawan. Most are composed of quarry rock but Palawan Artificial Reef off Torrance Beach consists of the sunken liberty ship Palawan (Lewis and McKee 1989).

KELP BEDS

Wastewater discharges are thought to have contributed to the loss of giant kelp (Macrocystis pyrifera) near Los Angeles and San Diego (North and Schafer 1964). Kelp plants have been shown to be sensitive to many of the contaminants introduced by man, and although there are other sources, most of these in the study area are from treated wastewater (CSWQCB 1964). Aside from the coincidence that the Palos Verdes kelp beds began to degenerate shortly after the White Point discharge became operational in 1937 and spread outward from the outfall, there is a strong relationship between mass emissions through the JWPCP outfalls and kelp canopy coverage on the Palos Verdes Peninsula. Conversely, between 1974 and 1987 mass emissions of total suspended solids in the JWPCP effluent decreased by 72%, while the area of kelp coverage increased.

Toxic materials in wastewaters may harm kelp, but the accumulation of particulates on rock surfaces probably have the greatest impact. The small, young plants (sporophytes) which are contacted by the particulates are not only more sensitive than adults to toxic materials, but they do not settle and grow on rocks covered with a particulate film. In areas of heavy particle concentration the few sporophytes which settle are often on ridges which bottom

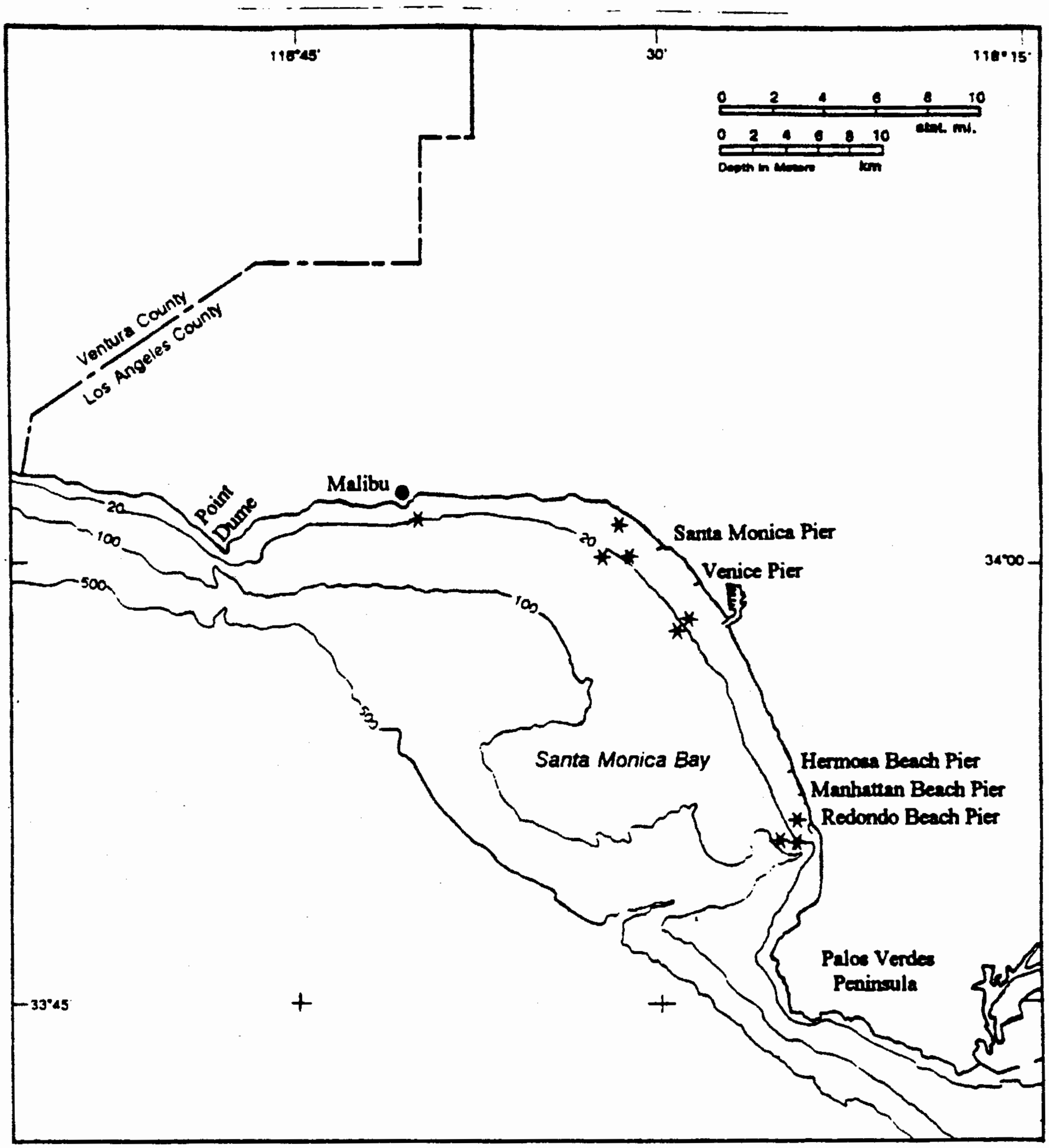


Figure 9-13. Artificial reefs in Santa Monica Bay (Lewis and McKee 1989).

currents sweep clear of sediment. Normally rocks in a well-developed kelp bed support large numbers of small sporophytes, which do not grow to maturity because the existing canopy keeps light levels too low for active photosynthesis. When adult plants die back because of summer nutrient limitations or are torn up by storms, light penetrates to the bottom and the sporophytes grow.

Turbidity and light reduction may also result from wastewater discharge and may affect kelp. Even though this would not prevent settlement of sporophytes, it might prevent their growth by reducing bottom light levels. At present there is not enough evidence to distinguish between these two effects, or to establish the role of toxic materials in kelp growth and survival in the study area. The relationship between JWPCP mass emissions and kelp die-off during the late 1950s to the early 1970s strongly suggests wastewater involvement, but it does not indicate which constituent was responsible.

Kelp plants were virtually absent along the Palos Verdes Shelf from the late 1950s to the mid-1970s. Coverage has generally increased since the mid-1970s (Figure 9-14), although in 1983 and 1988 it suffered losses of 90% and 95%, respectively, due to extremely severe winter storms. Other beds in Southern California suffered similar losses. Recovery of giant kelp was rapid at Palos Verdes: the surface canopy in 1989 was four times that in 1978. Between 1989 and 1992, kelp coverage has declined because of increased grazing pressure from expanding sea urchin populations. Some areas are essentially devoid of vegetation because of sea urchins, although this appears to be a natural episodic event, unrelated to the discharge of treated wastewaters (Stull 1993, pers. comm.).

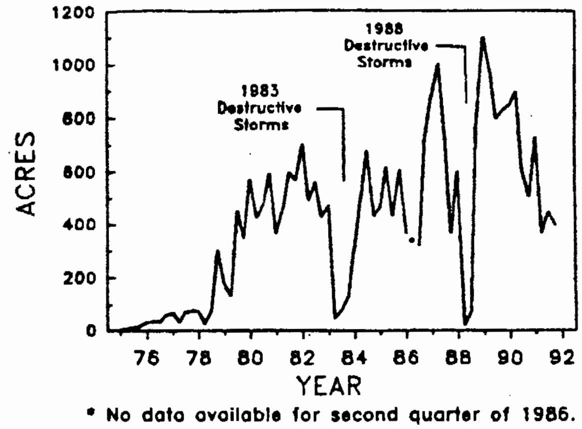


Figure 9-14. Changes in the Palos Verdes Peninsula kelp canopy 1974 to 1992 (modified from CDFG unpubl. data; LACSD unpubl. data).

MARINE VERTEBRATE RESOURCES

10

CHAPTER 10
MARINE VERTEBRATE RESOURCES

The marine vertebrates of Santa Monica Bay are important to the general public, especially to commercial and recreational fishermen as well as to recreational SCUBA divers. In the past, fish diseases have been an obvious indicator of contaminated areas. Sea birds, shore birds, and waterfowl are some of the most obvious members of the Santa Monica Bay fauna, and are important scavengers and foragers throughout the Bay. They are aesthetically and recreationally pleasing, and have shown some of the most striking responses to marine contamination. Marine mammals are important to Bay tourists, particularly whale watchers and party-boat fishermen; being near the top of the food web, they often accumulate high levels of contaminants.

FISHES

DISTRIBUTION BY HABITAT

PELAGIC

The most obvious and abundant pelagic nekton in the study area are bony fishes, species which typically school and are often migratory. Most pelagic fishes feed on copepods when small, on shrimp-like prey when larger, and on other fish as adults.

The dominant pelagic fishes in the study area are chub (or Pacific) mackerel, jack mackerel, northern anchovy, and Pacific sardine. These species make up most of the commercial wetfish fishery catch, the dominant commercial fishery in Southern California. Oceanic species such as swordfish are important in the driftnet fishery and northern anchovy are caught in the bait fishery.

Some pelagic sport fishes such as yellowtail and Pacific barracuda are migratory species which move into the Bay in summer, and may be especially abundant during an El Niño period. Chub mackerel and Pacific bonito are commonly taken from piers and jetties as well as charter and private boats. In the 1980s, chub mackerel and Pacific bonito accounted for about 27% and 13%, respectively, of the sport catch in the Bay proper, and 31% and 18% of that of the Palos Verdes Shelf (MBC 1985, Stull et al. 1987). Chub mackerel, Pacific barracuda, and Pacific bonito accounted for 29%, 7%, and 7%, respectively, of the recreational fish catch of Santa Monica Bay in 1991-1992 (MBC, in prep.).

Many neuritic species occur in the Bay, including queenfish, jacksmelt, and topsmelt in shallow depths and shortbelly rockfish along the outer shelf. White seabass are important in the commercial set gillnet fishery (which will end in 1994) others are taken by recreational fishermen.

The deeper waters of the Bay support northern and Mexican lampfish, California smoothtongue, and Pacific hake. These species migrate between the surface waters at night and the deepwater mesopelagic zone below 300 feet during the day.

Many species are temporary members of the pelagic community. Vermilion rockfish, bocaccio, and sablefish feed in the water column at night but rest on or remain near the bottom during the day. White croaker and white seaperch school in the water column but feed on the bottom.

The eggs and larvae (ichthyoplankton) of many bony fishes are planktonic, even though the adult stages may not be. The planktonic stage lasts for a few weeks to months before the larvae transform into nektonic or demersal juveniles. Ichthyoplankton are of particular concern because of their relationship to the abundance of adults in particular fishing grounds. The most abundant fish larvae in an area are typically those of the most abundant adult species, but this is not always the case.

Sharks are the dominant cartilaginous fishes in the pelagic environment of Santa Monica Bay, with blue shark the most abundant, although thresher sharks, basking sharks, and others are seen occasionally. Most sharks feed on adult fish and squid but basking sharks feed on juvenile fish and euphausiids.

SOFT-BOTTOM

The soft-bottom habitat supports an abundant and diverse assemblage of demersal fishes which swim occasionally, but spend much of their time on the bottom. Flatfishes, rockfishes, sculpins, combfishes, and eelpouts make up most of the soft-bottom fish fauna. Different basic assemblages are found on the inner, the middle, and the outer shelf (SCCWRP 1973, Fay *et al.* 1978, Allen 1982). The inner shelf assemblage is dominated by speckled sanddab, the middle shelf by stripetail rockfish, and the outer shelf by slender sole (Allen 1982).

California halibut, California scorpionfish, barred sand bass, and white croaker are fished by sport fishermen. In the 1980s, barred sand bass accounted for 8% of the sport fish catch off the Palos Verdes Shelf and 6% of that of the Bay proper (MBC 1985, Stull *et al.* 1987). In 1991-1992 they accounted for 11% of the recreational fish catch from piers, private boats, and commercial passenger fishing vessels (MBC, in prep.). Sablefish, Dover sole, and English sole are important in commercial fisheries to the north, although they are not fished in Santa Monica Bay.

HARD-BOTTOM

The hard-bottom fish assemblage differs in composition with depth. Common shallow water families include the sea basses, surfperches, rockfishes, kelpfishes, sculpins, damselfishes, and wrasses. Important species locally include kelp bass, brown rockfish, pile perch, black perch, white seaperch, rubberlip seaperch, señorita, and opaleye (Carlisle *et al.* 1964; Stephens *et al.* 1984b; MBC 1987a; Dorsey 1988, pers. comm.). In deeper water, vermilion rockfish, bocaccio, cowcod, and flag rockfish dominate (Allen *et al.* 1976, Moore and Mearns 1980). Because these species occur off-bottom they are readily observed by divers or remote cameras; however, hard-bottom species such as kelpfishes, sculpins, and pipefishes are cryptic and hence difficult to see.

Hard-bottom fishes are pursued by divers on the Malibu and Palos Verdes Shelves and by anglers from shore, piers, and private or party boats. Because outfall pipes constitute hard substrate, party boat fishing is sometimes conducted along their length. Rockfishes and kelp bass are the most important hard-bottom sport fish in the Bay, rockfishes in deep water and kelp bass in shallow water. In the 1980s, rockfishes and kelp bass accounted for 43 and 6%, respectively, of the sport catch in the Bay proper and 17 and 10% of that of the Palos Verdes Shelf (Mearns 1977; MBC 1985, Stull *et al.* 1987). In 1991-1992, more kelp bass than rockfishes were taken by recreational anglers in Santa Monica Bay; kelp bass and rockfishes comprised 9 and 6%, respectively, of the catch during that period (MBC, in prep.).

KELP-BED

The vertical complexity of kelp beds attracts many fishes which use the beds for schooling, shelter, and foraging. Kelp bass, black perch, rubberlip seaperch, opaleye, kelp rockfish, and olive rockfish are common in kelp holdfast zones. Yellowtail, white sea bass, rubberlip seaperch, halfmoon, and halfblind goby have been observed in the stipe region of the bed. Fishes of the kelp canopy include the topsmelt, kelp pipefish, kelp perch, giant kelpfish, kelp clingfish, and kelp gunnel.

Opaleye and halfmoon feed primarily on algae, whereas kelp bass, yellowtail, and white seabass eat fish and squid. The remaining species feed largely on crustaceans such as amphipods, copepods, mysids, crabs, and shrimp. The kelp bass is important in the sport fishery, comprising 10 and 6% of the catch of the Palos Verdes Shelf and Santa Monica Bay, respectively (MBC 1985, Stull *et al.* 1987). In 1991-1992, they comprised 9% of the recreational fish catch from Santa Monica Bay.

NATURAL VARIABILITY

The fish populations in Santa Monica Bay vary in size as a result of major climatological events and minor oceanographic and biological events. The species composition in fish assemblages also varies for similar reasons; although the effects of these natural events have only been described qualitatively.

The abundance of fish scales in sediments from basins off Southern California indicates that populations of pelagic species have fluctuated greatly during the last 1,800 years (Figure 10-1) (Soutar and Isaacs 1969). Pacific sardine abundance has ranged from periods of high abundance lasting 20 to 200 years to periods of low abundance averaging 80 years in duration. Population peaks in the past were about twice those of the present century. However, fluctuations during the 19th century were similar in magnitude to those during this century: the low abundance of sardines since the 1940s is similar to that of the period between 1865 and 1885 (Soutar and Isaacs 1974).

Northern anchovy and Pacific hake populations did not crash as severely as did the Pacific sardine, but they have fluctuated greatly. The abundance of northern anchovy peaked about 1,500 years ago and has declined gradually since. Pacific hake has peak abundances about every 300 years, the last being about 250 years ago (Soutar and Isaacs 1969).

The abundance of these pelagic fishes combined was greater from 1900 to 1925 than anytime since (Soutar and Isaacs 1974). These long term changes may be related to variations in the California Current. During El Niño periods, warm-water species either recruit to the Bay from the south as larvae or move into the Bay as adults. Many species move into the area from their more typical habitat off Mexico (Radovich 1961, Mearns 1988).

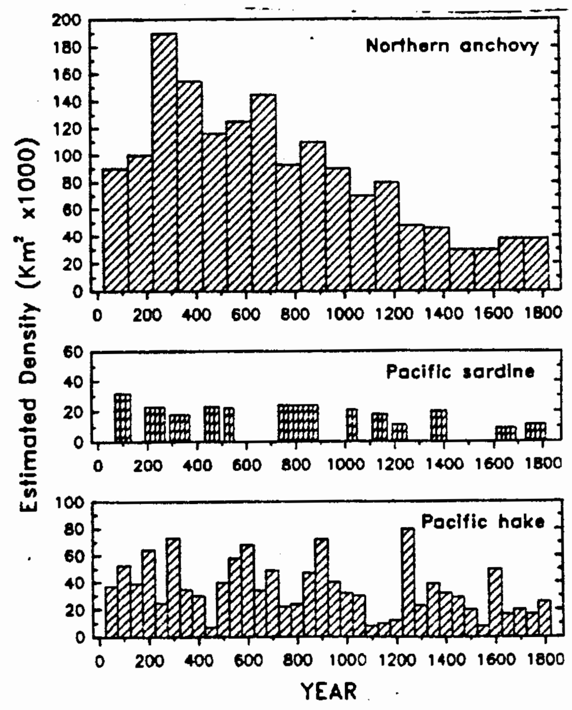


Figure 10.1 Minimum population estimates (based on scale abundance) in Santa Barbara Basin during the past 2,000 years for a) northern anchovy, b) Pacific sardine, and c) Pacific hake (Soutar and Isaacs 1969).

Pelagic, warm-water, and migratory sport fish abundance increased in Santa Monica Bay during the 1957-1959 El Niño (Mearns *et al.* 1976). During the El Niños of 1978 and 1982-1983, several species of warm-water reef fishes recruited into King Harbor where they are still abundant (Stephens 1988, pers. comm.). Similarly, during 1985-1986 the shallow, demersal fish assemblage of the Palos Verdes Shelf had more warm-water species than it did in 1972-1973, a period of cold water (MBC 1987b).

Cold water species are negatively affected during an El Niño event. The abundance of demersal fish in Santa Monica Bay was about one-third of normal during the 1957-1959, El Niño. This decrease coincided with the initiation of sludge discharge into Santa Monica Submarine Canyon (Carlisle 1969). Although the potential effect of sludge disposal cannot be discounted, the abundance of demersal fish did increase immediately after the El Niño.

During the 1982-1983 El Niño, many cool water soft-bottom species moved to deeper water in Santa Monica Bay (Love *et al.* 1986). Several coastal species disappeared from Marina del Rey, (presumably moving into the Bay proper) and these did not return until the water was cooler in 1986 (Soule and Oguri 1987). Apparently some cool-water species also recruited poorly during this period, possibly due to a decrease in zooplankton abundance (Love *et al.* 1986).

The development of kelp beds on the Palos Verdes Shelf during the late 1970s had little effect on the rocky-bottom fish fauna in general, but the abundance of kelp bass increased (Stephens *et al.* 1984b). Extreme wave turbulence destroys reef and kelp bed habitats and disrupts inshore sandy bottoms. Artificial rocky reefs in King Harbor were lost during a major storm of January 1988 (Stephens 1988, pers. comm.). Turbidity from storm runoff and landslides may linger for weeks or months, making the area unsuitable for many fish (Allen 1982). The movement of sand into tidepools during the summer reduces the amount of habitat for intertidal fishes.

Although a red tide in 1945 (from San Luis Obispo to Los Angeles Harbor) killed sharks, stingrays, and California halibut (Sommer and Clark 1946), no other red tides have caused major fish kills along the California coast in recent years (Bongersma-Sanders 1957).

Recruitment of juveniles to the Bay is not necessarily related to local spawning, primarily because most fishes have planktonic larvae. The coastal current regime during a spawning event may act to retain larvae spawned in the Bay, may carry them away, or may import larvae from outside the Bay.

IMPACTS

MUNICIPAL DISCHARGE IMPACTS

Population Changes. The effects of wastewater discharges on the fishes of Santa Monica Bay were first studied after the discharge of sludge was initiated at the HTP 7-mi outfall in 1957. The abundance of most small, trawl-caught fishes in Santa Monica Bay declined in 1959, but returned to previous levels between 1960 and 1963 (Carlisle 1969). The decline probably resulted from poor recruitment of cool-water fishes during the El Niño Event of 1957-1959 (Mearns *et al.* 1976). Speckled sanddab appeared to be attracted to the 7-mi outfall, but yellowchin sculpin, California tonguefish, as well as the speckled sanddab were absent in the area near the terminus of the 5-mi outfall (Carlisle 1969).

From 1957 to 1975, the abundance and diversity of demersal fish were low around the 5- and 7-mi outfalls (Mearns *et al.* 1974, Allen and Voglin 1976, Mearns *et al.* 1976), but from 1976 to 1979 species richness, biomass, and individual fish size were greater in the sludge field than in reference areas. Underwater cameras showed that Pacific electric ray, white croaker, and shiner perch were abundant in the sludge field, the latter two apparently feeding in the sludge (Bascom *et al.* 1980). From 1984 to 1986, fish biomass was higher and fish abundance was generally high near the outfall stations while white croaker dominated the fish abundance near both outfalls although not in other offshore areas of the Bay (Johnson and Roney 1988).

By the late 1980s, the number of fish per trawl in the contaminated zone near HTP 7-mi outfall were still below reference levels (SCCWRP 1989) and white croaker and Dover sole were the most abundant species collected (SCCWRP 1989). Immediately following termination of the sludge discharge fewer white croaker were collected at the contaminated sites, but sludge did not appear to impact fish communities at water depths of 200 m (SCCWRP 1989). The number of fish per trawl have not indicated any trends toward recovery.

Five demersal fish assemblages were described in Santa Monica Bay in 1989-1990 (Figure 10-2) (CLA,DPW 1991). The three offshore assemblages consisted of northern, mixed, and outfall site-groups; the two nearshore assemblages were separated by seasonal differences. Mean numbers of species and individuals were highest along the 60-m isobath, depressed in the vicinity of the outfalls, and lowest nearshore.

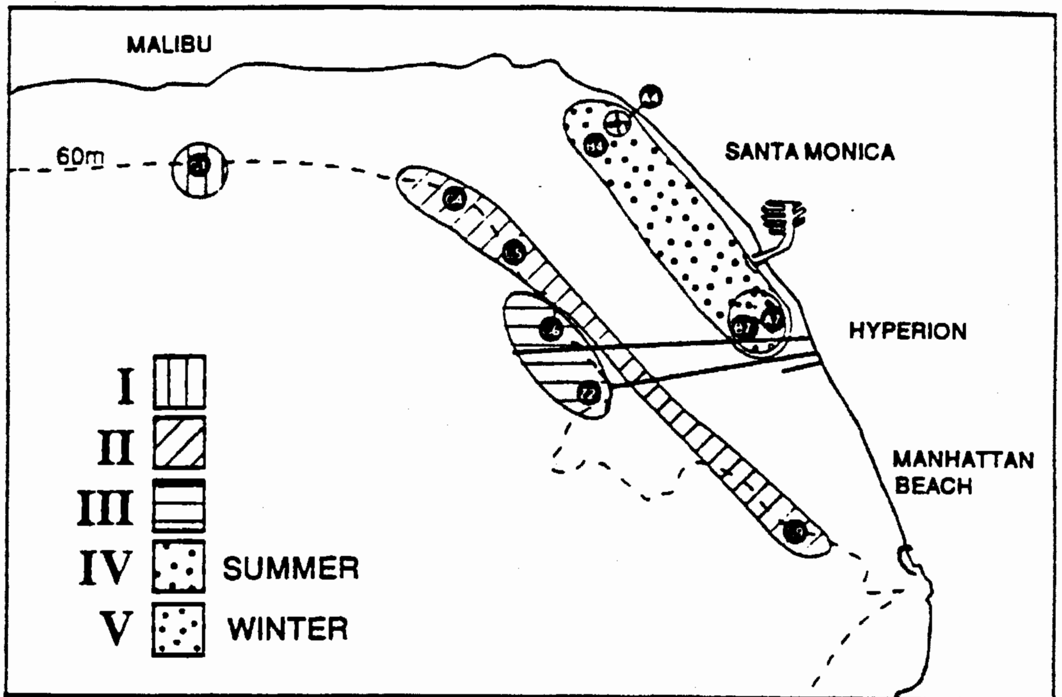
Flatfishes were the most abundant group; hornyhead turbot was the most widely distributed, California lizardfish the most abundant species near the outfalls. Contaminated sediments near HTP's 5-mi and terminated 7-mi outfalls may exclude, depress, or enhance the abundance of certain species (CLA,DPW 1991).

The distribution of fish species in Santa Monica Bay is also related to distribution of their prey. Changes in the composition of the benthic infauna can result in a change in the composition of demersal fish assemblages (Cross *et al.* 1985, MBC 1987b). Crustaceans (the preferred prey of most common demersal fish) are uncommon near the outfall sites. Fish that feed predominantly on benthic and epibenthic crustaceans are rare or absent from outfall sites (CLA,DPW 1991). Hornyhead turbot and English sole, on the other hand, feed primarily on infaunal polychaetes and mollusks (Allen 1982). Infauna near the outfalls were dominated by these invertebrates, thus those fish species were dominant there.

Between 1970 and 1976, the fauna of the Palos Verdes Shelf was more severely affected by wastewater discharge than that near the HTP outfalls. The abundance and diversity of demersal fish were low near the JWPCP discharges on the 200-ft isobath and were severely depressed at a depth of 450 ft, 0.6 to 1.2 mi northwest of the outfalls. Although fish biomass was enhanced at a depth of 450 ft near the discharge; hornyhead turbot, California tonguefish, plainfin midshipman, and yellowchin sculpin were rare or absent whereas white croaker, shiner perch, and curlfin sole were unusually abundant (Mearns *et al.* 1976, Allen 1982).

By 1985 and 1986, the demersal fish assemblage had changed from that characteristic of the early 1970s and some of the differences appeared to be related to improved effluent quality. Previously rare or uncommon species such as hornyhead turbot, California tonguefish, yellowchin sculpin, and plainfin midshipman were common whereas previously abundant species such as white croaker, shiner perch, and curlfin sole were absent or rare (MBC 1987b). Some of these shifts appear to be related to food availability; e.g., several species which fed on gammarid amphipods were absent when amphipods were uncommon during the mid-1970s whereas fish species which fed upon polychaetes were abundant when polychaetes were dominant (Allen 1982, Cross *et al.* 1985, MBC 1987a).

From 1988 to 1990, the fish fauna of the Palos Verdes Shelf changed little (LACSD 1992). At first, bigmouth sole was the most common species and slender sole the most abundant; in 1991 plainfin midshipman was the most abundant and most common species. Larvae of the most abundant species had settled on the Palos Verdes Shelf and thus most species were represented by several age-classes (LACSD 1992). Some species that feed on benthic microcrustaceans continue to be less abundant near the outfalls, but California tonguefish has been



SITE GROUP	MEAN NO. OF SPECIES	S.D.	MEAN NO. OF INDIVIDUALS	S.D.	SPECIES NAME	PERCENT ABUNDANCE
I	11.9	1.7	210	90.8	Pacific sanddab	33.5
					Pacific argentine	21.9
					pink seaperch	13.3
					California tonguefish	6.4
II	11.6	2.3	142	72.2	Pacific sanddab	26.3
					yellowchin sculpin	18.9
					California lizardfish	10.2
					longspine combfish	8.1
					bigmouth sole	5.8
					pink seaperch	5.7
					hornyhead turbot	5.3
III	9.5	2.6	83	30.6	California lizardfish	24.6
					hornyhead turbot	15.1
					Pacific sanddab	14.6
					English sole	13.8
					gulf sanddab	10.4
IV	7.4	1.6	49	24.4	hornyhead turbot	28.4
					speckled sanddab	17.1
					California tonguefish	16.5
					white croaker	11.1
					California halibut	5.7
V	4.9	1.0	10.6	3.2	California tonguefish	26.3
					California halibut	17.5
					hornyhead turbot	17.5
					speckled sanddab	8.8
					fantail sole	7.3

Figure 10.2. Trawl stations, site group locations, and community variables for demersal fish assemblages in Santa Monica Bay during 1989-1990 (modified from CLA,DPW 1991).

consistently more abundant. Curlfin sole and shiner perch were abundant near the outfall in the early 1970s and were described as being "discharge-associated" (Allen 1982), but they are now rare or absent (LACSD 1992); whereas several species that were absent in the early 1970s are now present (Stull 1992, pers. comm.).

The HTP 5- and 7-mi outfalls function as artificial reefs, attracting many rocky bottom fishes. Schools and aggregations of fishes near the conduit in deep water may simply orient to the pipes, and may feed there. In shallow water, the ballast rock provides cover for rockfishes; shortbelly rockfish, vermilion rockfish, cowcod, and bocaccio are most common along deeper portions of the pipes (Allen *et al.* 1976).

Wastewater-related changes in intertidal fish populations have not been documented, although changes in the algae assemblage probably affect some fishes. Human disturbance has probably reduced intertidal fish populations throughout southern California (Cross 1982b).

Diseases and Abnormalities. Diseases and abnormalities in marine organisms have been related to pollution throughout the world (Sindermann 1979, Sindermann *et al.* 1980, Mix 1986). Diseases and abnormalities in marine organisms from Southern California have been documented since the 1950s (Mearns and Sherwood 1977), although careful evaluations of the cause and effect relationships were not conducted until the early 1970s. Since then, many studies have surveyed the prevalence (i.e., percentage of a population affected) and geographic distribution of fish diseases and abnormalities. The major abnormalities that may be related to pollution in Santa Monica Bay include fin erosion, epidermal tumors, oral papillomas, and microscopic liver abnormalities.

Fin Erosion. Fin erosion is an obvious abnormality and has been linked to degraded marine environments throughout the world. It is characterized by the degeneration or absence of fins (Mearns and Sherwood 1974), but the causes are complex and may include chemical contamination, low dissolved oxygen, and secondary bacterial invasion (Sindermann *et al.* 1980). Although little is known about how the disease affects survival rates, it is less common in fish more than three years old (Cross 1985).

In 1969 to 1972, fin erosion in Dover sole was exceptionally high (42%) on the Palos Verdes Shelf and declined sharply both upcoast and downcoast from that area (Mearns and Sherwood 1974). The overall prevalence in Santa Monica Bay was 6%, but it was greater than 10% near the HTP outfalls and less than 2% elsewhere.

Fin erosion was found in 33 of 151 species (22%) from the study area and prevalence was 5% or greater in seven species: Dover sole (30%), greenstriped rockfish (14%), rex sole (13%), barred sand bass (9%), greenblotched rockfish (6%), and vermilion rockfish (5%) (Mearns and Sherwood 1977). The prevalence pattern of fin erosion in five species was similar to that in Dover sole: it peaked on the Palos Verdes Shelf (11 to 39%) and declined both upcoast and downcoast from that area (Sherwood 1978). Mearns and Sherwood (1974, 1977) and Sherwood (1978) concluded that fin erosion in fishes on the Palos Verdes Shelf is probably a result of the JWPCP effluent.

From 1971 to 1983, fin erosion was found in 29 fish species near the JWPCP outfalls: approximately 90% of all individuals with fin erosion were Dover sole (Cross 1985). The prevalence of fin erosion in Dover sole declined with increasing distance from the outfalls along both the 200- and 450-ft isobath. Within 0.6 mi of the outfalls prevalence was approximately 30%, whereas 14.4 mi from the outfalls it was close to 0.0%. The prevalence of fin erosion in Dover sole exhibited a fairly steady decline from 1971 to 1983. Values within 5.4

miles of the outfalls ranged from 51 to 81% in 1971-1972, and declined to less than 10% by 1983. The number of fish species with fin erosion near the JWPCP outfalls also declined, from 18 in 1971 to just six in 1983 (Cross 1985). Cross (1985) also concluded that this abnormality was the result of exposure to sediment contaminants. Fin erosion in Dover sole on the Palos Verdes Shelf was even lower (0.7%) in 1988. Within 0.6 mi of the outfall about 1.1% of the fish have the condition (Stull 1988, pers. comm.).

The extent of fin erosion has also declined over the years. In the 1970s, most fins were completely lost, whereas in the 1980s only a small section of the mid-dorsal fin was afflicted. Fin erosion was high at all locations along the Palos Verdes Shelf in the early 1980s, but has been low at all sites since 1986 (Stull 1992, pers. comm.). No fin erosion was observed on fishes collected near HTP outfall during sampling conducted from 1987-1989 (CLA,DPW 1991).

Fin erosion has been found in fishes from many other areas of the United States. Between 1967 and 1971 in Raritan, Lower, and Sandy Hook Bays (New York City), relatively high levels of fin erosion were found in four species bluefish 24%; summer flounder 16%; weakfish 11%; and winter flounder 8% (Mahoney *et al.* 1973). This condition was limited to inner portions of the New York Bight and was thought to be caused by bacteria in conjunction with environmental stress from chemical contamination (Mahoney *et al.* 1973). Fin erosion was found in two of 22 fish species from the highly contaminated Duwamish River in Puget Sound: 8% of the starry flounder and 0.5% of English sole. The abnormalities were attributed to an interaction of the genetic constitution of the organisms with multiple environmental variables, (such as chemical contaminants and physical factors), and mechanical injury (Wellings *et al.* 1976).

These studies confirm those from Southern California which suggest that a high prevalence of fin erosion are found only in highly contaminated areas, i.e., that the disease is induced by pollution. They also suggest that not all species are equally susceptible to fin erosion, although the reasons for different susceptibilities is not known.

Epidermal Tumors. Epidermal tumors appear as nodular growths on the skin and are most prevalent in flatfishes less than three years old. They have been found in several flatfish species on the west coasts of both Canada and the United States but have not been found in any species on the east coast of either country (Stich *et al.* 1977). They are thought to be caused by a unicellular parasite or a virus (Cross 1988). Epidermal tumors are frequently prevalent near urbanized areas (Sindermann 1979). Individuals with epidermal tumors exhibit reduced growth, increased mortality, and failure to participate in normal seasonal migrations (Stich *et al.* 1976, Campana 1983, Cross 1986).

Of 151 species examined from Southern California between 1972 and 1975, only Dover sole was consistently affected with tumors (Mearns and Sherwood 1977). Tumors were most prevalent in Dover sole less than 120 mm standard length (SL) (Mearns and Sherwood 1977); 8% in Santa Monica and San Pedro Bays and about 5% on the Palos Verdes Shelf. Dover sole <120 mm SL were 34 times more abundant on the Palos Verdes Shelf than in Santa Monica Bay. Epidermal tumors were not seen in fish (fewer than 25 specimens) from Dana Point and Santa Catalina Island.

From 1969 to 1972, the prevalence of epidermal tumors in all size classes of Dover sole was highest (>2%) off Port Hueneme and in San Pedro Bay and ranged from 1 to 2% at other sites, (Mearns and Sherwood 1974, Sherwood and Mearns 1976).

Museum specimens from Southern California as early as 1946 revealed that diseased Dover sole were found in relatively uncontaminated areas far from the Southern California Bight (Mearns and Sherwood 1976). Mearns and Sherwood (1977) concluded that epidermal papillomas are not related to discharges from Southern California outfalls. The prevalence in juvenile fish was similar throughout the area; because juvenile fish were more abundant on the Palos Verdes Shelf, more juvenile fish with tumors were found there.

From 1971 to 1983, epidermal tumors were found in 15 species near the JWPCP outfalls (Cross 1988). Dover sole accounted for 93% of all individuals with tumors, largely fish less than 120 mm SL. The prevalence of the tumors decreased with increasing distance from the outfalls. The maximum prevalence (3.3%) was at a water depth of 200 ft within 0.6 mi of the outfalls; prevalence was less than 0.6% 14.4 mi from the outfalls. The prevalence of tumors within 5.4 mi of the outfalls declined temporally in the mid-1970s, but appeared to increase in the early 1980s (within 1.8 mi from the outfalls). The number of fish species with epidermal tumors near the JWPCP outfalls declined from 6 in 1971 to 1 in 1976 and remained at one or two through 1983.

In 1988, the prevalence of epidermal tumors near the JWPCP outfalls was 1.1% for small fish and 0.1% for large fish (Stull 1988, pers. comm.). In 1991, 2.1% of all Dover sole had epidermal tumors; 87% were <120 mm SL (Stull 1992, pers. comm.). Cross (1988) concluded that these epidermal tumors in Dover sole were directly related to the chemical contaminants in the sediments.

In 1986, 2.8% of the Dover sole near the HTP 7-mi outfall had epidermal tumors, compared to an incidence rate of 1.5% in northern Santa Monica Bay (Johnson and Roney 1988), rates similar to those from this area in 1971 and 1972 (Mearns and Sherwood 1974). Epidermal tumors were not observed on fishes collected in 1987 to 1989 (CLA,DPW 1991).

Epidermal tumors have been found in young flatfishes from contaminated and uncontaminated areas on the west coasts of Canada and the United States. The highest prevalence (15 to 59%) in English sole were from contaminated areas near Vancouver, British Columbia; Bellingham, Everett, Seattle, and Aberdeen, Washington; and San Francisco, California (Cooper and Keller 1969, Stich *et al.* 1977). A prevalence of 54% was found in starry flounder from Bellingham, Washington. The prevalence of epidermal tumors in fishes from uncontaminated areas has generally been less than 1%, but a few high values have been observed: 30% in sand sole from the Queen Charlotte Islands, British Columbia; 23% in rock sole from the Bering Sea, Alaska; and 15% in flathead sole from the San Juan Islands, Washington (Miller and Wellings 1971, Stich *et al.* 1977, McCain *et al.* 1978). Thus, epidermal tumors may be unrelated to human pollution.

Oral Papillomas. Oral papillomas on fish from Southern California were first reported in white croaker collected in 1956 within 1.4 mi from the HTP 1-mi outfall in Santa Monica Bay (Russell and Kotin 1957). The prevalence of oral papillomas in fish near the outfalls was approximately 3%, whereas none were found in fish from a reference area 48 miles away, suggesting that the papillomas may have resulted from exposure to a contaminant.

Between 1970 and 1976, the prevalence of oral papillomas in white croaker was less than 1% in Santa Monica Bay and on the Palos Verdes Shelf, less than 5% in San Pedro Bay, and 0% south of Oceanside (Mearns and Sherwood 1977). The prevalence of this disorder continues to be relatively low up to the present (Cross 1988, pers. comm.). Because of the low prevalence rates and their wide distribution, they do not appear to be related to municipal wastewater discharges (Mearns and Sherwood 1977).

Microscopic Liver Abnormalities. No microscopic abnormalities were found in livers of Dover sole from Dana Point in 1976, but those from the Palos Verdes Shelf had fatty vacuolations of cells, structural disarray, cellular degeneration, and increases in the numbers and sizes of melanin macrophage centers (Pierce *et al.* 1977). There was no evidence that the observed abnormalities were caused by pathogens or parasites and the authors suggested that they may have resulted from exposure to the chlorinated hydrocarbons DDT or PCBs.

From 1983 to 1984, Rosenthal *et al.* (1984) studied microscopic liver abnormalities in fishes from nine locations in Southern California; yellowchin sculpin, California tonguefish, Pacific sanddab, longspine combfish, and California scorpionfish. Abnormalities were found in most fishes, but they were no more prevalent in contaminated areas than in reference areas. The prevalence of cellular vacuolation and hypertrophy (increased size) in California tonguefish was significantly different among locations. The authors concluded that liver abnormalities may be the result of widespread chlorinated hydrocarbon contamination.

In 1984, Malins *et al.* (1986) examined microscopic abnormalities in white croaker, hornyhead turbot, and California tonguefish from the HTP and JWPCP outfalls, Los Angeles Harbor, and Dana Point. Only in Los Angeles Harbor was the prevalence of one or more of the 11 abnormalities in white croaker substantially higher than at Dana Point. The prevalence of abnormalities in hornyhead turbot near the outfalls was similar to that at Dana Point. The prevalence of abnormalities in California tonguefish was similar near the outfalls and in Los Angeles Harbor.

The most serious liver abnormalities evaluated by Malins *et al.* (1986) included tumors and pretumorous conditions. Liver tumors were found in only three white croakers from the HTP outfalls (4%) and from Los Angeles Harbor (3%); pretumorous conditions were found in one white croaker from Los Angeles Harbor (2%).

Microscopic liver abnormalities are relatively widespread in fishes in contaminated and uncontaminated areas in the Southern California Bight. If they are the result of human contamination, it is unlikely that they can be related to specific sources. They may be related primarily to natural stresses, such as temperature, dissolved oxygen, and food availability.

Liver tumors and pretumorous conditions are also prevalent in fishes from other contaminated areas in the United States. The prevalence of tumors and pretumorous conditions in English sole frequently exceed five and 15%, respectively, in highly contaminated areas of Puget Sound (Malins *et al.* 1984, 1985a,b; Krahn *et al.* 1986; Becker *et al.* 1987). The highest (32 and 52%) prevalence in Puget Sound were in an area contaminated with creosote (Malins *et al.* 1985a,b). In Boston Harbor, the prevalence of liver tumors and pretumorous conditions in winter flounder collected near a major sewer outfall were 8% (Murchelano and Wolke 1985).

Other Conditions. Studies around Santa Monica Bay have indicated that fishes from contaminated areas may have impaired reproduction and chromosomal abnormalities (Cross and Hose 1988). Reproductive success in white croaker from San Pedro Bay was significantly less ($P \leq 0.05$) than at Dana Point. [Impaired reproduction was indicated by increased early oocyte destruction, lower batch fecundities, and lower fertilization rates.] Concentrations of total DDT and PCBs in liver and gonads were significantly higher ($P \leq 0.001$) in fish from San Pedro Bay than fish from Dana Point. These contaminants may have been partly or wholly responsible for the impaired reproduction in fish from Santa Monica Bay (Cross and Hose 1988).

Hose *et al.* (1987) evaluated circulating erythrocyte micronuclei in the blood of fish from contaminated and reference areas in and near Santa Monica Bay. The frequency of micronuclei in kelp bass was 11 times higher at contaminated sites than at the reference site; micronuclei frequencies in white croaker were four times higher at the contaminated site than at the reference site. Although the frequency of micronuclei may be partly a function of blood cell kinetics, temperature, life history stage, and sex differences, the results also suggest a relationship between contaminant exposure and genotoxicity in fishes.

INDUSTRIAL DISCHARGE IMPACTS

As seawater is circulated through the cooling system of generating stations, planktonic larvae are entrained and some are killed. Studies in 1979-1980 estimated that about 3.4 billion fish larvae are entrained in the Redondo Generating Station each year. White croaker was the most abundant species overall, accounting for about 36% of the larvae, but the dominant species varies throughout the year (Connally *et al.* 1982). On the basis of average flows, about two billion and one billion larvae would have been entrained at the El Segundo and Scattergood Generating Stations, respectively.

The cooling water conduits function as artificial reefs. Intake conduits of the El Segundo and Redondo Generating Stations attract rocky-bottom and schooling species; the former utilize the riprap around the pipes for cover and the latter use the pipes as a point of reference (Helvey and Smith 1985). Both juveniles and adults are sucked into the conduits and killed by impingement on protective screens, by the physical habitat, or, by elevated temperatures during heat treatments. The most abundant species taken are nearshore pelagic or schooling demersal species. Between 1978 and 1980, approximately 71,000 fish/year were estimated to have been impinged at Redondo Generating Station, about 78,000/year at El Segundo Generating Station, and about 48,000/year at Scattergood.

Generating Station (Herbinson 1981, Damron 1988, pers. comm.). Queenfish accounted for about 48% of those at Redondo and 45% at El Segundo (Herbinson 1981); queenfish were the most abundant species impinged at Scattergood in 1986-1987 but surfperches were often dominant in the past (Damron 1988, pers. comm.). The numbers of fish impinged at all three stations has decreased since this period (Herbinson 1988, pers. comm.).

Fish impingement losses at Redondo Generating Station were the lowest in 1988 and 1989 since 1978, although they climbed again in 1990 and 1991 (MBC 1991b). In 1991, over 21,000 fish were impinged at Redondo Generating Station; blacksmith and white croaker accounted for 37% and 17% of the total (MBC 1991b). The decrease in 1988 and 1989, was due to a reduction in the number of circulating pumps in operation, which results in a lower current velocity at the intake (MBC 1991b).

Approximately 30,000 fish were impinged during heat treatments in 1991 at Scattergood and El Segundo Generating Stations (MBC 1991c). Over 90% of the fish impinged at El Segundo occur during heat treatments (Curtis 1992, pers. comm.). Blacksmith was the most abundant fish impinged at El Segundo whereas white croaker was most abundant at Scattergood (MBC 1991c). About 99% of the fish near generating station intakes are expected to survive for at least five years: a ten-fold increase in intake volume would reduce this to 82% (SCE 1982).

URBAN RUNOFF IMPACTS

The potential impacts of surface runoff on fishes has not been studied specifically. The input of freshwater to inshore zones would cause fishes that cannot tolerate low salinities to move offshore temporarily. Turbidity from suspended sediments in stormwater may linger for days or weeks, and could cause decreased visibility and respiratory problems (Allen 1982). Contaminant effects are not known.

The abundances of fish larvae and benthic-feeding fishes in Marina del Rey have decreased since 1984. These changes are probably the result of post-El Niño cooling but could be related to TBT concentrations in the Marina. TBT was used as a biocide in boat antifouling paint and is known to be more toxic to larvae than to adults (Soule and Oguri 1987).

The development of Marina del Rey drastically altered the original lagoon habitat. The amount of shallow bottom habitat was reduced whereas water exchange between the harbor and the ocean was increased. The abundance of lagoon species such as the arrow goby and California killifish undoubtedly decreased. The amount of habitat suitable as a nursery ground for California halibut was reduced. Juvenile halibut utilize warm-water lagoons for development (Kramer 1988, pers. comm.) and thus the development of the Marina may have resulted in fewer adult halibut in Santa Monica Bay. The construction of rock breakwaters and jetties at King Harbor and Marina del Rey provide habitat for many species (Stephens and Zerba 1981), thus benefitting rocky bottom fishes.

Commercial Fisheries. Sport and commercial catches are reported by block to the California Department of Fish and Game (Figure 10-3). Pelagic species have been the major component of the commercial purse seine and gillnet fisheries of Southern California; however, those methods are prohibited in most of Santa Monica Bay (Figure 10-4). Commercial fishing for pelagic fish outside of the study area could impact sport fishing in the Bay.

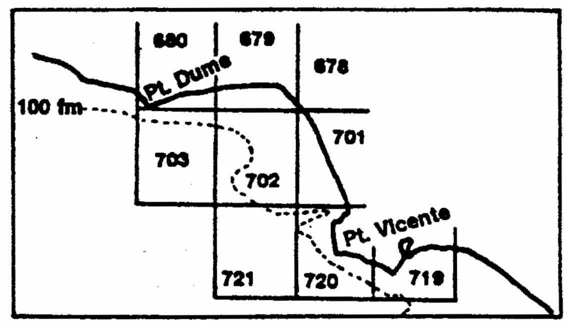


Figure 10.3. CDFG fish catch blocks for Santa Monica Bay (CDFG, unpubl. data).

Between 1934 and 1950, Pacific sardine accounted for over 50% of the annual commercial catch in the Bight. When the sardine population collapsed, the commercial fishery shifted first to jack mackerel and then, after 1969, to the northern anchovy. The crash of the Pacific sardine population appears to have been the result of a long-term population fluctuation pattern (Figure 10-1; Soutar and Isaacs 1969), although it may have been aggravated by intense fishing pressure (Browning 1980).

A moratorium on fishing for Pacific sardine and chub mackerel was implemented in the mid-1970s. By 1975 the chub mackerel population had recovered and by 1985 it was the major fishery in California, 83% from Southern California in 1985 (CDFG 1986, 1987). Chub mackerel has been important in the catch from the Palos Verdes Shelf and Santa Monica Bay since 1978 (MBC 1985, Stull *et al.* 1987).

From 1969 to 1983, northern anchovy was generally the dominant fish in the Southern California catch: prior to 1978 it accounted for about 90% of the wetfish fishery, but for only 42% since then (Stull *et al.* 1987). In part this shift reflects a poor market for anchovy and a better one for other pelagic species (CDFG 1987).

Gillnet fishing has increased in importance in California, although it is not allowed in the inner part of Santa Monica Bay. California halibut is fished on the Shelf west of Malibu Point and from Palos Verdes Point to Point Fermin. Halibut gillnets are set at depths less than 120 ft for California halibut (Vojkovich 1988, pers. comm.), and in 1986-1987 the CDFG observed about 34 sets per year in the Malibu Point-Point Dume area and about 22

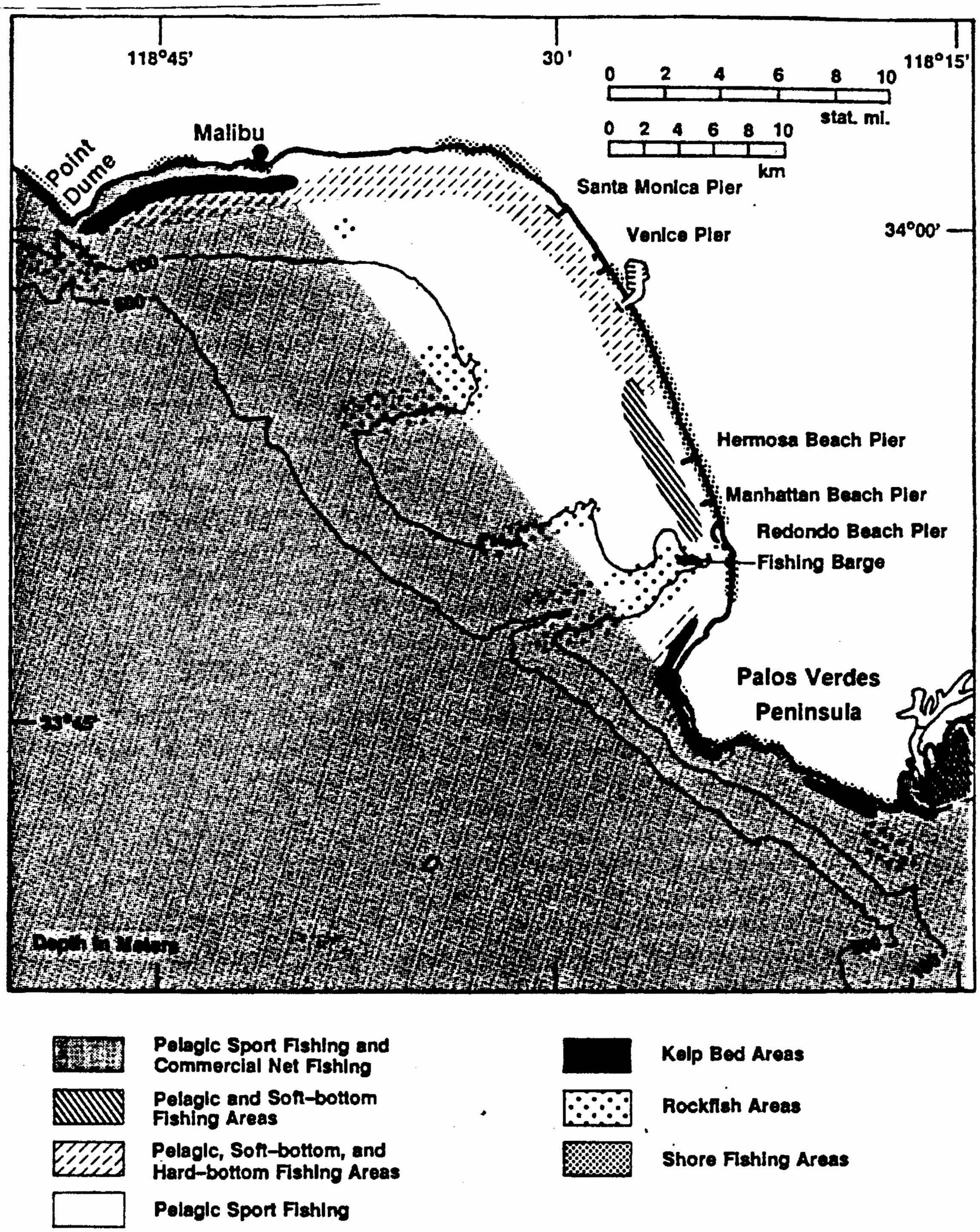


Figure 10.4. Fishing areas in and near Santa Monica Bay (based on Squire and Smith 1977, MBC 1988).

sets per year in the Palos Verdes Point-Point Fermin area (McCormick 1988, pers. comm.). These observations represent about 1 to 2% of the total fishing effort (Vojkovich 1988, pers. comm.); the actual fishing effort is probably 50 to 100 times greater. The annual catch of California halibut from Southern California decreased 1976 to 1978, but has generally increased since then with a peak in 1985. In 1986, the minimum mesh size for gillnets was increased and a moratorium on the issuance of new permits for set gill nets and trammel nets was implemented (CDFG 1987).

White croaker are targeted with set gillnet on the Palos Verdes Shelf; the catch is sold fresh, primarily to ethnic markets in Los Angeles. Drift gillnet fishing for swordfish and pelagic sharks has not been observed in the study area (Vojkovich 1988, pers. comm.). The closures to net fishing in most of the Bay protect resident fishes from overfishing. However, commercial gillnetting for California halibut, (along with the recreational fishery and reduced nursery grounds), probably limits the halibut population in the Bay by intercepting adult halibut moving in from other areas.

Sport Fisheries. Sport anglers fish from beaches, piers and jetties, private boats, and commercial passenger fishing vessels (CPFV or party boats); divers use spears or their hands in shallow water to harvest fish and invertebrates (Squire and Smith 1977). Between 1981 and 1984 an average of 11,100,750 fish was taken per year in the Southern California Bight by an average of 1,551,000 sport fishermen (NFSP 1984, 1985).

Between 1985 and 1991, an average of 390,414 fish was taken from CPFVs in the study area. CPFV catches within Santa Monica Bay have dropped compared to previous years (Figure 10-5) (CDFG, unpubl. data), due in part to a shift in the fishery from deepwater to pelagic species following the 1982 El Niño (Gregory 1993, pers. comm.). The 1982-1983 El Niño provided exceptionally good sport fishing in the Bight (CDFG 1986) and in 1984 the catch was four times that in 1982. Chub mackerel, rockfishes, and Pacific bonito dominated the catches during these years (NFSP 1984, 1985).

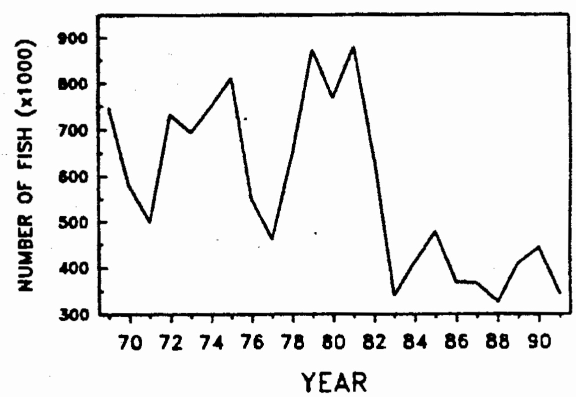


Figure 10.5. Total number of fish caught from commercial passenger fishing vessels for Santa Monica Bay and Palos Verdes Peninsula from 1969-1991 (CDFG, unpubl. data).

The total sportfish catch has decreased in most of the study area since 1982, although it increased between Ocean Park and Redondo Beach reflecting the sport fishing near piers, jetties, and wastewater and generating stations outfalls (CDFG, unpubl. data). In 1973, nearly one-third of the entire catch of 3.7 million fish in the Southern California Bight was taken within 12.5 mi of the largest wastewater outfalls. Outfalls appeared to receive about ten times more fishing pressure than the rest of the coast (Mearns 1977).

Most sport fishing in Santa Monica Bay is conducted nearshore or along the edges of submarine canyons and the Shelf (Figure 10-4). The area from Point Dume to Playa del Rey is fished for California halibut, kelp bass, barred sand bass, rockfishes, chub mackerel, Pacific bonito, white seabass, and Pacific barracuda. The area from Playa del Rey to Hermosa Beach is fished for Pacific bonito, California halibut, and Pacific barracuda. Vermilion rockfish, bocaccio, and chilipepper are taken along Redondo Submarine Canyon; along the shelf off Hermosa Beach; and in Santa Monica Submarine Canyon. Vermilion rockfish, olive rockfish, and bocaccio are caught off Point Dume (Squire and Smith 1977). The sport fishes most frequently caught in Santa Monica Bay in 1987 were Pacific bonito, chub mackerel, and barred sand bass (CDFG, unpubl. data). In addition to these species, the rockfish complex and kelp bass are also important on the Palos Verdes Shelf (Stull *et al.* 1987).

The sport catch per angler in Santa Monica Bay fell during World War II and did not reach pre-war levels until the early 1960s, except in 1957 (the largest on record) which was probably a result of the El Niño that year. The catch per unit effort (CPUE) peaked again in 1971-1972, decreased 1976-1977, peaked in 1979, and fell in 1982-1983, during another El Niño. CPUE has remained fairly low since 1982-1983; even the peak in 1989-1990 was low compared to catches prior to 1982 (Figure 10-6) (CDFG 1992, unpubl. data).

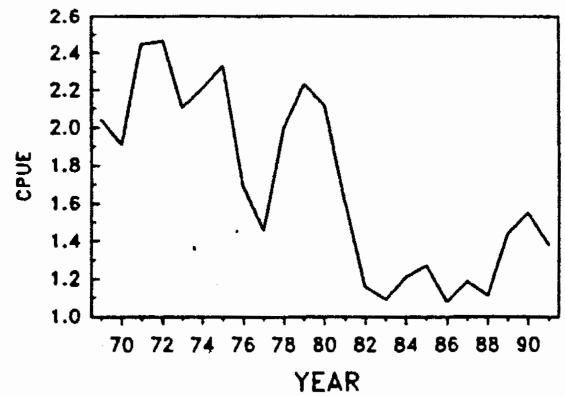


Figure 10-6. Catch per unit effort for commercial passenger fishing vessels for Santa Monica Bay and Palos Verdes Peninsula from 1969-1991. CPUE = numbers of fish divided by angler hours. (CDFG, unpubl. data).

Fishing effort increases during an El Niño because the pelagic species which enter the area are highly prized. However, CPUE in Santa Monica Bay is usually greater during periods of cool, turbid water, when resident rockfishes dominate the catch. The general increase in CPUE from the 1940s to 1976 may have been a function of cooler water, but probably also reflects improvements in fishing gear and knowledge of fishing areas. Recent decreases reflect overfishing and oceanographic conditions (MBC 1985).

Total catch and CPUE along the Palos Verdes Shelf peaked in the late 1970s, but dropped to previous levels during the 1980s. From 1980 to 1985, catches of chub mackerel, California sheephead, kelp bass, barred sand bass, yellowtail, California scorpionfish, ocean whitefish, and Pacific bonito from the Shelf were greater than the 50-year average; whereas catches of California halibut, lingcod, white seabass, and rockfishes were lower than the average.

The catch of white croaker declined after 1985 when the California Department of Health Services (CDHS) posted warnings that it was contaminated with DDT and PCBs. The decline in California halibut catch may reflect the elimination of its estuarine nursery grounds (Stull *et al.* 1987) or the harvest of adults in the commercial fishery. Lingcod is a cool-water species which may have been excluded by the El Niño Event of the early 1980s.

Although pollution is often perceived as causing the decrease in sportfish abundance, this has not been demonstrated with certainty. Changes in the sport catch in Santa Monica Bay during 1957-1963 could not be linked to the HTP wastewater discharge (Carlisle 1969): the reduced catch of white croaker on the Palos Verdes Shelf in 1985 was related to CDHS-posted warnings (Stull *et al.* 1987). There has not been a fish kill in the Bay that can be attributed to pollution. Sublethal contamination would presumably affect fish behavior and lead to increased mortality by predators; however, diseased fish did not appear especially susceptible to predation by spiny dogfish or sablefish (SCCWRP 1974).

SEA BIRDS

DISTRIBUTION BY HABITAT

Some seabirds feed in the pelagic realm and rest on land, but loons, grebes, scoters, California brown pelicans, gulls, and jaegers rest on the sea surface throughout the Bay. Shearwaters, fulmars, petrels, murres, puffins, and auklets are more oceanic and frequent the outer reaches of the Bay. California brown pelicans and terns (including the endangered California least tern) dive into the water from the air to catch fish; cormorants, murres, puffins, and auklets dive from the sea surface to pursue fish and zooplankton beneath the surface. Bonaparte's gulls congregate on the surface during the winter and feed on particulates and zooplankton.

NATURAL VARIABILITY

The abundance of seabirds, shorebirds, and waterfowl in Santa Monica Bay are highly seasonal. Bird diversity and abundance increase during the winter when migratory species arrive and decrease during the summer when they depart, leaving only resident species. Few species nest along the shores of the Bay; most use the Bay as either a stop over during migrations or for foraging.

IMPACTS

MUNICIPAL DISCHARGE IMPACTS

Bonaparte's gulls and other species have been observed feeding near the JWPCP outfalls in winter, but the primary interaction of most seabirds with municipal wastewater is indirect via consumption of contaminated prey. DDT and PCBs increase in concentration up the food chain (i.e., they are biomagnified), being accumulated first in phyto- and zooplankton, then in northern anchovy, other fish, and finally in seabirds.

California brown pelicans nest on West Anacapa Island, Scorpion Rock (Santa Cruz Island), Santa Barbara Island, and Los Coronado Islands - all well removed from Santa Monica Bay. During the 1950s the reproductive success of brown pelicans declined and excessive eggshell thinning appeared to be the primary cause of reproductive failure (Risebrough *et al.* 1971). Research indicated that their eggshells were 26% thinner in 1962 than previously. By 1969 the eggshell thickness had decreased to 50% of pre-1943 values (Anderson and Hickey 1970).

Eggshell thinning was found to be a physiological response to high levels of DDT. Out of 300 eggs examined at the Anacapa breeding colony in 1969, only 12 were intact and DDE residues averaged 43 ppm (wet weight). Eggshell thinning results from DDE inhibition of an enzyme needed to transport calcium ions from the blood to the developing egg (Miller *et al.* 1975). DDT may also depress estrogen levels in birds, resulting in late breeding or the inability to lay more eggs if early clutches are destroyed (Peakall 1970).

In 1971, the use of DDT and the disposal of production wastes into sewers were banned (USEPA 1983). This resulted in a sharp decline of DDT input into coastal waters, and residual levels in the marine food web decreased substantially following the initiation of landfill disposal (Anderson *et al.* 1975, Risebrough *et al.* 1976, Ohlendorf *et al.* 1978, Risebrough *et al.* 1979). Ocean disposal of total DDT compounds decreased from 2,177 kg/year in 1971, to 721 kg/year in 1979 (Schafer 1980), 50 kg/year in 1985 (SCCWRP 1986a) 30 kg/year in 1987, and less than 5 kg/year in 1992 (Stull 1988, 1993, pers. comm.).

At the same time eggshell contamination and thinning were reduced (Anderson 1977), and by 1974, reproductive success of the California brown pelican had stabilized, although it was still lower than previously. Productivity has increased substantially since 1969, with peaks in 1975 and 1985 (Table 10-1) (Gustafson, in prep.).

Since California least tern feed upon similar fishes as the brown pelican (northern anchovy and topsmelt), they may also have been impacted by the accumulation of chlorinated pesticides and PCBs.

OTHER IMPACTS

Diving birds such as cormorants and scoters are occasionally impinged in generating station cooling waters (Curtis 1988, pers. comm.); however, this is a minor source of mortality to the species.

TBT may impact shorebirds which forage on mollusks, crustaceans, polychaetes, or fish by reducing the quality or quantity of these food resources in the vicinity of Marina del Rey; however, no studies have attempted to establish this connection.

Although human disturbances do not constitute a population-level impact at present, they could adversely affect brown pelican productivity. Such disturbances include deliberate mutilation, accidental hooking by commercial and sport fishermen, drowning in gillnets, disruption of nesting habitats by photographers and educational groups (Schreiber 1976, Anderson and Keith 1980), noise from aircraft and boats (Evans *et al.* 1979, Cooper and Jehl 1980, Jehl and Cooper 1980), and oil spills (Holmes and Cronshaw 1977). Population-level impacts could also result in overfishing of northern anchovy, the brown pelican's primary food source.

Year	Nest Attempts	Young Fledged	Productivity
1969	750	4	0.005
1970	552	1	0.002
1971	540	7	0.013
1972	261	57	0.22
1973	247	34	0.14
1974	416	305	0.73
1975	292	256	0.88
1976	417	279	0.67
1977	76	39	0.51
1978	210	37	0.18
1979	1258	980	0.78
1980	2244	1515	0.68
1981	2946	1805	0.61
1982	1862	1175	0.63
1983	1877	1159	0.62
1984	628	530	0.84
1985	6194	7902	1.28
1986	7349	4601	0.63
1987	7167	4898	0.68
1988	2878	2500	0.87
1989	5959	3500	0.59
1990	2400 *	NC	NC

* Preliminary data.

Nest Attempts = a nest built by a pair of adult pelicans in an attempt to produce fledged young.

Productivity = number of fledged per nest attempt.

NC = not calculated

Source: Anderson and Gress 1983; Davis 1988, pers. comm.; Gustafson (in prep.)

Table 10-1. Yearly mean population data for California brown pelicans nesting in the Anacapa Island area (West Anacapa Island and Scorpion Rock) and the Santa Barbara Island area (Santa Barbara Island and Sultil Island), 1969-1990.

MARINE MAMMALS

DISTRIBUTION BY HABITAT

California sea lions and northern elephant seals have been observed in outer parts of Santa Monica Bay (Bonnell *et al.* 1981, Dohl *et al.* 1981). California sea lions are common, and forage beneath the surface and in kelp beds for fishes and invertebrates.

Four species of baleen whales and eight species of toothed whales have been observed in the Bay. Gray whales, bottlenose dolphins, common dolphins, and Pacific white-sided dolphins are the most common species (Dohl *et al.* 1981; Shulman 1988, pers. comm.), and most sightings are within nine miles of Point Dume or Point Vicente (Bonnell *et al.* 1981). Southerly migrating gray whales pass the Bay from December to February enroute to calving lagoons in Baja California; northerly migrating whales pass by the Bay from February to May enroute to feeding grounds in the Bering Sea (Dohl *et al.* 1981, Poole 1984). Although most gray whales cross the outer part of the Bay, juveniles have been seen north withintwo miles of shore from March to May (Figure 10-7).

NATURAL VARIABILITY

Because of their long lifespans and low reproductive potential, natural population changes in marine mammals generally occur slowly. Prior to human influence, food availability and disease were probably the major influences on marine mammal abundance.

Most strandings in Santa Monica Bay are of single animals. Autopsies of stranded animals indicate various causes of death, including parasites (in the liver, pancreas, and brain); cirrhosis of the liver and lung diseases (Ridgway and Johnston 1965; Ridgway and Daily 1972; Cowan *et al.* 1986; LACMNH, unpubl. data); traumatic injury such as boat propeller and gunshot wounds (Woodhouse 1984, Cowan *et al.* 1986); and entanglement with fishing gear (LACMNH, unpubl. data; NMFS, unpubl. data).

IMPACTS

CONTAMINANT IMPACTS

Specimens of marine mammals (washed ashore in Southern California) often have elevated levels of DDT and PCBs; in general, small nearshore species such as the California sea lion, common dolphin, and bottlenose dolphin have the highest levels (Britt and Howard 1983, Schafer *et al.* 1984). However, although the stranded marine mammals often have high tissue burdens of pesticides and PCB, data are insufficient to show a cause-and-effect relationship between the contaminant load and the stranding death.

Gray whales generally avoid embayments such as Santa Monica Bay because of the high turbidity due to runoff or waste discharges (Dohl *et al.* 1981). However, since gray whales seldom feed during their migration, the bioaccumulation of contaminants from Santa Monica Bay is not likely.

MARINE VESSELS & HARBORS

Marine mammals frequently interact directly with marine vessels. Marine vessels may collide with or harass them. Vessel collisions are rare, (although many go unreported) but are the most detrimental impact of the encounters, since impacts may kill the animal. The most recent (reported) local collision was on March 12, 1988 when a tanker collided with one or two animals offshore the Palos Verdes Peninsula (Lewis 1988, pers. comm.).

Gray whales are frequently harassed by boaters who do not follow NMFS guidelines for whale watching. Human actions which interrupt whale behavior constitute "harassment" under the Marine Mammal Protection Act and the Endangered Species Act. Although violators can be prosecuted, enforcement is difficult and harassment hard to prove. Because of intensive local whale watching and concern that gray whales may be changing migrating habits as a result, the present guidelines may become official NMFS regulations in the near future (Jozwiak 1988, pers, comm.).

Vessel engine noise may cause short-term stress to individuals, although gray whales may have acclimated to human activity (BLM 1981). When approached by vessels whales often change their swimming course, and some researchers have suggested that the gray whale migration corridors are farther offshore than in previous years (Dohl *et al.* 1981, Reilly 1984, Shulman 1986).

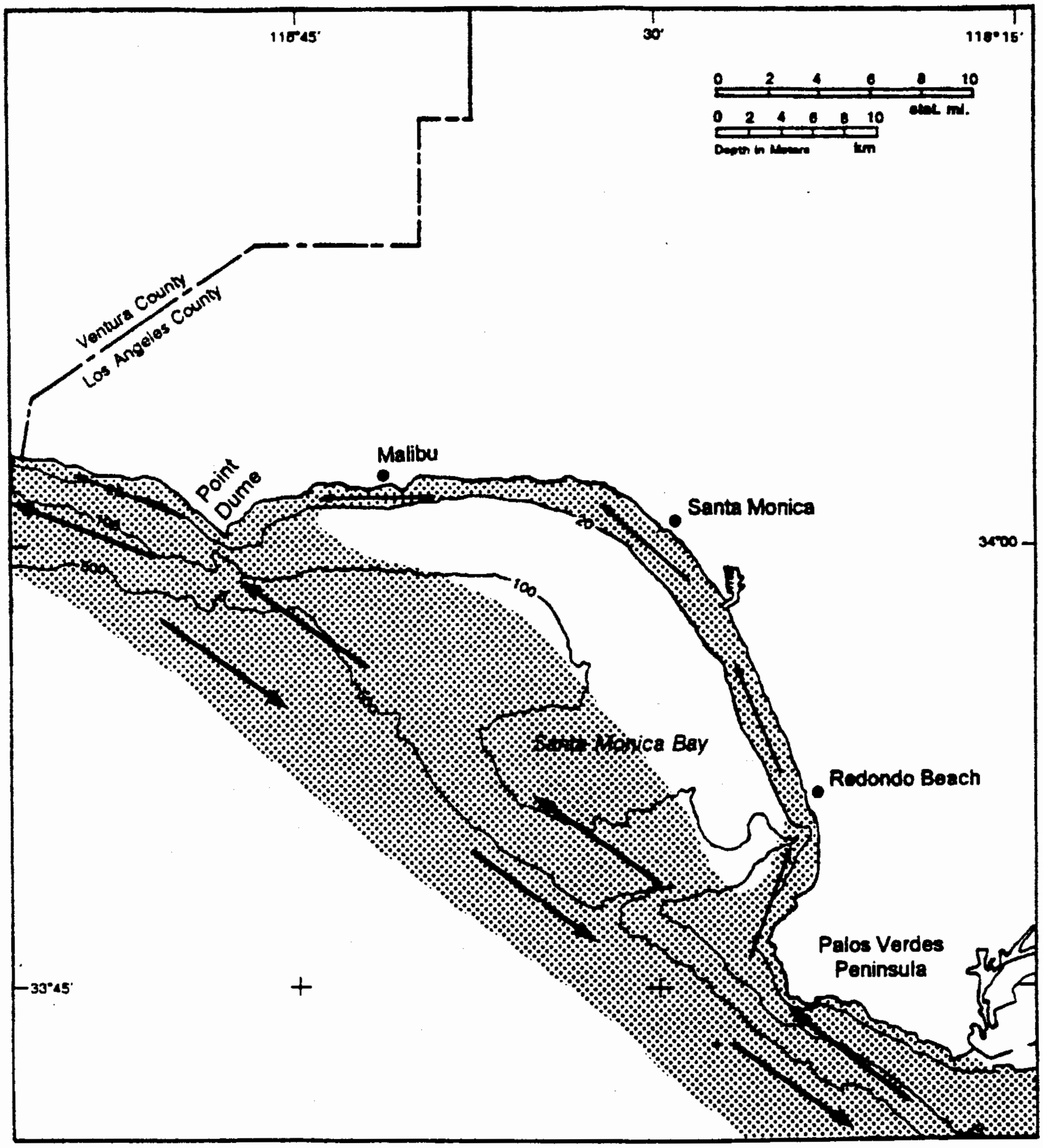


Figure 10-7. Generalized gray whale migration routes in the Santa Monica Bay area (modified from MBC 1988).

Gray whales react more to cavitating propellers and sudden changes in engine speeds (Richardson *et al.* 1983) than to constant engine speeds (Dahlheim *et al.* 1984). Responses may include changing course, and/or altering swimming, diving and breathing patterns until the sound source is out of its hearing range (Malme *et al.* 1983, Richardson *et al.* 1983).

FISHERIES IMPACTS

Marine mammals are occasionally caught in set gillnets. Since gillnetting became legal in the 1970s in Southern California, California sea lions, common dolphin, bottlenose dolphin, and gray whales have been caught incidentally (NMFS, unpubl. data). The rate and number of entanglements of nontarget species are uncertain because: 1) fishermen may not report entanglements; 2) dead animals cut loose from the nets may not strand; and 3) the cause of death is not always possible to determine. Most deaths occur where gillnetting occurs, whereas strandings occur throughout the Bay because of the currents. There is no evidence that these entanglements have impacted any marine mammal populations (Lecky 1985).

In Santa Monica Bay gillnets are set along headlands between Point Dume and Malibu and from Palos Verdes Point to Point Fermin. From 1986 to 1988, at least six gray whales were caught in set gillnets; three near Point Dume and three along the Palos Verdes Peninsula. Four of the six were released by biologists or lifeguards; the outcomes of the other two were not determined.

Between 1983 and 1987, five gray whales which stranded in Santa Monica Bay either had gillnet around them or evidence which suggested that the cause of death was by gillnet (NMFS Stranding Network, unpubl. data).

Sea lions have been observed eating "hooked" sportfish and live bait used for chumming; there is also evidence that the catch rate slowed or stopped when sea lions were present (Scholl 1983). Partyboat operators are permitted to use nonlethal means (seal bombs or acoustical deterrents) to keep sea lions from interfering with fishing operations (Hanan 1988, pers. comm.).

ENDANGERED VERTEBRATE SPECIES

California brown pelican, California least tern, and Belding's savannah sparrow (of salt marshes) are federally-protected under the Endangered Species Act of 1973. In 1993 the gray whale was removed from the Endangered Species List, however, it is still a federally-protected marine mammal under the Marine Mammal Protection Act of 1972.

11

SWIMMING - RELATED HEALTH HAZARDS

CHAPTER 11
SWIMMING-RELATED HEALTH HAZARDS

The health risks of swimming in Santa Monica Bay derive from sources common to swimming in any body of water, such as drowning, ripcurrents, shark attacks, jellyfish stings, and injuries due to diving into shallow water. Drowning and diving injuries are typically associated with swimming anywhere, whereas ripcurrents, shark attacks, and jellyfish stings are generally limited to the ocean. In addition, biological pathogens and hazardous chemicals that are associated with large human populations and/or specific human activities may also pose a risk in certain areas. Because Santa Monica Bay lies adjacent to the largest population center on the West Coast, swimmers in the Bay are potentially exposed to biological pathogens and hazardous chemicals from urban runoff, accidental spills, and permitted municipal and industrial wastewater discharges.

Concern about the health risks of swimming in Santa Monica Bay has increased because of beach closures due to sewage spills and storm drain runoff. Thus, contamination of the Bay by microbial pathogens (i.e., bacteria and viruses) and toxic chemicals is recognized as a potential threat to human health. Articles in the press, which have increased public, scientific, and government awareness, may have fostered misconceptions about the magnitude of health risks by assigning causal roles to specific pollutants, specific sources, and specific human activities. However, a comprehensive study of the human health risks associated with Santa Monica Bay has not yet been performed.

This chapter first presents information on hazardous chemicals, then on microbial pathogens, and finally discusses public health approaches.

HAZARDOUS CHEMICALS

Bathers in Santa Monica Bay may be exposed to a variety of harmful chemicals resulting from improper disposal of household toxins; illegal disposal of motor oil, antifreeze, and battery acid into storm drains; and industrial discharges both into and "upstream" of the Bay. Depending on the nature of the contaminant, the duration of exposure, and the concentration at the point of contact, organic solvents and toxic chemicals may produce acute and long-term health effects such as sore throats, conjunctivitis, gastrointestinal illness, caustic burns, and even cancer. However, etiological relationships between chemical contamination and human health are difficult to establish because of the uncertainties in dose responses, contaminant sources and distribution patterns, differences between acute and long-term exposure, possible synergistic interactions of different compounds, and the long latency (possibly years) between exposure and subsequent disease, especially for cancer. Thus, very few studies have attempted to link human illness with chemical contamination of marine waters.

HAZARDOUS CHEMICAL SPILLS

Numerous chemical spills have occurred in the Santa Monica Bay watershed during the past several years. Some of these reached storm drains or creeks and were subsequently discharged to the ocean. Although such spills occasionally resulted in public health warnings, only one verified report of a chemical spill between 1986 and 1992 caused beach closures in Santa Monica Bay (Appendix I). On March 16 1991, 9,240 gallons of diesel oil mixed with naphthalene spilled from a tanker off the Chevron USA refinery at El Segundo (MBC 1991a). The spill resulted in beach closures at Surfrider Beach in Malibu on 24 March and between Imperial Highway and Grand Avenue on 29 March (LACDHS unpubl. data).

EXPOSURE ROUTES

Human health risks from chemical contamination may develop via several exposure routes. Direct water contact routes include absorption of contaminants through the skin, ingestion of contaminants along with seawater, and inhalation of volatilized contaminants (Brown *et al.* 1984). Exposure routes from contact with sediments include dermal absorption and ingestion of contaminated sediments.

Direct contact with contaminated seawater and/or sediments may occur during swimming, diving, wading, fishing barefoot, or playing in the surf zone. Dermal absorption and inhalation are potentially important routes for volatile organic compounds. While inadvertent ingestion of small quantities of seawater is likely to occur during any swimming activity, ingestion of sediments is unlikely to be significant except in children that exhibit pica behavior (i.e., abnormally high rate of soil ingestion).

BIOLOGICAL PATHOGENS

Direct water-contact activities (swimming, surfing, and skin-diving, etc.) and the consumption of raw molluscan shellfish are the major routes for the transmission of infectious diseases to man from the marine environment. Certain microorganisms native to the marine environment (for example, the genus Vibrio) occasionally cause human infections via both transmission routes (MBC 1988). Although pathogens from marine fauna may pose a human health risk, pathogens in the fecal wastes of ill persons and carriers are of most concern in the United States.

Such pathogens have accounted for most illnesses, resulted in the development of water quality standards, and led to the development of control technologies. These pathogens reach marine waters from municipal wastewater discharges, urban runoff, boat wastes, and swimmers. In small urban populations (less than about 40,000 people), the abundance of pathogens in the wastewater discharge varies with the numbers of ill or carrier individuals in the population, but in areas adjacent to large population centers, such as Los Angeles, the pathogen density remains fairly constant (McGee 1993, pers. comm.). In addition to pathogens derived from human wastes, the fecal matter of other vertebrates, particularly mammals, may also pose a threat to human health. Most biological pathogens are thought to be species specific (Atlas 1984), but the relative human health risk from pathogens derived from non-human sources is unknown.

PATHOGENS

Pathogenic bacteria, viruses, fungi, and protozoa all may occur in the nearshore waters of Santa Monica Bay and all could have adverse effects on swimmers. Pathogenic bacteria that have been found in the Bay include Pseudomonas, Enterobacter/Citrobacter, Streptococcus, Escherichia coli, Klebsiella, and marine Vibrio (Cabelli in MBC 1988). These opportunistic pathogens can cause a variety of human illnesses, ranging from skin infections, gastroenteritis, upper respiratory problems, and wound infections to pericarditis and spinal meningitis (Cabelli 1982).

Viral agents in recreational ocean waters have also been suspected of causing human illness (Cabelli *et al.* 1979, 1982; Gerba et al. 1979, 1985). Human-specific viruses such as hepatitis A, poliovirus, and Norwalk virus (which is suspected of causing gastroenteritis), have been found in marine waters (CDC 1987). Enteric human viruses are especially suspect in marine waters that receive municipal waste because they commonly escape secondary sewage treatment (Edmond *et al.* 1978) and because many persist for prolonged periods in the environment (Akin *et al.* 1971, Gerba and Schaiberger 1975, Melniek and Gerba 1980, Rao and Melniek 1986), thus increasing the potential for human exposure. However, no appropriate epidemiological study to discern a viral etiology in human illness has been conducted. Parasitic pathogens, such as Cryptosporodium, Giardia, and certain yeasts may also cause human illnesses (Atlas 1984). However, there have been no documented cases of either of these diseases associated with swimming in ocean waters.

DISEASES

Numerous bacterial and viral pathogens have been recovered from human fecal wastes and municipal wastewater and potentially all of them could be transmitted back to man via contaminated shellfish and recreational waters. Because of the difficulty in conducting epidemiological studies, there is little, if any, evidence that these routes are significant in the transmission of infectious disease in the U.S. at present. There are, however, three exceptions: infectious hepatitis caused by hepatitis A virus; acute gastroenteritis caused by the Norwalk-like viruses; and pharyngo-conjunctivitis caused by adenovirus types 3 and 4 (Cabelli 1983a).

The most frequently reported waterborne disease in outbreak and epidemiological studies is acute gastroenteritis. Of the biological indicators examined in epidemiological studies conducted by the EPA, enterococcus levels in the water correlated best ($r=0.75$) with the rates of swimming-associated gastroenteritis (USEPA 1986). This relationship was recommended by the EPA as the marine recreational water quality criterion. The EPA also recommended a guideline of a geometric mean of 35 enterococci/100 ml, a value that corresponds to a predicted illness rate of about 19 cases of acute gastroenteritis per 1,000 swimmers (USEPA 1986).

INDICATOR ORGANISMS

With the exception of areas adjacent to nondisinfected waste discharges, human bacterial pathogens and enteric viruses are generally rare in the marine environment, which makes their enumeration and subsequent risk analysis difficult. Thus, to study the distribution and density of biological pathogens, researchers have used "indicator" organisms, which can be associated with the pathogens and may be more abundant. The indicators are easily-counted bacteria that are part of the normal intestinal flora of humans and some other animals. The rationale for their use is that their concentration in the environment is an indication of possible human fecal contamination and, hence, the potential for human disease (Atlas 1984).

BIOTYPES

At the turn of the century three bacterial species (Escherichia coli, Streptococcus faecalis, and Clostridium perfringens) were suggested as fecal indicators of water quality (Cabelli in MBC 1988). Each of these is found in human feces and none has appreciable extrafecal sources, although all three are found in the fecal wastes of other vertebrates. Because of procedural problems, each indicator system has been expanded to include biotypes that include non-fecal species.

The E. coli system was expanded to "total coliforms," which also includes three other genera, Enterobacter, Citrobacter, and Klebsiella. Although these organisms are not always found in human feces, they are usually abundant in sewage, presumably because they multiply there (Dufour 1976). The total coliform system was subsequently replaced with the "fecal coliform" system, more properly called thermotolerant coliforms because only those coliforms that ferment lactose at 44.5°C (as opposed to 35.0°C for total coliforms) are counted. Thermotolerant coliforms include E. coli, a portion of the Klebsiella biotype, and some extrafecal types (Dufour 1976).

The Streptococcus faecalis system was expanded to include S. mitis and S. salivarius, which are part of the oral flora; S. equinus and S. bovis, which are found primarily in the feces of mammals other than humans; and S. faecalis and S. faecium, which are found in the wastes of humans and other endotherms (Greenberg *et al.* 1992).

The enterococcus system is a sub-group of the fecal streptococci that is composed of S. faecalis, S. faecium, S. avium, and S. gallinarum (Greenberg *et al.* 1992). The enterococci group has proven to be a valuable indicator of fecal contamination in both fresh- and salt-water systems (Greenberg *et al.* 1992) and both enterococci and fecal coliform have been evaluated as indicators of gastroenteritis at public beaches (Cabelli *et al.* 1983, Dufour 1976). The best correlation between indicator concentration and general and acute gastrointestinal symptoms was seen for enterococci (Fattal *et al.* 1983), a relationship that is consistent with the observation that, with regard to their survival in seawater, fecal streptococci resemble the viruses more than the coliforms do. Current concepts of pathogenic risk from contact with bacteria-contaminated marine water are based on the indicator enterococcus (Cabelli *et al.* 1982).

LONGEVITY

Viruses appear to be more resistant to environmental stress than bacterial indicators (Keswick *et al.* 1985) and they generally survive longer than human enteric bacteria in seawater and shellfish (Akin *et al.* 1971, Morris and Kim 1975, Gerba and Schaiberger 1975, Morris *et al.* 1976, Melniek and Gerba 1980, Rao and Melniek 1986). Mussels and other shellfish effectively concentrate bacteria and viruses and they have been used to examine pathogen die-off rates in seawater. Morris *et al.* (1976) found that viruses survived longer than total coliform bacteria in tissues of mussels near the Hyperion Treatment Plant (HTP) and Joint Water Pollution Control Plant (JWPCP) outfalls in 1975-1976 and enteroviruses have been detected in mussels collected from Ballona Creek and Marina del Rey (Morris and Kim 1975), which probably reflects the better survival of viruses than coliform bacteria in the ocean and shellfish.

Greater survival in the marine environment is also true of the Norwalk virus and of F male-specific coliphage, a virus that infects E. coli bacteria that have produced F pili. F male-specific coliphage survive chlorination and natural salinity better than either coliforms or enterococci (Cabelli in MBC 1988). Because of this, F-male specific coliphage has been suggested as an indicator of human fecal contamination (Cabelli in MBC 1988). However, Gold *et al.* (1990, 1991, 1992) found that F-male specific coliphage was a poor indicator of human enteric viruses in Santa Monica Bay.

Because many viruses appear to survive longer in seawater than bacterial indicators of fecal pollution, viruses may be present in sufficient number to produce illness after the indicators become undetectable. Thus, the potential health risks from human enteric viruses may be greater than that predicted by the bacterial indicators. This emphasizes the need for more sensitive indicators for human fecal contamination, particularly for known pathogens.

CALIF. OCEAN PLAN BACTERIAL STANDARDS

To limit the risk of human infection from biological pathogens from municipal sewage, the California Ocean Plan (COP) has instituted the following objectives for bacterial indicators for shoreline and nearshore areas (CSWRCB 1990):

1) Water samples from each sampling station shall have a total coliform density of less than 1,000 cfu (colony forming units) per 100 ml, provided that not more than 20% of the samples at any station, in any 30-day period exceed 1,000 cfu/100 ml; and providing further that no single sample, when verified by a repeat sample taken within 48 hours exceed 10,000 cfu/100 ml.

2) Water samples for fecal coliform densities are based on a minimum of not less than five samples for any 30-day period per sampling station. For fecal coliform, geometric means shall not exceed 200 cfu/100 ml and less than 10% of the total samples during any 60-day period shall exceed 400 cfu/100 ml.

The COP also states that in waters where shellfish may be harvested for human consumption, the median total coliform density shall not exceed 70 cfu/100 ml, and not more than ten percent of the samples shall exceed 230 cfu/100 ml (CSWRCB 1990).

Although enterococcus density standards have not been developed, California has adopted the following enterococcus guidelines for shoreline and nearshore stations when the total or fecal standards have been exceeded: a geometric mean of 24 cfu/100 ml for any 30 day period and a geometric mean of 12 cfu/100 ml for any six-month period, based on at least five samples per month (CSWRCB 1990). If a shore station consistently exceeds one of these bacterial objectives, the COP requires a sanitary survey to determine the source of the contamination. However, the protocol for such a survey has not been developed.

SOURCES & DISTRIBUTION
BIOLOGICAL PATHOGENS

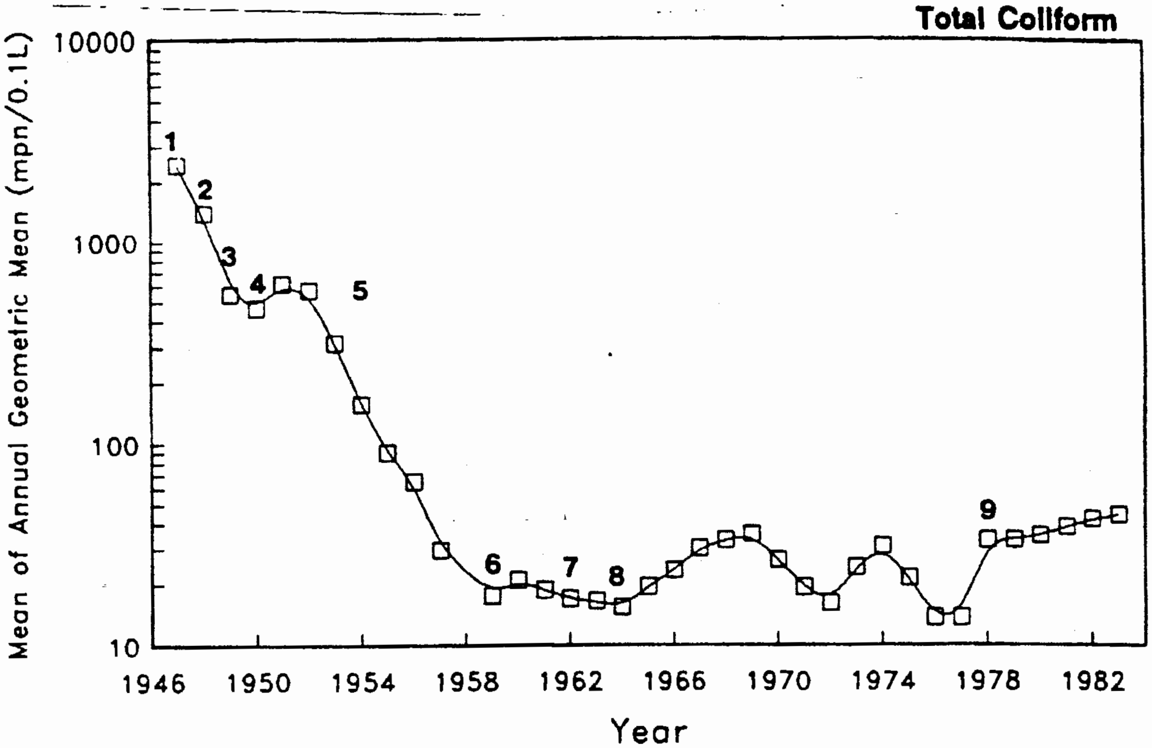
Fecal waste is the primary HP LaserJet Series IIHPLASEII.PRShese include treated wastewater discharges, urban runoff, sewage spills into storm drains, small boat waste discharges, bathers, and marine fauna. Although the risk of disease from human fecal contamination is paramount, it is important to emphasize that the relative importance of pathogens from non-human sources is not known.

Wastewater from sewage treatment facilities may be a potentially large source of human fecal contamination to bathers in Santa Monica Bay. Treated wastewater is discharged directly to the Bay from both the HTP and the JWPCP outfalls, which discharge offshore, and indirectly from the Tapia water reclamation facility (TWRF), which discharges into Malibu Lagoon via Malibu Creek. The relative importance of the offshore sources and their impact on the health of bathers depends upon the transport of associated pathogens shoreward to bathing beaches. Both HTP and JWPCP regularly monitor bacterial indicators at offshore, nearshore, and shoreline sites throughout the Bay and in the past ten years there has been no evidence from microbial indicators that sewage from the effluents has reached the beach. Occasionally high bacterial counts at shoreline stations is a result of other sources of contamination, such as storm drains, shorebirds, and bathers.

Hyperion Treatment Plant. HTP began monitoring total coliform levels at shoreline stations near the 1-mi outfall in the 1940s. Between 1947 and 1959, total coliform levels along shore decreased dramatically (Figure 11-1), due to improved treatment and because the 1-mi outfall was extended to five miles offshore in 1957 (WSED 1982, Garber and Wada 1988). Increases in bacterial densities at shoreline stations between 1959 and 1974 were probably due to urban runoff via storm drains, especially those in the north with large drainage basins (MBC 1988).

The present HTP monitoring program was initiated in 1974 and is focused on recreational waters of Santa Monica Bay. HTP monitors 17 shoreline stations between Topanga and Torrance Beaches (Figure 11-2), 11 nearshore stations located 1,000 ft from shore, and several stations along Ballona Creek and at the Pico-Kenter Storm Drain in the city of Santa Monica. Shoreline samples are collected and analyzed daily for total coliforms and enterococci and at least five times per month for fecal coliforms. Nearshore samples are analyzed for all three indicators four or five times per month (CLA,DPW 1992). In addition to the shoreline and nearshore stations, HTP also monitors bacterial densities associated with plume tracking and microlayer investigations.

The results of the present monitoring program indicate that levels of indicator bacteria (and presumably microbial pathogens) continue to decline in the receiving waters. All nearshore samples have been in compliance with indicator bacterial levels since 1987, suggesting that HTP's five miles outfall is not the source of occasionally high bacterial counts in the Bay.



1 1943-1947: screening, solids incineration
2 1948: 192 MGD - screening, chlorination, solids incineration
3 1949: 201 MGD - screening, chlorination, new 1 mi outfall, solids digestion
4 1950: 201 MGD - screening, chlorination, new 1 mi outfall, solids digestion
5 1951-1957: 250 MGD - high rate secondary, chlorination, solids digestion, filtration drying
6 1959: 254 MGD - high rate secondary, chlorination, solids digestion, 7 mi outfall
7 1962: 184 MGD - primary - 5 mi outfall, 100 MGD - standard rate secondary, 1 mi outfall, solids digestion, 7-mi outfall
8 1963-1977: 240 MGD primary - 5 mi outfall, 100 MGD standard rate secondary, 5 mi outfall, solids digestion, 7 mi outfall
9 1978-1983: 263 MGD primary - 5 mi outfall, 85 MGD standard rate secondary, 5 mi outfall, solids digestion, 7 mi outfall

Figure 11-1. Temporal trend in total coliform bacteria at Santa Monica Bay shoreline. Values are mean of annual geometric mean in mpn/100 *ml* (Garber and Wada 1988).

This trend is due primarily to improved treatment: new digesters, chemical additives (ferric chloride and polymer), sludge dewatering, and an increase in the amount of flow receiving secondary treatment. The trend should continue as the plant is scheduled for full secondary treatment by 1998 (CLA,DPW 1992).

Although densities of bacterial indicators are generally low at nearshore stations, water quality limits have been exceeded in recent years at several shoreline sites, most frequently those near storm drains. Thus, the major sources of bacterial contamination at the surf zone appear to be urban runoff, sewage overflows to storm drains, and marina activities, rather than the HTP effluent.

JOINT WATER POLLUTION CONTROL PLANT

JWPCP regularly monitors bacterial indicators in the nearshore waters of the Palos Verdes Peninsula. Between 1972 and 1982 total coliform counts were made at seven shoreline and five nearshore stations near White Point (Figure 11-3). Over that period, total coliform counts decreased at all stations except one, and those high values were attributed to a colony of California sea lions. The decrease in coliform levels is attributed to improvements in treatment.

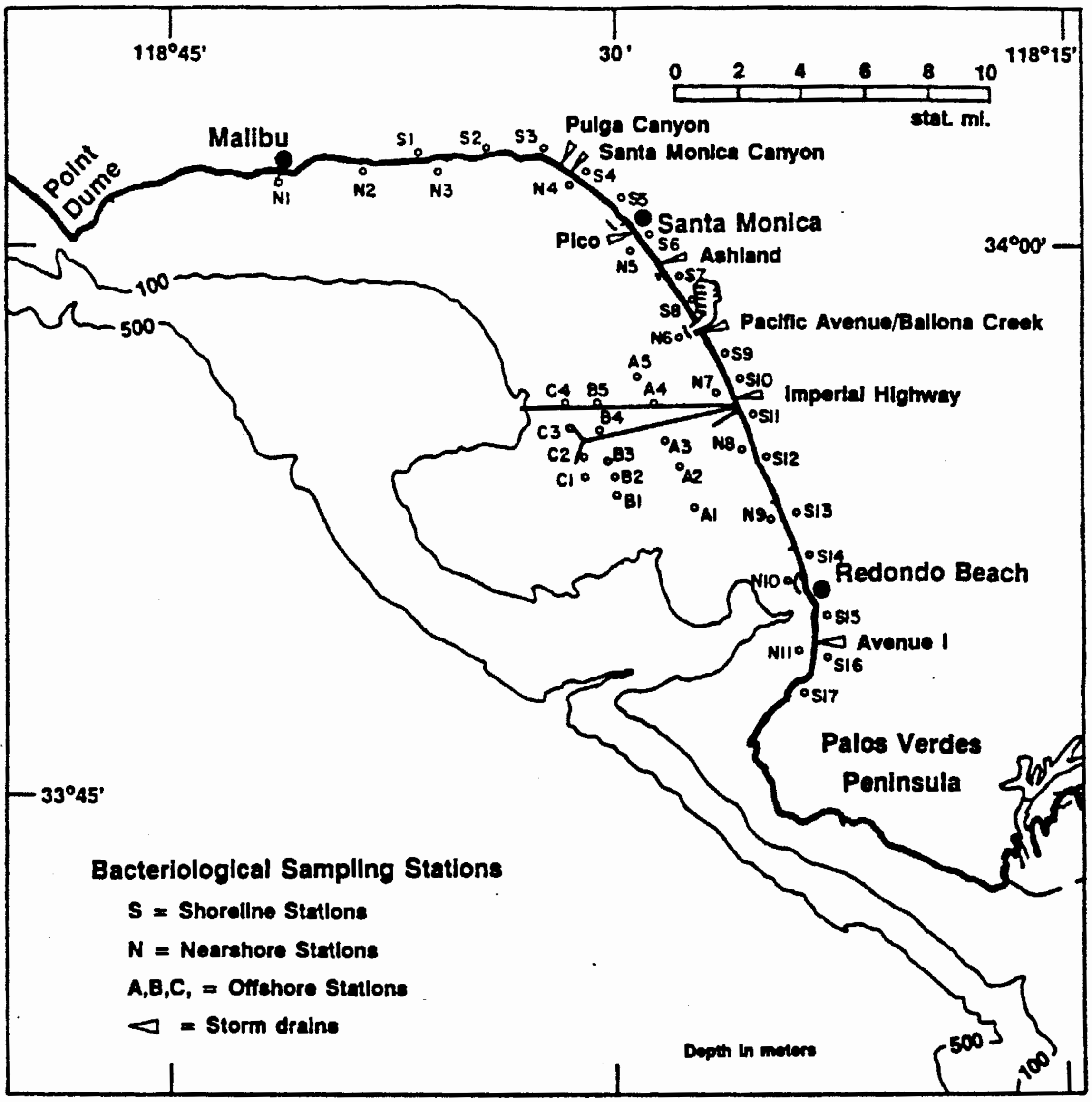


Figure 11-2. HTP bacteriological sampling stations in Santa Monica Bay.

Because elevated subsurface counts had been measured during previous interruptions in chlorination (Weisman 1992, pers. comm.; Stull 1992, pers. comm.), the chlorination facilities and procedures at JWPCP were modified in 1987 and 1988 to meet more stringent requirements. Chlorine dosage was increased and from 1988 to 1990 a backup chlorination station was constructed for use on primary effluent when the main facility was inoperative. In 1991 another standby disinfection facility was constructed for use in the secondary waste treatment system.

These improvements resulted in further decreases in bacterial densities at both shoreline and nearshore stations. In 1991, total coliform densities exceeded 1,000 cfu/100 ml on less than 0.6% of the sampling days at the seven shoreline stations (Stull 1992, pers. comm.). No surface or subsurface coliform limits were exceeded at the nearshore stations, although near-bottom samples occasionally exceeded the limits at some stations.

Since total coliform counts have been continuously lower than standards for fecal coliform, fecal coliform measurements have not been required since 1988. JWPCP began monitoring enterococcus levels in December 1991, and all counts since then have been at or near detection limits at all stations.

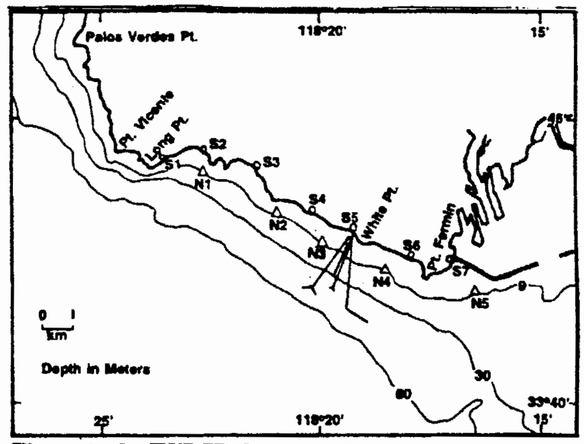


Figure 11-3. JWPCP shoreline (S) and nearshore (N) bacteriological stations on the Palos Verdes shelf.

Although chlorination appears to have reduced levels of indicator bacteria at both shoreline and nearshore stations, the efficacy of chlorination in reducing viral concentrations has never been determined. Furthermore, the potential for toxic effects on marine life from extensive chlorination has not been adequately addressed (Gold 1993, pers. comm.).

URBAN RUNOFF

More than 68 storm drains discharge into Santa Monica Bay between Ventura County and Point Fermin. The majority of these storm drains convey appreciable run-off to the Bay only intermittently, but during periods of heavy rainfall they may carry high concentrations of biological pathogens as well as chemical contaminants from a variety of residential and industrial sources. Although storm drains may constitute point sources at the site of entry into the Bay, the contaminants that they convey derive from a variety of non-point sources, making monitoring and regulation of storm drain effluents difficult. Bacterial pathogens may be transported to the Bay when stormwater overflows into sewage lines, causing sewage to flow into the storm drain system. These overflows cause the most extensive human fecal contamination of Santa Monica Bay. However, high indicator bacteria levels and human enteric viruses have been found in storm drains even during dry weather (CLA,DPW 1988, 1990, 1991, 1992; Gold *et al.* 1990, 1991, 1992). Because most storm drains in the Bay discharge directly into the surf zone, and because of the high levels of contamination that have been found in storm drain runoff, surf zone areas near storm drains are considered high risk areas to swimmers, especially during rain storms.

Dry-weather Flow. Monitoring recently conducted by HTP indicates that high levels of indicator bacteria in the Bay are usually associated with flowing storm drains (CLA,DPW 1988, 1990, 1991, and 1992). For example, since at least 1987 indicator levels at Stations S3, S6, S11, and S16 (Figure 11-2) have exceeded one or more of the Ocean Plan standards. Each of these stations is adjacent to a storm drain: Station S3 is just north of the Pulga Storm Drain; Station S6 is midway between the Pico-Kenter and Ashland Storm Drains; Station S11 is just south of the Imperial Storm Drain; and Station S16 is just south of the Avenue I Storm Drain. High counts have also been recorded at Station S9, which is adjacent to Marina Del Rey and Ballona Creek, and at Stations S14 and S15, which are adjacent to King Harbor in Redondo Beach (CLA,DPW 1988, 1989, 1990, 1991, and 1992). When high levels of bacterial indicators were recorded at the shoreline stations, low levels were recorded at nearshore stations, suggesting that the HTP outfall was not the source of bacterial contamination at the shoreline.

Because high levels of indicator bacteria in the Bay are consistently found near storm drains, the Santa Monica Bay Restoration Project (SMBRP) conducted a series of studies to assess storm drain contamination of the Bay (Gold *et al.* 1990, 1991, 1992). These studies examined storm drain runoff at several sites throughout Santa Monica Bay and they provide the most recent analysis of dry-weather biological contamination from urban runoff.

The first study was conducted over a period of nine weeks during August and September 1989. Samples were collected at the Pico-Kenter and Ashland Storm Drains in the city of Santa Monica, which have had high densities of indicator bacteria in the past (CLA,DPW 1987, 1988, 1989, 1990, 1991, 1992). At each site, samples were taken from inside the drains and from the surf zone at several sites at ankle and chest depths. These samples were analyzed for total and fecal coliforms and enterococcus densities. Human enteric viruses and F-male specific coliphage densities were analyzed in samples taken from the storm drains. In addition, viral seeding experiments were conducted to determine the effectiveness (i.e., percent of recovery) of the enumeration methods and to test for possible toxic effects of the storm drain effluent on the viruses (Gold *et al.* 1992). In 1990 and 1991, the sampling program was expanded to include the Pico-Kenter Storm Drain; the Santa Monica Canyon, the Ballona Creek; the Herondo Storm Drains, which are located just north of King Harbor in Redondo Beach; and several sites within Malibu Lagoon (Gold *et al.* 1991, 1992). Ankle and chest-deep samples were taken only near the Pico-Kenter Storm Drain. The 1991 study was also designed to evaluate the effectiveness of the 600-ft pipeline extension at the Pico-Kenter Storm Drain, which was completed in August 1991, in dispersing the effluent beyond the surf zone. The densities of bacterial indicators were evaluated on whether they exceeded "excessive limits" or "levels of concern," which were defined as 1,000 cfu/100 ml for total coliform, 200 cfu/100 ml for fecal coliform, and 24 cfu/100 ml for enterococcus (Gold *et al.* 1990, 1991, 1992).

In 1989, 1990, and 1991, all three bacterial indicators exceeded levels of concern in virtually all samples taken from the Pico-Kenter Storm Drain (Figures 11-4 and 11-5). In general, densities of bacterial indicators decreased with depth and distance along the shoreline. In 1989 most surf zone samples taken ten yards from the storm drain exceeded limits on 100% of the sampling days, but chest-depth samples exceeded limits much less frequently (Figure 11-4, Gold *et al.* 1990). The geometric means of bacterial densities further demonstrate the decrease in the concentrations of bacterial indicators with distance from the storm drain (Figure 11-6). Pico-Kenter Storm Drain samples in 1989 had mean bacterial levels nearly one-hundred times greater than levels of concern, but levels of all three indicators in ankle-deep water were approximately one order of magnitude lower than storm drain samples and levels in chest—deep water were approximately two orders of magnitude lower. Bacterial densities in 1989 also exceeded levels of concern at a station 150 yds from the storm drain. However, during the 1989 sampling, HTP recorded bacteria levels below levels of concern at Station S6, 200 yards south of Pico-Kenter (CLA,DPW 1990), suggesting that the extent of bacterial contamination may be limited to within 150 to 200 yds from the storm drain.

Densities of all three bacterial indicators in 1991 were three to five times higher in the Pico-Kenter drain than the Herondo drain, and one to two orders of magnitude higher than at Malibu Lagoon. In the Pico-Kenter Storm Drain, densities of all three indicators exceeded levels of concern in all 13 samples. However, in the surf zone, levels of concern were infrequently exceeded at the ankle- or chest-deep stations. The results from the 1991 dispersion study were very different from that conducted in 1990 (Gold *et al.* 1991, 1992), in which bacterial levels of concern were frequently exceeded at ankle and chest-deep stations up to 100 yds from the drain (Figure 11-5). Furthermore, for all three indicators, at nearly every

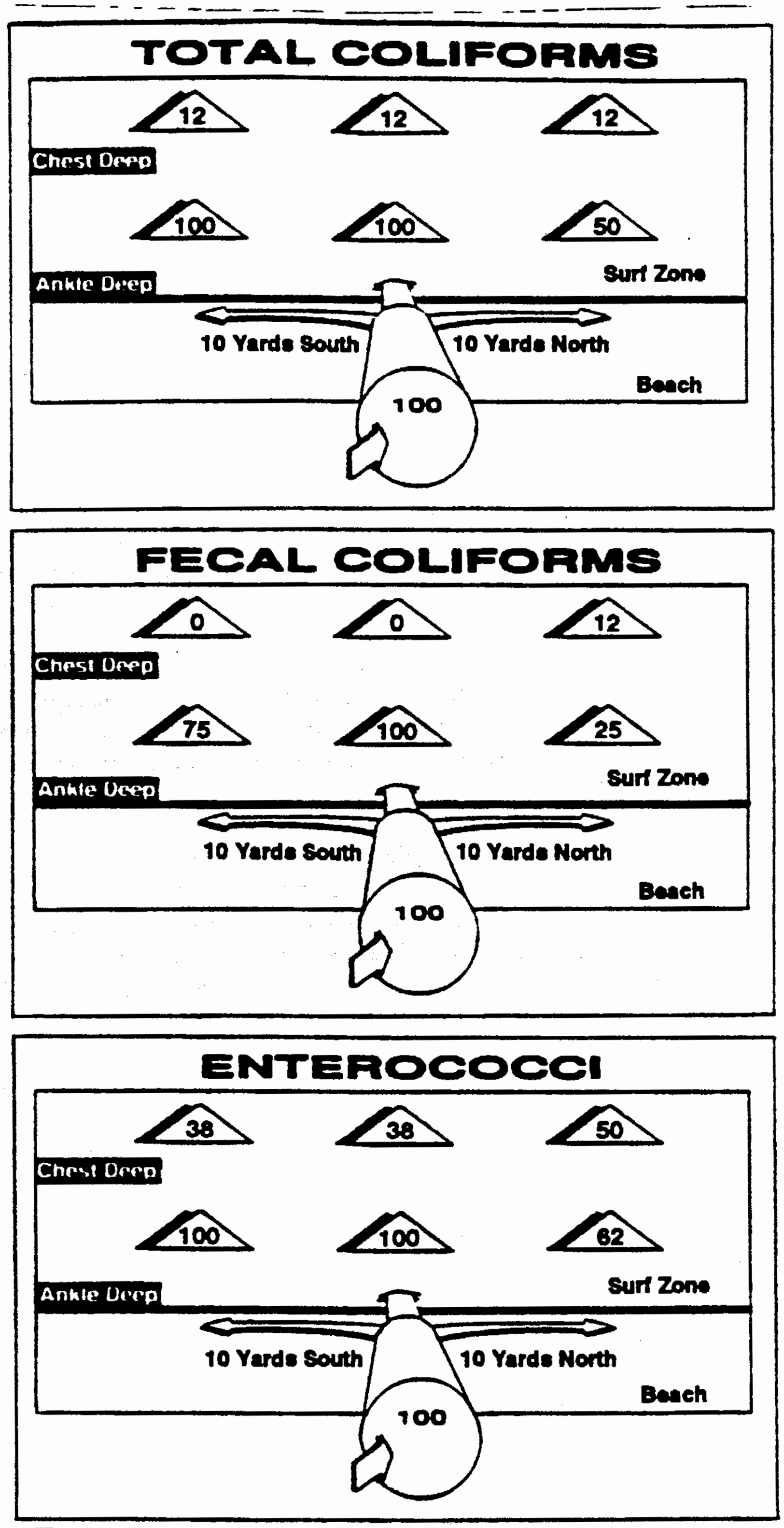


Figure 11-4. Percentage of sampling days where excessive levels of bacterial indicators were exceeded near the Pico-Kenter Storm Drain in August and September 1989 (excessive levels: total coliforms = 1,000 cfu/100 *ml*, enterococci = 24 cfu/100 *ml*). Triplicate samples were collected for eight days from the surf zone and on 15 days from the storm drain (Gold *et al.* 1990).

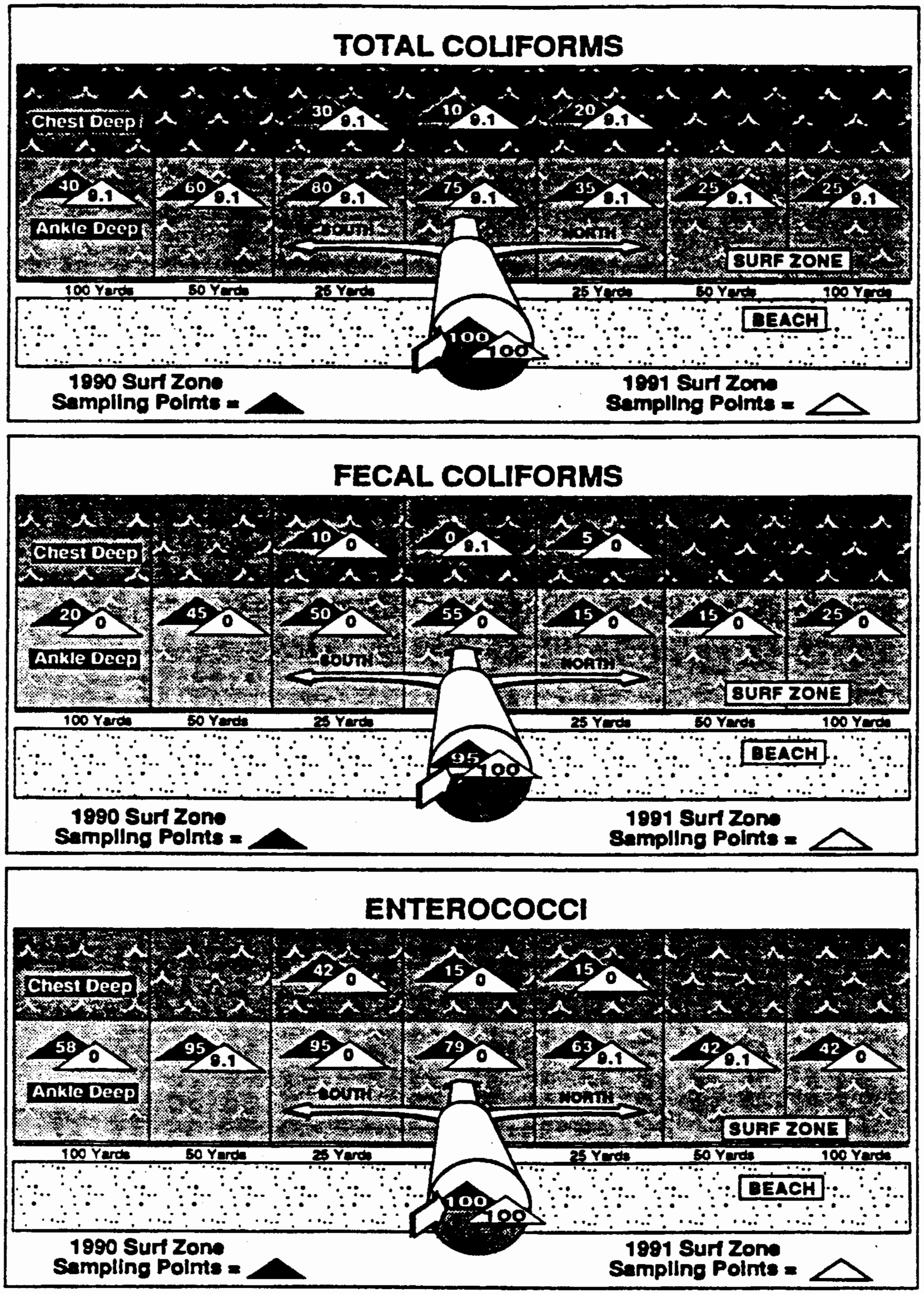


Figure 11-5. Percentage of sampling days where excessive levels of bacterial indicators were exceeded near the Pico-Kenter Storm Drain in 1990 and 1991 (excessive levels: total coliforms = 1,000 cfu/100 *ml*, fecal coliforms = 200 cfu/100 *ml*, enterococci = 24 cfu/100 *ml*). (Gold *et al.* 1992).

surf zone station, the geometric means in 1991 were significantly lower than the means in 1990. Thus, the 600-ft extension to the Pico-Kenter Storm Drain, when functioning properly, appears to be effective in reducing the densities of indicator bacteria in the surf zone, where the potential for human exposure is greatest (Gold *et al.* 1992).

The distribution pattern in and around the Ashland Storm Drain was similar to that seen at Pico-Kenter: levels of concern for all three bacterial indicators were exceeded in nearly 100% of the 15 storm drain samples and least frequently at the chest-depth stations (Figure 11-7).

Bacterial densities at ankle-depth were not as high as those at the Pico-Kenter site, but all three indicators exceeded levels of concern in most samples.

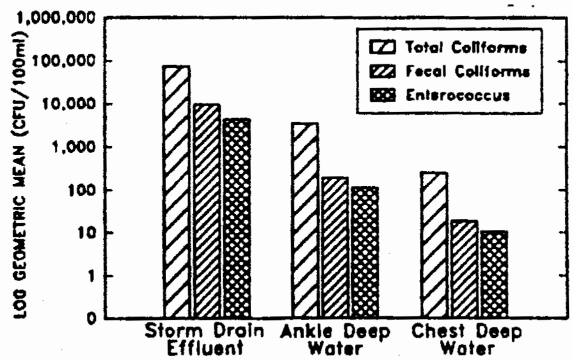


Figure 11-6. Geometric means of bacterial indicator densities (cfu/100 *ml*) near the Pico-Kenter Storm Drain in August and September 1989. Values were calculated from data collected on eight sampling days with three replicates per station (Gold *et al.* 1990).

Human enteric viruses were found in both the Pico-Kenter and Herondo Storm Drains (Gold *et al.* 1990, 1992). However, no viruses were detected in any of the samples taken from the Santa Monica Canyon, Ballona Creek, and Ashland Storm Drain. At Ashland Storm Drain, no viruses were detected even in the seeded samples (recovery of spiked viruses was 0%), suggesting that there were significant interferences in the collection or identification processes (Gold *et al.* 1990, 1992). Thus, the lack of viruses in the Ashland Storm Drain is not evidence of their absence. The presence of enteric viruses in the Pico-Kenter and Herondo Storm Drains indicates that human fecal waste was present in the runoff during the majority of the sampling period. The viruses were identified as Coxsackie B, which can cause gastroenteritis and on rare occasions, pericarditis and meningitis (Gold *et al.* 1992). Possible sources of the human fecal contamination detected in the storm drains include leaky sewer lines, overflows from blocked sewers, illegal inputs, or the local homeless population (Gold *et al.* 1992).

At all sites in Malibu Lagoon, the mean densities of all three bacterial indicators exceeded levels of concern. Densities were especially high in Malibu Creek, upstream of the main Lagoon. Furthermore, enteric viruses were found at all three sampling sites in the Lagoon, suggesting the presence of human fecal contamination. TWRF discharges tertiary-treated waste water into Malibu Creek approximately six miles upstream from the Lagoon and is a potential source of fecal contamination. However, levels of bacterial indicators in samples taken from the facility's effluent were very low during the study period and remained so throughout 1992 (LVMWD unpubl. data). Thus, the plant does not appear to be a direct source of fecal contamination, which confirms indications in 1987 when only a single human enteric virus was detected in TWRF's effluent during 25 days of sampling (James M. Montgomery Engineers 1988). Possible sources of human fecal input to Malibu Lagoon include the Malibu Colony Septic system, campers, picnickers, temporary residents, and illegal discharges from mobile homes or recreational vehicles (Gold *et al.* 1992).

The density of F-male specific coliphage was monitored to examine its usefulness as an indicator of human enteric viruses in marine waters polluted with human sewage. Coliphage densities were ten times higher at the Pico-Kenter Storm Drain than at the Ashland Storm Drain in 1989, but the data were extremely variable and there was not enough information available on human fecal inputs to explain the higher density at Pico-Kenter (Gold *et al.* 1990). Furthermore, there was no correlation between the densities of coliphage and bacterial indicators, nor between coliphage densities and the presence of enteric viruses. Thus, F-male specific coliphage is apparently a poor predictor of the presence or absence of human enteric viruses.

The ongoing monitoring studies conducted by HTP, JWPCP, and TWRF and the studies conducted by Gold *et al.* (1990, 1991, 1992) have established that the largest potential threat to swimmers in Santa Monica Bay from human pathogens is from urban runoff, particularly at the Pico-Kenter and Herondo Storm Drains and in the Malibu Creek/Malibu Lagoon drainage system, where the presence of human fecal contamination has been detected. Although there are several areas of potential fecal input into these drainage systems, it is important to emphasize that the source or sources of the sewage has not been determined conclusively at any site.

Furthermore, an epidemiological study, which would evaluate the impact of human sewage on swimmers, has not been conducted in Santa Monica Bay. The first step in reducing the potential for human health risks associated with swimming in waters contaminated with fecal waste is to carry out a sanitary survey, which would identify and reduce or eliminate the sources of fecal contamination. However, until the criteria and methods for such studies are developed, the public should continue to be informed about the potential risks of swimming in contaminated areas.

Station	Total Coliforms >1,000 CFU/100 mL		Fecal Coliforms >200 CFU/100 mL		Entero-coccus >12 CFU/100 mL	
	Wet	Dry	Wet	Dry	Wet	Dry
1	1	0	0	0	36	28
2	1	<1	0	<1	34	22
3	9	3	2	<1	57	56
4	14	2	2	<1	58	31
5	17	1	2	0	50	33
6	24	5	9	2	55	37
7	20	<1	0	<1	42	21
8	27	<1	6	0	44	15
9	31	<1	2	0	45	12
10	23	2	1	0	37	10
11	21	4	2	<1	31	11
12	7	<1	0	0	19	9
13	7	<1	0	<1	24	13
14	12	2	2	0	22	15
15	10	1	1	<1	40	29
16	9	1	2	0	31	19
17	2	<1	0	<1	22	17

Table 11-1. Percentage of wet and dry weather days where excessive levels of bacterial indicators were exceeded at the HTP shoreline stations (excessive levels: total coliforms = 1,000 cfu/100 *ml*, fecal coliforms = 200 cfu/100 *ml*, enterococci = 12 cfu/100 *ml*) (CLA, DPW 1991).

Wet-weather flow. Because of the relationship among wet weather, storm drains, and high bacterial counts, regulatory agencies distinguish between wet- and dry-weather sampling; HTP has defined wet weather as the day of rain plus the two subsequent days. Bacterial monitoring studies conducted by HTP from July 1989 through June 1990 (CLA,DPW 1991) indicate that total coliform, fecal coliform, and enterococcus densities all increase during wet weather, especially at stations closest to storm drains (Figure 11-8). For example, in 1989-1990, densities of all three indicators were highest during wet weather at Station S3, which is adjacent to the Pico-Kenter Storm Drain, and at Stations S8 and S9, which are on either side of Marina Del Rey and Ballona Creek (Figure 11-2).

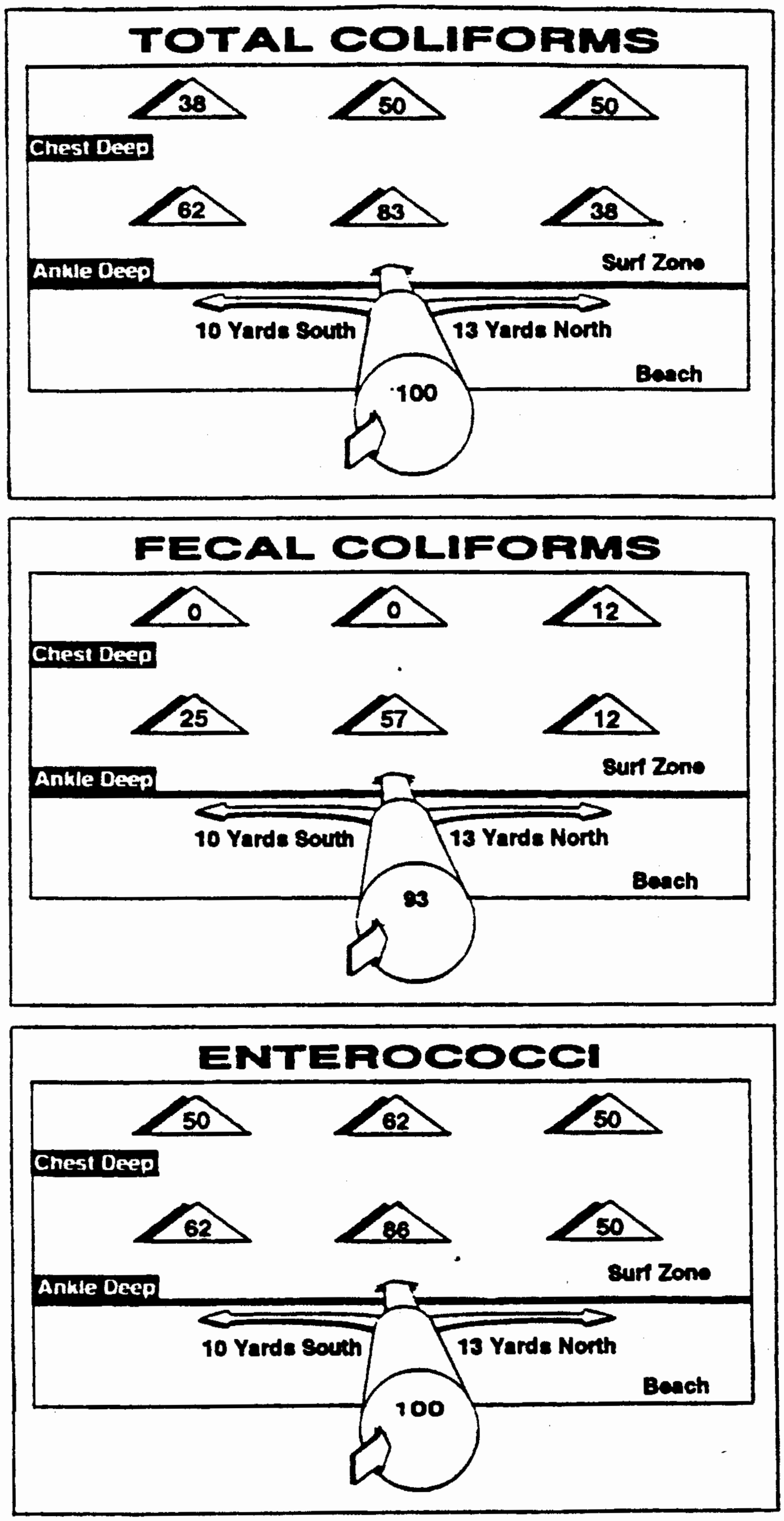


Figure 11-7. Percentage of sampling days where excessive levels of bacterial indicators were exceeded near the Ashland Storm Drain in August and September 1989 (excessive levels: total coliforms = 1,000 cfu/100 *ml*, fecal coliforms - 200 cfu/100 *ml*, enterococci = 24 cfu/100 *ml*). Triplicate samples were collected for eight days from the surf zone and on 15 days from the storm drain (Gold *et al.* 1990).

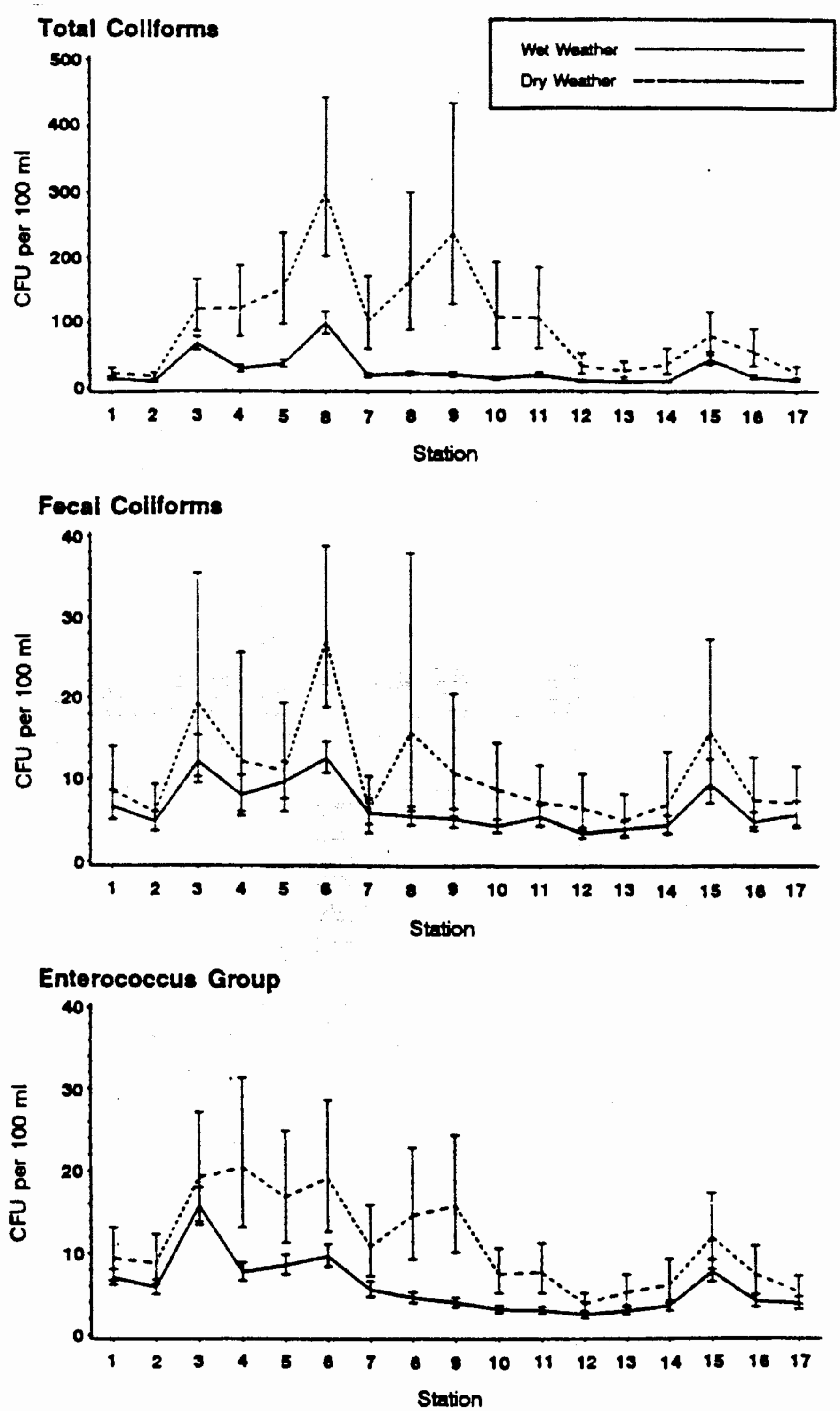


Figure 11-8. Annual geometric means for indicator bacteria collected from HTP shoreline stations during wet and dry weather, sampling year 1989-1990; error bars represent two standard errors (CLA,DPW 1991).

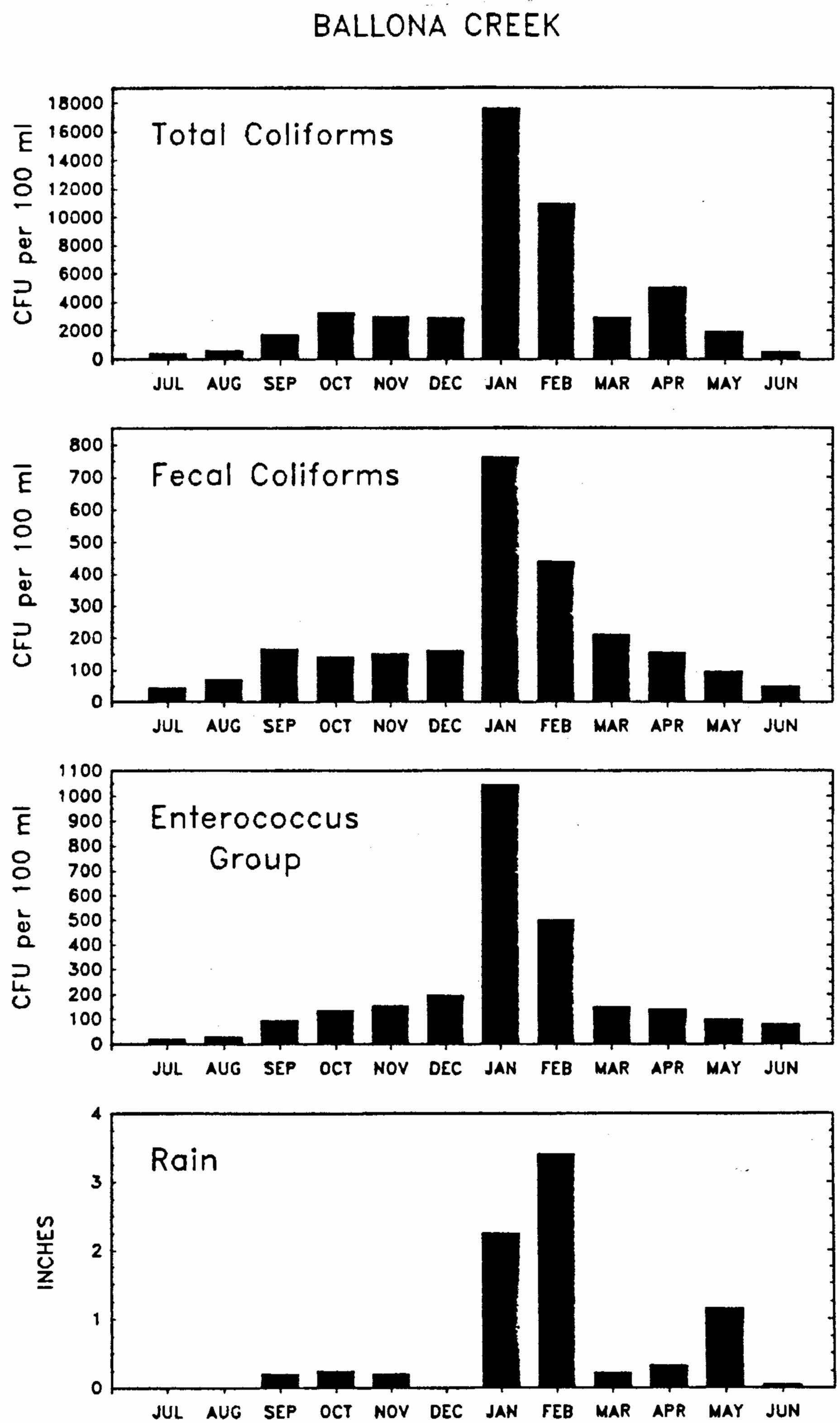


Figure 11-9. Monthly geometric means of indicator bacteria measured in Ballona Creek at Pacific Avenue, sampling year 1989-1990; rain data are in total inches per month (CLA,DPW 1991).

The effect of runoff on the densities of bacterial indicators in the Bay can be demonstrated by examining wet-weather vs. dry-weather days in which bacterial indicator standards were exceeded. For instance, between July 1989 and June 1990, total coliform levels exceeded standards on at least one day at every HTP station (Table 11-1, CLA,DPW 1991). Levels were particularly high between the Pulga Canyon Storm Drain and the Imperial Highway Storm Drain (Stations S3 through S11, Figure 11-2), an area that drains a large portion of Los Angeles County (Figure 7-1), and on either side of King Harbor in Redondo Beach (Stations S14 and S15). Fecal coliform and enterococcus levels were also higher during wet weather, but the difference between wet- and dry-weather days for fecal coliform and enterococcus were much less than that for total coliform. Although high levels of any one of these indicators by themselves is not necessarily indicative of fecal contamination, high levels of all three indicators at a single location suggests human fecal input.

The extent of contamination around a storm drain depends on local rainfall, runoff from the surrounding area, and the interval between storms. For example, densities of all three bacterial indicators were highest during periods of peak rainfall in Los Angeles between July 1989 and June 1990 (Figure 11-9) (CLA,DPW 1991). Bacterial densities are usually highest during the first few months of the rainy season and tend to decrease as the season progresses. This pattern is known as the "first flush" and it assumes that coliform-bearing materials accumulate throughout the dry season. For the same reason, bacterial densities may also be particularly high during the first few hours of a rain that follows an extended dry period. Densities of bacterial indicators (and presumably human pathogens) may remain high for three or four days following the initial runoff (Figure 11-10), during which time swimmers are at greatest risk (CLA,DPW 1991).

SEWAGE SPILLS AND OVERFLOWS

When sewage spills into Santa Monica Bay occur, they are usually a result of heavy rainfall or construction near sewer lines. Spills have lasted anywhere from an hour to several days and they may carry large volumes of sewage to the Bay through local storm drains. Although overflows cannot be predicted, there is usually enough time to warn the public about impacted areas and thus minimize exposure to potential pathogens.

Unusually high inflow and/or infiltration occasionally requires the North Outfall Treatment Facility of HTP to discharge into Ballona Creek or other storm drains. In the past some of these overflows have consisted of raw, untreated sewage (Sowby 1988, pers. comm.), but normally the sewage receives primary sedimentation, two stages of screening, and chlorination at a concentration of 40 mg/l (Crosse 1988, pers. comm.; Dorsey 1988, pers. comm.). A new sewer line and associated upgrades, which will virtually eliminate these discharges, are scheduled for completion in 1993-1994 (CLA,DPW 1992).

Between January 1987 and September 1992, at least 26 sewage overflows were recorded that resulted in beach closures (Appendix I). There were no beach closures resulting from the Los Angeles County Sanitation Districts' collection system. Most of the closures were the result of excess storm water in collector lines leading to HTP, although, some sewage has been released from septic tanks and coastal restaurants. The largest of the spills occurred on February 10, 1992, when heavy rains caused the discharge of over 66 million gallons of partially treated sewage the North Outfall into Santa Monica Bay. Because of the high bacterial levels, beaches were closed along the entire Los Angeles County coast for 11 days (Appendix I).

SMALL BOAT WASTES

The overboard discharge of wastes from boats, particularly those berthed in the marinas, may present a risk of infectious disease to people that use recreational resources in the immediate vicinity. However, because of the small numbers of individuals who contribute to this source and their intermittent nature, the risks are not predictable by fecal indicators or

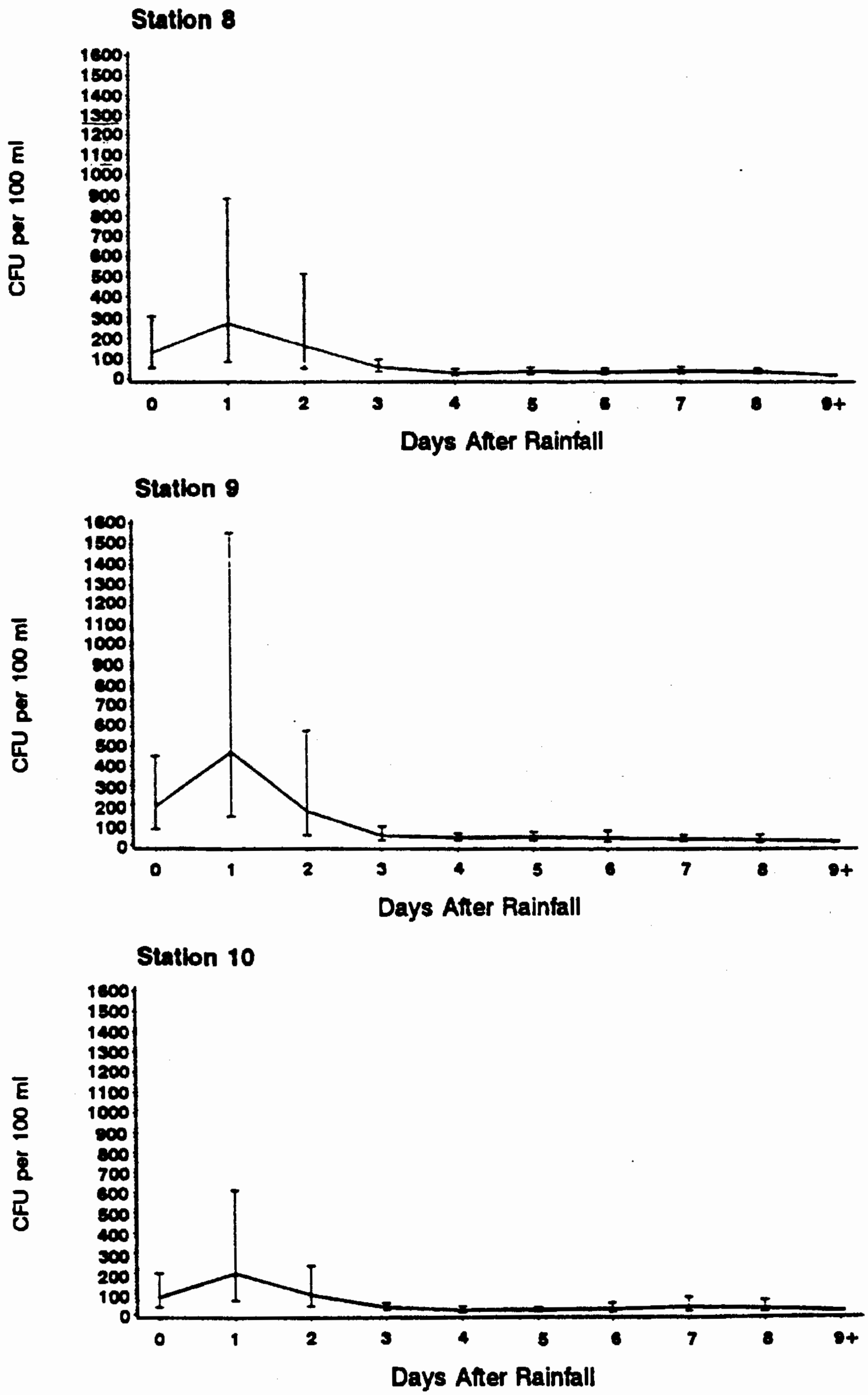


Figure 11-10. Bacterial counts on the days following rain at HTP shoreline stations S8, S9, and S10 (CLA,DPW 1991).

pathogen levels in the water. Therefore, the conventional water quality guidelines and standards do not apply. The recognized solution is to restrict body-contact activities in the immediate vicinity of marinas and to enforce regulations that prohibit sewage discharges from boats. However, since enforcement is often difficult, education of recreational boat users about the potential hazards of sewage discharge is also essential.

BATHERS

At least two epidemiological studies have related swimming-associated illness and bather density in areas of poor water exchange (Fattal *et al.* 1986, Calderone and Dufour 1988, pers. comm.). Although there appears to be a health risk to swimmers from other bathers in the area, the extent of the risk is unpredictable and not amenable to usual control technology. The levels of Staphylococcus aureus, a potential human pathogen that has been found to be a good predictor of illness in freshwater, correlate well with bather density and could be used to identify such situations (Fattal *et al.* 1986, Calderone and Dufour 1988, pers. comm.). However, the link between S. aeureus density and illness has not been established in marine waters.

MARINE FAUNA

Fecal wastes from marine mammals, water fowl, and shorebirds may contain bacteria (notably Salmonella) pathogenic to humans. Although the infectious dose for Salmonella is very high, heavy contamination of the water could produce disease among swimmers or consumers of shellfish. The impacts on swimmers of pathogens from non-human sources has not been examined, except for swimmer's or clam-digger's itch, a problem caused by a bird schistosome (MBC 1988). Because bacterial indicators originate from several sources other than human feces and because most viruses are thought to be species-specific (Atlas 1984), water contaminated with non-human feces would probably have to markedly exceed bacterial indicator limits before a significant risk of human illness would result.

PUBLIC HEALTH APPROACHES

BEACH CLOSURES & WARNINGS

Santa Monica Bay beaches are closed when high indicator bacteria levels are linked to sewage spills or when there are other health-risk concerns.

Santa Monica Bay beaches were closed to swimmers 39 times from January 1987 through September 1992 (Appendix I). Beach closures ranged from three in 1990 to 10 in 1987, with eight from January through September 1992. Most closures lasted from one to three days, but the longest closure lasted for 42 days in 1987, due to high densities of bacterial indicators that apparently resulted from an excessive bird population at Marina del Rey Beach.

Most closures were for a small segment of the beach, usually near a storm drain, but some extended beyond the study area. Three closures during this period extended from the Ventura-Los Angeles County Line to the Long Beach City border; these closures occurred on October 22 and 31,1987, and on February 10, 1992, and lasted for six, 12, and 11 days, respectively. These closures were due to sewage discharges of 2.7, 4.1, and 66.1 million gal, respectively from the North Outfall Treatment Facility resulting from heavy rains.

RISK ANALYSIS

Procedure. Health risks to swimmers from microbial contamination in Santa Monica Bay was predicted according to the method of Cabelli *et al.* (1983b) in 1988 (MBC 1988). This analysis was based on sewage-contaminated waters which, considering the results of Gold *et al.* (1990, 1991, 1992), appears to be a valid, conservative risk assessment (Gold 1993, pers. comm.). Sampling days were first segregated into two groups, wet and dry, based on the mean enterococcus levels for the 17 shoreline stations sampled by HTP. The risk of acute gastroenteritis was estimated for wet and dry days using enterococcus data. Values of enterococci-based risks were evaluated for multiple stations to describe spatial patterns of contamination and risk.

The Cabelli method for evaluating risk is based on a regression equation between enterococcus density in swimming water and the rate of swimming-associated cases of acute gastroenteritis (Cabelli 1983b). "Swimming" is defined as the exposure of upper-body orifices to the water and illness rates are predicted from measurements of enterococcus levels in bathing water. The log to the base ten of the median enterococcus level (median number per 100 ml) is entered into the regression equation obtained from epidemiological studies that were conducted at othereast coast locations:

$Y = 12.17 (\log \text{Median}) + 0.02$ where:

Y = the predicted number of illnesses/1000 swimmers.

If the geometric mean of enterococcus counts from at least ten days is used to represent enterococcus levels, the predicted rate is equivalent to the illness rate that would not be exceeded on half the days during the swimming season. From a public health point of view, this is not a protective prediction. When there are sufficient data points, the 90th percentile enterococcus level can, with some mathematical reservations, be entered into the equation to obtain an approximation of the predicted illness rate that will not be exceeded on 90% of the days during the time period represented.

Cabelli calculated the risk of swimming-associated acute gastroenteritis from the illness-indicator relationship in the above equation (MBC 1988) using the 50th and 90th percentile enterococcus levels for each shoreline station during wet and dry weather (Table 11-2). The values in Table 11-2 may be viewed as the predicted swimming-associated rates of gastroenteritis that would not be exceeded on 50% and 90% of the days, respectively. During dry weather, the predicted 50th percentile rates for all stations were less than that accepted by the EPA enterococcus guidelines; this was also true for most of the stations during wet weather.

Assumptions and Uncertainties. Most of the uncertainty in microbial risk assessment is related to the sources of the indicators, particularly those that are unpredictable or not related to human fecal contamination. Enterococci or coliforms reaching the beaches of Santa Monica Bay could derive from several sources, including off-shore municipal wastewater outfalls, sewage spills, urban runoff, discharges from pleasure boats, marine and shore fauna, and the bathers themselves.

Untreated discharges from pleasure craft and fecal contamination from bathers may pose a risk of swimming-associated illness, but these discharges are small relative to the number of contributing individuals. Therefore, the risk may not be predictable using bacterial indicator guidelines.

One major uncertainty in calculating risk from stormwater runoff results from the occurrence of indicator bacteria unrelated to human fecal inputs, notably those from the feces of other endotherms. These extraneous bacteria confound the relationship between the indicator and actual pathogens. For stormwater discharges that contain nonhuman fecal wastes but

Station	Dry Weather (111 days) [a]				Wet Weather (97 days) [a,b]			
	Enterococci/ 100 mL		AGI/1,000 persons [c]		Enterococci/ 100 mL		AGI/1,000 persons [c]	
	Percentile		Percentile		Percentile		Percentile	
	50th	90th	50th	90th	50th	90th	50th	90th
S1	3	15	6	14	11	82	13	24
S2	2	11	4	13	7	61	11	22
S3	9	23	12	17	22	224	17	29
S4	7	16	11	15	20	95	16	24
S5	7	22	11	16	20	113	16	25
S6	9	24	12	17	22	172	17	27
S7	4	10	8	12	21	127	16	26
S8	3	9	6	12	19	200	16	28
S9	2	13	4	14	20	92	16	24
S10	2	12	4	13	22	242	17	29
S11	2	14	4	14	12	56	13	22
S12	1	6	0	10	11	75	13	23
S13	1	7	0	11	9	61	12	22
S14	1	7	0	10	9	82	12	24
S15	4	16	8	15	14	67	14	23
S16	1	11	0	13	9	85	12	24
S17	1	11	0	13	9	42	12	20

Source: CLA,DPW, unpub. data

a Defined from log-probability plot (MBC 1988) by day of the 17-station GM enterococcus levels. Cut-off of 5.5 CFU/100 mL.

b Includes spills and unexplained events leading to 17-station GMs in excess of 5.5.

c Predicted from equation (Cabelli 1980). Swimming-associated acute gastroenteritis (AGI) rate/1,000 persons:

$$y = 12.17 \log x + 0.2$$

where:

y = predicted swimming-associated rate for acute gastroenteritis
x = GM enterococcus level/100 mL

d Assumes, with reservations, that the equation developed from GMs can be used with 50th and 90th percentile values. 90th percentile rate can be thought of as the rate which will not be exceeded on 90% of the days during bathing season.

Table 11-2. Enterococcus levels and predicted swimming-associated gastroenteritis rates at HTP shoreline (S) stations in Santa Monica Bay in 1987 (MBC 1988).

little of human origin, the risk of illness may be markedly overstated by the enterococcus or coliform levels in the water. However, since the survival rate of some human enteric viruses may be greater than that of the indicator bacteria, health risks may be understated in some areas.

Finally, it must be realized that recreational water quality criteria may not apply under certain conditions such as unusually high levels of illness in the population whose wastes potentially contaminate the resource.

EPIDEMIOLOGY

To assess the potential risk to human health from swimming in Santa Monica Bay, it would be necessary to conduct an epidemiological study, which would evaluate the impact of pathogenic organisms or toxic chemicals on swimmers. However, such a study has not been conducted for Santa Monica Bay. Adequate chemical data are lacking for intertidal and shallow subtidal areas near storm drains and sewage overflow points, which are the primary areas of concern in the Bay other than possible unknown spill sites. However, as a result of studies by SMBRP (1990, 1991, 1992), there appears to be sufficient evidence from biological data that an epidemiological study is warranted. Such a study has been designed and proposed by Dr. Robert Haile and it has been approved and recommended for implementation by the Santa Monica Bay Restoration Project Management Committee (Gold 1993, pers. comm.).

The first step in reducing the potential for human health risks associated with swimming in waters contaminated with fecal waste is to carry out a sanitary survey, which would identify and reduce or eliminate the sources of fecal contamination. However, until the criteria and methods for such studies are developed, the public should continue to be informed about the potential risks of swimming in contaminated areas.

RECREATIONAL WATER QUALITY STANDARDS

As noted above, viruses survive longer in seawater and shellfish than do human enteric bacteria, which suggests that the risk of swimming-associated illness may be greater than suggested by the indicators. However, because of the problems in identifying an etiological relationship between water-borne pathogens and human illness and because of the lack of a mechanism for swimming-associated illness surveillance, there has never been a reported outbreak of a specific illnesses associated with swimming in Santa Monica Bay.

Cabelli (in MBC 1988) suggested that a predicted illness rate of 17 to 18 cases of swimming-associated gastroenteritis per 1,000 swimmers corresponds to a dry-weather recreational water quality standard of a 90 percentile limit of 25 to 30 enterococci/100 ml. A somewhat crude interpretation of this limit is that this is the rate that will not be exceeded on more than ten percent of the days during the swimming season. The decision as to whether this risk is acceptable or not is properly one of policy.

With regard to Santa Monica Bay, the predicted rate probably overstates the actual one to the extent that the sources of enterococci are often non-human wastes. Even if a worst case situation is assumed (i.e., all the enterococci derive from human fecal sources), the predicted rates are appreciably less than those accepted by the USEPA guideline and the corresponding enterococcus limits are attainable. Moreover, the implementation of these limits as interim guidelines or standards should provide an impetus for the conduct of the monitoring, research, and epidemiological programs needed to better assess and manage risks.

A better operating procedure for dealing with events leading to unusually high enterococcus levels that are linked with high total or fecal coliform levels at multiple stations is needed. The response to sewage spills in the absence of stormwater runoff is a relatively simple problem; the potentially affected beaches are temporarily closed until the bacterial standard is achieved. At present there is no epidemiological database for Pacific coast waters regarding the risk of swimming-associated illness from biological pathogens; this information is needed. In addition, an indicator system that is more reflective of human fecal wastes or sewage than the present system is needed. Until these are available, the current practice of issuing health advisories concerning swimming at beaches near storm drains after rainfall should continue. Based on recent studies by Gold *et al.* (1990, 1991, 1992) and ongoing monitoring by HTP (CLA,DPW 1987, 1988, 1990, 1991, 1992), bathers should stay at least 200 yards away from storm drains during dry weather and refrain from swimming during and immediately (two to three days) after rain storms.

12

HEALTH HAZARDS OF SEAFOOD CONSUMPTION

CHAPTER 12
HEALTH HAZARDS OF SEAFOOD CONSUMPTION

Marine environments adjacent to heavily populated urban areas may be exposed to a variety of chemical contaminants from anthropogenic sources, including pesticides such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), chlordane, dieldrin, as well as heavy metals such as arsenic, mercury, silver, selenium, and lead. Marine organisms living in impacted areas may also be exposed to the same contaminants through direct water contact soon after discharge from a point source, or through contact with sediments in which contaminants have accumulated over time. Human health may in turn be at risk if animals exposed to contaminants are consumed. The contaminants that pose the greatest risk to human health from consumption of seafood are those that "biomagnify" or increase "up the food chain." The degree of accumulation in aquatic organisms depends on the type of food chain, on the availability and persistence of the contaminant in the environment, and especially on the physical and chemical properties of the contaminant. The most extensively studied and tractable contaminants in Santa Monica Bay are heavy metals, PCBs, and DDT and its by-products.

CONTAMINANTS AND DISEASES OF CONCERN

Many trace metals are important in animal nutrition, where, as micronutrients, they play an essential role in tissue metabolism and growth. The essential trace metals include cobalt, copper, chromium, iron, manganese, nickel, molybdenum, selenium, tin, and zinc (Rand and Petrocelli 1985). However, the optimum concentration range for trace metals is usually very narrow and severe imbalances in their availability can contribute to poor health, retarded growth, and death. Some non-essential trace metals, such as lead, cadmium, and mercury, also can be toxic at concentrations found in marine sediments and natural waters.

Uptake of metals in invertebrates and fishes can occur through contact with contaminated sediments and waters or through ingestion of contaminated food. Heavy concentrations of trace metals in the environment can pose a health risk to humans that eat seafood from the contaminated area. The mechanisms of accumulation and storage of trace metals in aquatic animals are diverse, varying with chemical form of the metal, mode of uptake, and animal species (Luoma 1983). However, many aquatic animals are able to excrete a higher than normal proportion of their metal intake under contaminated conditions and thus maintain trace metal concentrations in the body at a normal level (Phillips 1980). A major exception to this pattern is mercury, which is readily bioaccumulated when it is in the organic form of methylmercury (Phillips 1980). Thus, the idea of bioaccumulation, where the highest trophic levels contain the highest toxin concentrations, does not hold for most heavy metals (Rand and Petrocelli 1985). For this reason, sediments generally contain higher concentrations of heavy metals than are present in aquatic organisms.

PCBs are a class of synthetic chlorinated organic chemicals that were used in many industrial products (e.g., hydraulic fluids, plasticizers, adhesives, and paper coatings) from 1929 to 1971. Beginning in 1970, their use was voluntarily restricted by the Monsanto Chemical Company to closed electrical systems in the mid-1970s (Cordle *et al.* 1978). Because of their toxic properties, a partial ban was imposed on PCB use and manufacture in 1976 [Section 6(e) of the Toxic Substance Control Act (TSCA)]. In 1979, TSCA regulations were finalized to prohibit their use in heat transfer systems used for the manufacture of food, drugs, and cosmetics. After July 1, 1984, PCBs were no longer allowed for use in electrical equipment.

After distribution in the Santa Monica Bay environment from stormwater, and sewage inputs, PCBs may be absorbed and accumulated by seafood organisms. Consumption of fish and shellfish (including freshwater species) represents the major pathway of human exposure to PCBs today.

Although PCBs have low toxicity in short-term exposures, they are of public health concern because of their persistence and their long-term toxic effects in humans and other animals (Calabrese and Sorenson 1977, Kurzel and Cetrulo 1981; Rogan *et al.* 1986). The low short-term toxicity of PCBs means that a massive dose would be required to cause death or other severe health effects from short-term exposures. Such extreme doses are unlikely to occur in the environment. However, a series of smaller doses over a long period of time (e.g., decades) may cause toxic effects on skin and liver tissue, including liver cancer. A variety of reproductive effects of PCBs have been demonstrated in humans and other animals (e.g., mink, chickens, monkeys, rats). For example, in Michigan and North Carolina infants born to women that were heavy consumers of PCB-contaminated fish exhibited a reduced size at birth, poor muscle tone, and behavioral deficiencies (Jacobson *et al.* 1985, Rogan *et al.* 1986). Because PCBs are lipophilic, long-term exposure to PCBs may result in high concentrations in breast milk (Schwartz *et al.* 1983; Jacobson *et al.* 1984; Humphrey 1987, 1988). Recently, the Los Angeles County Health Department, the California Department of Health Services, and the Office of Environmental Health Assessment conducted a comprehensive study of concentrations of PCBs, DDT, dioxin, and dibenzofurans in breast milk of women in Los Angeles County. The report from this study is currently being prepared.

From the 1950s to the early 1970s, the Montrose Chemical Company dumped tons of the insecticide DDT into the Palos Verdes Shelf via the JWPCP outfalls (Chartrand 1988). Although DDT has been banned in the U.S. since 1972, high levels are still found in the sediments near the JWPCP outfall (NOAA 1991a), which themselves now act as source of DDT contamination for benthic and demersal organisms. Like PCBs, DDT and related compounds (referred to as DDTs) are readily accumulated in animal tissues and tend to persist once uptake has occurred. Although there is some concern that DDTs may cause premature birth in humans (Kurzel and Cetrulo 1981), the evidence for potential toxic effects in humans concerns primarily liver and pancreatic cancer (Garabrant *et al.* 1992). USEPA (1985) concluded that DDT, DDD, DDE, and dicofol, a DDT-related pesticide, are probable carcinogens (cancer-causing chemicals) based on evidence from experiments with rats, mice, and other animals. The extent to which these substances are carcinogenic to humans remains unknown because appropriate epidemiologic data for calculating carcinogenic potency are lacking. As with PCBs, DDT and related chemicals may occur in high concentrations in breast milk of females that consume large amounts of DDT-contaminated fish, but appropriate studies to show health effects in infants are not yet available. Nonetheless, Rogan *et al.* (1986) demonstrated a positive correlation between DDE concentration in breast milk and slow reflexes in infants.

SOURCES OF CONTAMINANTS

The contaminants that may be taken up by animals in Santa Monica Bay originate from many potential sources. Sewage treatment facilities discharge an enormous volume of wastewater to the Bay. Although all sewage that enters the Bay, aside from occasional leaks and overflows, has undergone primary, secondary, or tertiary treatment, sewage outfalls historically have been considered the principal sources of contaminants to the Bay. However, effluent quality has improved dramatically over the past two decades. Now the principal sources of many contaminants may be the historically deposited sediments near the outfalls. Other sources include coastal generating stations, oil refineries, and storm drains, which deliver a variety of contaminants, particularly during periods of heavy rainfall or sewage overflows. The specific constituents originating from these sources are discussed in Chapter 5.

DISTRIBUTION OF CONTAMINANTS IN MARINE ORGANISMS

The amount of a contaminant that is bioaccumulated by an organism depends on several factors, including the chemical characteristics of the contaminant, its concentration in the marine environment, and the characteristics of the organism. For example, the chemicals that have the highest potential for bioaccumulation are least soluble in water. Such compounds are highly soluble in fats and oils and tend to be retained in tissues once they enter organisms. These same chemicals generally have a high affinity for organic particles and tend to concentrate in bottom sediments. Chemicals with a high potential for bioaccumulation include pesticides such as DDT, complex chlorinated hydrocarbons such as PCBs, and organo-metallic compounds such as methylmercury. Highly soluble or volatile compounds such as chloroform have a very low potential for bioaccumulation, even when highly concentrated.

Organisms with a high bioaccumulation potential generally have characteristics such as 1) high fat content, 2) live on or near the bottom sediments, 3) filter-feed on organic particles, and 4) are high on a food chain (i.e., top carnivores). Examples of such organisms include Dover sole and other flatfish species (demersal fishes), mussels and clams (filter feeders), and seals (high fat and top carnivores).

INVERTEBRATES

Except for mussels, contaminant levels in invertebrates from Santa Monica Bay have not been well studied. Data on mussel contamination levels have been generated primarily by the California State Mussel Watch (SMW) Program, a periodic assessment that has been conducted since 1977 by the State Water Resources Control Board (SWRCB). The program uses both blue (= bay) and California mussels to assess spatial and temporal trends in the contamination of native and transplanted organisms. Mussels are good indicators of environmental contamination because they are filter feeders, and therefore ingest small organic particles and associated contaminants. Mussels are also attached to a substrate and as such provide a better indication of localized conditions than motile organisms, such as fishes.

Other invertebrates that have been assessed for tissue contamination include yellow rock crab, ridgeback rock shrimp (= ridgeback prawn), black abalone, California spiny lobster, and giant rock scallop; species names are listed in Appendix C.

SPATIAL PATTERNS

Metals. In 1979, the SMW Program conducted an intensive survey of resident intertidal mussels in Santa Monica Bay. The distributions of metals in mussels showed distinct patterns that related to metal sources and to fate processes in the Bay. For example, the mussels Royal Palms, on the Palos Verdes Peninsula, had the highest tissue levels of silver in the study area (about six times those at Point Dume); intermediate and relatively constant levels of tissue silver were measured at locations in central and southern Santa Monica Bay (Figure 12-1). The high silver levels in Royal Palms mussels probably resulted from contamination from the JWPCP outfalls.

In contrast, lead contamination of mussels had a very different pattern in the Bay, with the highest concentrations measured along the central inshore Bay from Playa del Rey to Redondo Beach. This pattern suggests that the major lead sources were probably urban surface runoff and marinas. One of the highest lead concentrations measured in resident mussels (49 ppm at Marina del Rey) was about 50 times the lead concentrations typically found at uncontaminated coastal sites.

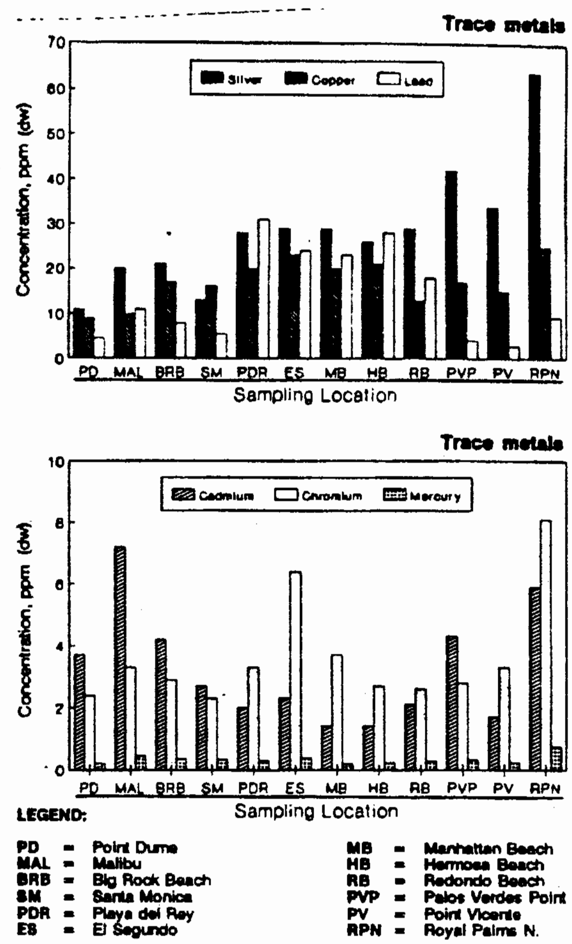


Figure 12-1. Regional variations in concentrations of trace metals in resident sea mussels (*Mytilus* spp.) from Santa Monica Bay, 1979 (CSWRCB 1982.

Brown *et al.* (1986) and Thompson *et al.* (1987a) measured hepatopancreatic concentrations in ridgeback rock shrimp and found that copper, zinc, and cadmium had very different spatial patterns (Figure 12-2). Concentrations of copper and zinc in shrimp from Santa Monica Bay were less than, or similar to, concentrations of these metals in shrimp from adjacent coastal areas. In contrast, cadmium was highly elevated in shrimp from northern and central Bay sites, but not in shrimp from the Palos Verdes Shelf, possibly reflecting the high degree of cadmium complexing with organic matter near that outfall (MBC 1988).

Analyses of edible tissue of six invertebrate species collected near the JWPCP outfalls from 1974 to 1976 indicated that most metals, including those of greatest concern relative to human health (lead, mercury, and cadmium), were not substantially elevated above reference areas (Jan *et al.* 1977). For most of the species and metals tested, the concentrations in outfall organisms ranged from one to three times the control levels. The only metal showing substantial bioaccumulation in outfall organisms was chromium, which was elevated about ten times reference levels in edible tissues of scallops and abalone. These data suggest relatively minor bioaccumulation of metals in these species, since sediment metal concentrations near the outfalls were elevated from 16 to 36 times control areas.

Organic Compounds. Resident mussels from a few sites in Santa Monica Bay have been analyzed for tissue concentrations of organic chemicals. From 1982 to 1983, mussels from Royal Palms on the Palos Verdes Peninsula contained about 1,400 ppb total DDT (Ladd *et al.* 1984). This value was over 6 times the total DDT concentration in mussels from a reference area off Oceanside and over 140 times the levels at northern California reference sites such as Trinidad Head. High DDT levels have also been reported for giant rock scallop, black abalone, and California spiny lobster collected from the Palos Verdes Peninsula (Young *et al.* 1978). Most of the total DDT present in animal tissues is in the form of DDE, with lesser amounts of DDD and very small amounts of DDT, suggesting that there has not been a recent input of the parent compound. Most pesticides other than DDT (e.g., chlordane, endrin, aldrin, endosulfan, heptachlor, and toxaphene) do not have elevated concentrations in animals from Santa Monica Bay (SCCWRP 1992, CSWRCB unpubl. data).

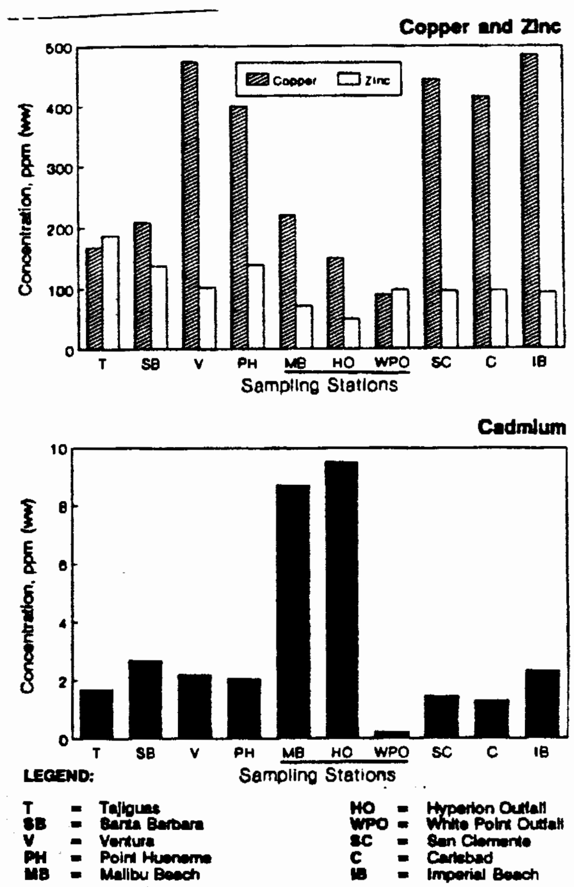


Figure 12-2. Regional variations in concentrations of trace metals in hepatopancreas of ridgeback rock shrimp (*sicyonia ingentis*) from Southern California Bight, 1982-1985 (Brown *et al.* 1986, Thompson unpubl. data).

Data for ridgeback rock shrimp collected in 1982 (Brown *et al.* 1986) and 1985 (Thompson *et al.* 1987a) indicate widespread DDT contamination in this species throughout the Southern California Bight (Figure 12-3). In particular, shrimp from Santa Monica Bay displayed highly elevated tissue levels when compared with adjacent coastal areas. The highest mean DDT concentration (49,000 ppb) was measured in shrimp from near the JWPCP outfall at White Point (Figure 12-3), which were over 370 times the mean DDT concentration in shrimp from Imperial Beach. Shrimp from Malibu and HTP outfall areas also had high DDT concentrations in hepatopancreas tissue, with mean values exceeding 10,000 ppb (Figure 12-3). These data suggest that, in addition to the large source of DDT near the JWPCP outfall, the HTP outfall or perhaps other sources such as runoff from the Malibu watershed, may have contributed to the DDT contamination in northern Santa Monica Bay.

The historically high levels of contaminants in sediments and animal tissue at the Palos Verdes Peninsula prompted the Santa Monica Bay Restoration Project (SMBRP) to conduct a study on the distribution of PCBs and DDT in yellow rock crab to assess the extent of contamination in the animals near the JWPCP outfall (SCCWRP *et al.* 1992). The mean DDT concentration in the muscle of yellow rock crab taken from White Point in 1990 (31 ppb) was an order of magnitude greater than from crabs collected at Dana Point (Figure 12-4). Over 90% of the total DDT at both sites was in the form of DDE, suggesting that there has been no recent input of the parent compound, but that sediments near the outfall are still contaminated with DDT by-products. PCB levels (Figure 12-5) were about three times higher in yellow rock crab taken from White Point (9.1 ppb) than those from Dana Point (2.7 ppb) (SCCWRP *et al.* 1992).

In mussels, the spatial distribution of PCBs is similar to that seen for DDT and its constituents. In 1990, PCB concentrations were 150 ppb in mussels from Royal Palms, while tissue levels at Oceanside were 54 ppb (CSWRCB unpubl. data). Levels at Santa Monica (65 ppb) and Malibu (70 ppb) were similar to those at Oceanside and other sites in Southern California (CSWRCB unpubl. data). In contrast, ridgeback rock shrimp hepatopancreatic PCB contamination was highest in northern and central Santa Monica Bay near Malibu Beach and the HTP outfall, where concentrations exceeded 3,000 ppb in 1983-1985 (Figure 12-3) (Brown *et al.* 1986, Thompson unpubl. data). The PCB levels in Santa Monica Bay shrimp were about ten times the levels at Tajiguas, the most northerly site sampled. Brown *et al.* (1986) found similar patterns of hepatopancreatic concentrations of PCBs and DDT in armed box crabs from Santa Monica Bay. The most likely source of PCB contamination in northern Santa Monica Bay is effluent from the HTP outfall.

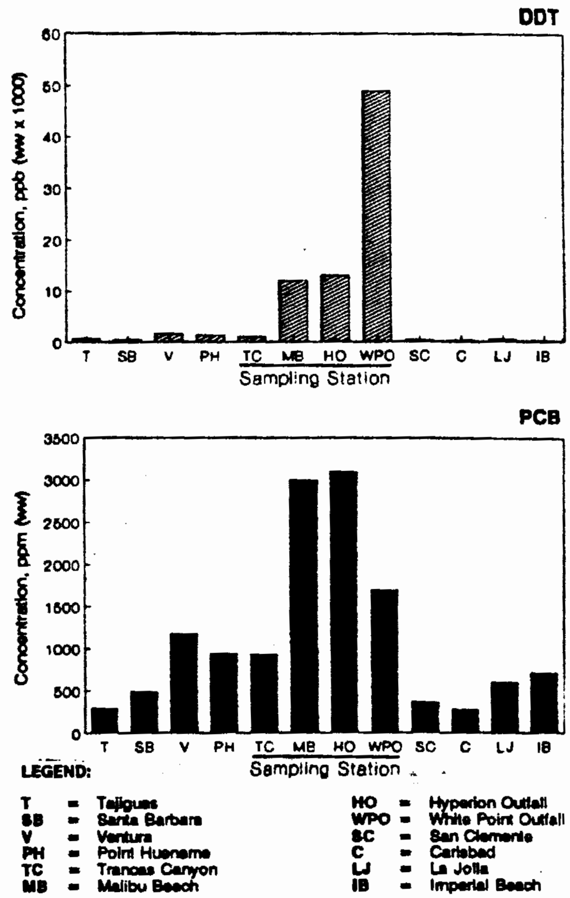


Figure 12-3. Regional variations in concentrations of DDT and PCB in hepatopancreas of ridgeback rock shrimp (*Sicyonia Ingentis*) from the Southern California Bight, 1983-1985 (Brown *et al.* 1986, Thompson unpubl. data).

TEMPORAL TRENDS

Metals. Data from the SMW Program indicate temporal trends in contaminant levels because the same sites have been sampled through time with consistent methods. The only SMW site in Santa Monica Bay with good temporal data is at Royal Palms, on the Palos Verdes Peninsula. Lead levels in Royal Palms mussel tissue declined substantially from 1977 to 1983 (Figure 12-6). However, copper, silver, and cadmium levels were consistent through that time period. Data collected in 1990 showed lead concentrations at Royal Palms have continued to decrease, but concentrations of other metals in 1990 were similar to those in 1982 and 1983 (CSWRCB unpubl. data).

Recently, SCCWRP (1992) analyzed HTP monitoring data to determine the effects of sludge that had been discharged through HTP's 7-mi outfall from 1957 through 1987. Data collected in 1986, 1987, and 1988, was used to assess the impacts of sludge discharge on contaminant levels in marine organisms in the impacted area and the recovery of organisms following sludge discharge cessation. This summary provides a good database for analyzing recent temporal trends in contamination levels near the outfall.

SCCWRP (1992) analyzed tissues of ridgeback rock shrimp and Dover sole from the 100-m isobath at a "contaminated" site surrounding the discharge, a reference site approximately six miles west of the discharge, and a transition zone between the two areas. The concentrations of trace metals in hepatopancreas tissue in ridgeback rock shrimp from contaminated sites changed very little from 1986 through 1988 (Figure 12-7) (SCCWRP 1992). Copper and silver concentrations decreased slightly after sludge termination, but zinc and cadmium showed no appreciable changes. Although sludge abatement had little effect on metals contamination, concentrations of all metals in shrimp tissue from the outfall area were similar to those from animals taken elsewhere on the southern California mainland shelf (SCWWRP 1992).

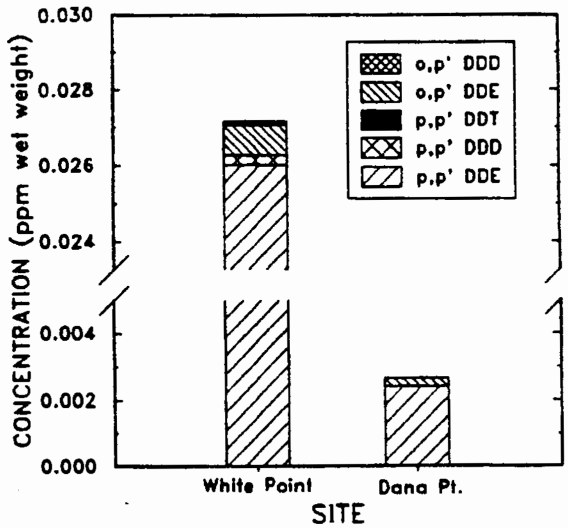


Figure 12-4. Mean concentrations of total DDT in composites of muscle tissue of yellow rock crab (*cancer anthonyi*) collected from White Point and Dana Point, 1990 (SCCWRP *et al.* 1992).

Organic Compounds. Levels of DDT and PCBs in mussels collected from the Palos Verdes Peninsula have declined substantially since 1971 (Figure 12-8). In 1982-83, concentrations of PCBs and DDT were only about 12% and 7%, respectively, of the concentrations measured in 1971. Concentrations of both contaminants from mussels collected in 1990 (CSWRCB unpubl. data) were similar to those in 1982-1983 (Ladd *et al.* 1984). Thus, PCB and DDE levels in Palos Verdes mussels have remained fairly constant since about 1977.

The decrease in DDT and PCB levels at Palos Verdes is also evident in yellow rock crab body burden levels. Heesen and McDermott (1974) showed widespread DDT contamination of yellow crab muscle in 1971 and 1972. Total DDT concentrations were highest in crabs from the Palos Verdes Shelf, ranging from 500 to 2,100 ppb in edible tissue (Heesen and McDermott 1974). In 1990, mean DDT levels in yellow rock crab taken from White Point averaged 31 ppb (SCCWRP 1992). Thus, it appears that DDT levels in crabs from the Palos Verdes Peninsula have greatly decreased in the last 15 or 20 years.

PCB contamination of crabs was much more uniform throughout the Bay in the early 1970s. The overall range was 400 to 1,900 ppb PCBs in 1972, with maximum concentrations in crabs from central Santa Monica Bay near the HTP 5-mi outfall (Heesen and McDermott 1974). By 1990,

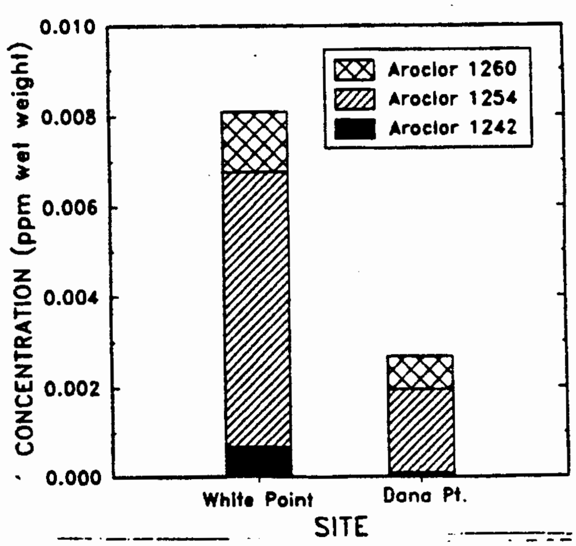


Figure 12-5. Mean concentrations of total PCB (Aroclors 1242 + 1245 + 1262) in composites of muscle tissue of yellow rock crab (*Cancer anthonyi*) collected from White Point and Dana Point, 1990 (SCCWRP *et al.* 1992).

PCB levels had decreased greatly, with a mean value of 9.1 ppb in yellow rock crab taken at White Point (SCCWRP 1992).

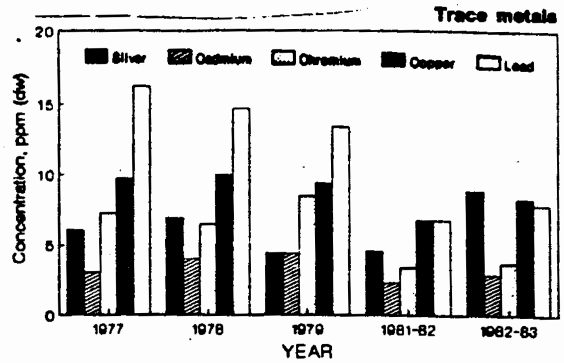


Figure 12-6. Temporal variation in concentrations of trace metals in resident mussels at Royal Palms State Beach on the Palos Verdes Peninsula, 1977-1983 (Stephenson *et al.* 1979, Ladd *et al.* 1984).

In 1986-1987, SCCWRP (1992) found that concentrations of PCBs in shrimp hepatopancreas from the contaminated areas near HTP's 7-mi outfall were high compared to levels in animals from the reference site (Figure 12-9). PCB levels decreased in shrimp from the impacted area in 1987, and by 1990 levels were similar to those of the reference site (Figure 12-9). This trend correlates well with levels of PCBs in the sediments in the study area (SCCWRP 1990). Although the data are somewhat variable, it appears that sludge abatement in 1987 eliminated, or at least decreased, a potentially large source of PCBs to Santa Monica Bay, which subsequently reduced PCB uptake in shrimp near the 7-mi outfall.

In contrast to PCB levels, the concentration of DDT in ridgeback rock shrimp hepatopancreas did not decrease from 1986 to 1990 (Figure 12-10) (SCCWRP 1992). However, with the exception of 1988, DDT levels from 1986 through 1990 remained below 1,000 ppb in animals taken near the outfall terminus. These values are much lower than those collected in 1983-1985, when hepatopancreas levels were greater than 10,000 ppb (Brown *et al.* 1986, Thompson *et al.* 1987a). The high DDT values in 1988 are difficult to explain, but higher values at the reference site suggest that previously contaminated sediments may be periodically exposed through tectonic activity or storms, or that sources other than the 7-mi outfall are present, such as urban runoff through local storm drains.

FISHES

Studies of fish contamination in Santa Monica Bay have emphasized contaminants in edible muscle and liver tissue. The edible muscle tissue is important because it represents the contaminants that could be passed on to humans. However, liver body-burden levels are indicative of the total range of contaminants entering the fish because of the role the liver plays in regulation and storage of toxic chemicals (Fowler 1982). Consideration of contaminants in both edible muscle and liver tissue can therefore provide an assessment of the potential human health impacts as well as the health of fishes.

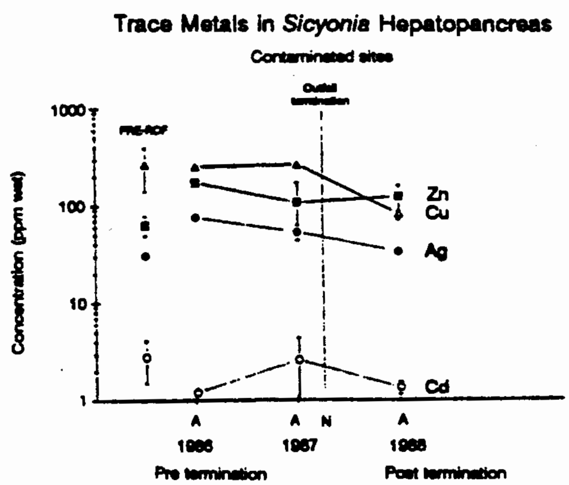


Figure 12-7. Concentrations of trace metals in hepatopancreas of ridgeback rock shrimp (*Sicyonia Ingentis*) from contaminated sites near the HTP seven mile outfall, 1986-1988 (SCCWRP 1992).

Demersal fishes are preferred as indicators of contamination because they live in close contact with bottom sediments, often feed on benthic organisms, and are not generally migratory. Contaminants in fishes with these characteristics can be related to localized sources with confidence.

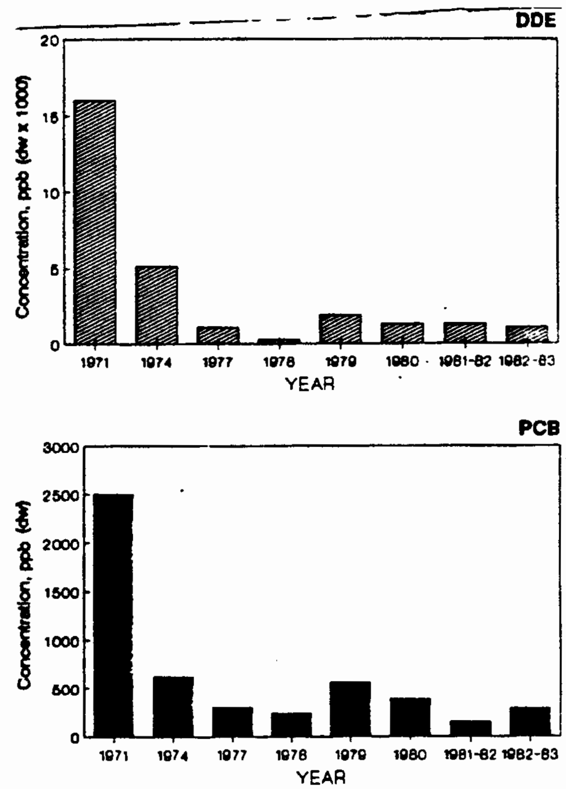


Figure 12-8. Temporal variation in concentrations of DDE and PCB in resident mussels at Royal Palms State Beach on the Palos Verdes Peninsula, 1971-1983 (Stephenson *et al.* 1980, Ladd *et al.* 1984).

SPATIAL PATTERNS

Metals. In general, metals concentrations in edible muscle and liver tissue in fishes from Santa Monica Bay have not been elevated substantially above the levels observed in fishes from reference areas such as the Santa Barbara Channel, Santa Catalina Island, Point Dume, and Dana Point (DeGoeij *et al.* 1974, McDermott *et al.* 1976, Sherwood *et al.* 1978, Young *et al.* 1978, Young *et al.* 1980, Jenkins *et al.* 1982, Brown *et al.* 1986). Brown *et al.* (1986) and Thompson (unpubl. data) found that liver concentrations of copper, cadmium, and zinc were frequently lower in fish near the HTP and JWPCP outfalls than in fish from a number of relatively uncontaminated reference areas along the California coast (Figure 12-11). The low levels near the outfalls may result from reduced availability of the metals as a result of complexing with organic sewage material or from the inhibitory effects of organic contaminants on the retention of metals.

Organic Compounds. Most studies of organic compounds in fishes from Santa Monica Bay have dealt with PCBs and DDTs in muscle and liver tissue, although a few have considered other organic contaminants, primarily EPA priority pollutants (Young and Heesen 1977; Gossett *et al.* 1982, Gossett *et al.* 1983a, b; Malins *et al.* 1987). An early (1971 to 1972) study of DDT in Santa Monica Bay in Dover sole (Young *et al.* 1976a) found that concentrations of DDT were highest near the JWPCP (White Point) outfalls and rapidly declined both upcoast and downcoast from that location (Figure 12-12). Values in Santa Monica Bay were two to 36 times higher than the value observed at Point Dume. A similar pattern was also seen for DDT levels in livers of several demersal species in 1982 and 1985 (Brown *et al.* 1986, Thompson *et al.* 1987a). These studies show the DDT accumulated in the 1960s and 1970s into the Palos Verdes sediments continues to bioaccumulate in the tissues of fishes that inhabit the area.

The distribution of PCBs in Santa Monica Bay fishes is also usually highest at Palos Verdes, but fishes from other areas in the Bay often contain elevated levels. In 1982 and 1985, Brown *et al.* (1986) and Thompson *et al.* (1987a) found that liver concentrations of PCBs were highest near the JWPCP and HTP outfalls in four demersal fishes: Pacific sanddab, California scorpionfish, yellowchin sculpin, and longspine combfish. Although values generally declined both upcoast and downcoast from these two locations, unusually high concentrations in Pacific sanddab were found at Point Dume and Imperial Beach. Concentrations in Pacific sanddab from Santa Monica Bay ranged from 0.4 to 1.4 times the value at Point Dume. Concentrations in California scorpionfish from Santa Monica Bay ranged fromthree to four times the value at Dana Point. The more uniform distribution pattern of PCBs in the Bay reflects the numerous sources of this contaminant.

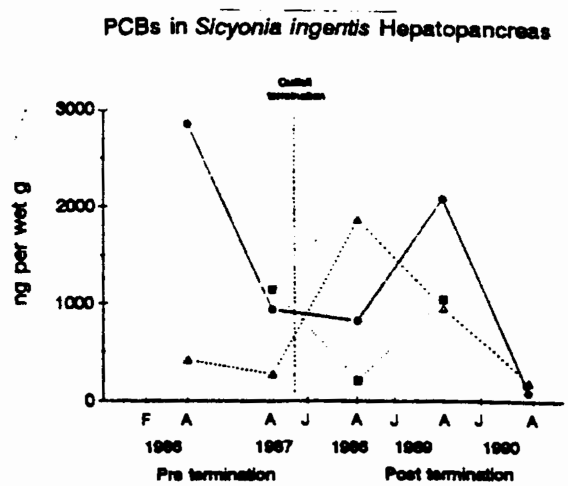


Figure 12-9. Concentrations of PCB in hepatopancreas of ridgeback rock shrimp (*Sicyonia Ingentis*) from contaminated (circles), transition (squares), and reference (triangles) sites near the HTP 7-mile outfall, 1986-1988 (SCCWRP 1992).

In 1991, the Office of Environmental Health Hazard Assessment (OEHHA) and the Department of Health Services (DHS) conducted a comprehensive study of chemical contaminants in fishes collected in southern California (Pollock *et al.* 1991). This report provides an excellent database for examining the distribution of contaminants in local fishes. Several fish species from twelve sites in Santa Monica Bay were included in this study. DDT and PCB levels in fish caught at stations in Santa Monica Bay and at Dana Point (reference) were examined for Pacific bonito, chub mackerel, California halibut, kelp bass, California scorpionfish, several species of surfperches, queenfish, and white croaker (Table 12-1).

The distribution and concentrations of contaminants in the fishes examined depends on the mobility, feeding habits, and metabolism of individual species (Table 12-1). For instance, Pacific bonito and chub mackerel are biologically similar in that they are pelagic fishes that migrate over a large area of the ocean (Eschmeyer *et al.* 1983). DDT and PCB levels are low in Pacific bonito and chub mackerel from all sites and it does not appear that contaminant concentrations in these fishes are site specific (Pollock *et al.* 1991). Kelp bass had high DDT levels at White Point and slightly high levels at Palos Verdes-Northwest, but levels were low in kelp bass caught throughout the rest of Santa Monica Bay. California halibut is a demersal ambusher (Allen 1982) that might be expected to have high contaminant levels due to its close contact with sediments and its trophic position. However, DDT levels were very low in California halibut at all sites where it was collected, possibly reflecting the consistently low lipid concentra-

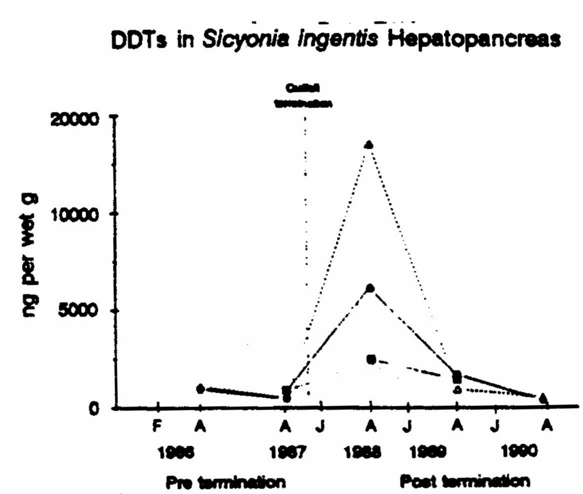


Figure 12-10. Concentrations of DDT in hepatopancreas of ridgeback rock shrimp (*Sicyonia Ingentis*) from contaminated (circles), transition (squares), and reference (triangles) sites near the HTP 7-mile outfall, 1986-1988 (SCCWRP 1992)

tions found in this species (Pollock *et al.* 1991) or because adults primarily feed on pelagic, non-resident northern anchovy (Allen 1982). California scorpionfish and the surfperches had elevated DDT levels at most stations on the Palos Verdes Peninsula, but levels generally were low throughout Santa Monica Bay.

The most elevated DDT levels were found in queenfish and white croaker (Table 12-1) (Pollock *et al.* 1991). Site-specific DDT levels for both species were almost always the highest levels found for all fishes analyzed. Similar to other species with elevated contaminant levels, the highest DDT concentrations in white croaker and queenfish were found at stations on the Palos Verdes Peninsula. White croaker from Point Vicente and White Point had the highest DDT levels of any fishes in the study area, with mean concentrations of 2,641 and 2,099 ppb, respectively. In addition to high DDT levels in fishes from Palos Verdes, contaminated white croaker and queenfish were also found in northern Santa Monica Bay at Point Dume, Malibu Pier, Malibu, and Santa Monica Pier.

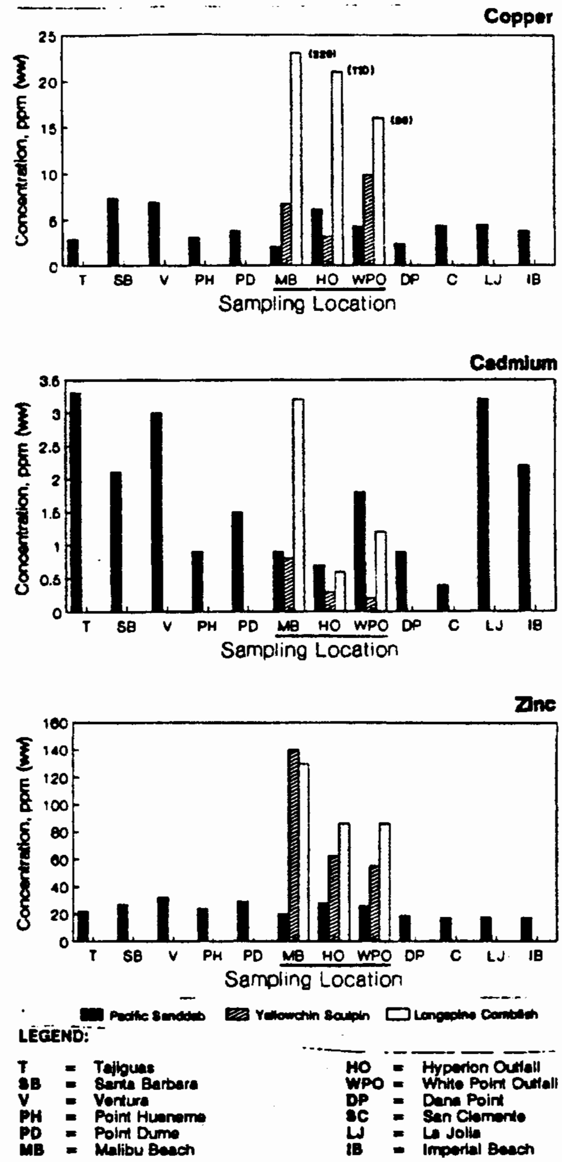


Figure 12-11. Regional variation in concentrations of selected metals in the livers of Pacific sanddab (*Citharichthys sordidus*), yellowchin sculpin (*Icelinus quadriseriatus*), and longspine combfish (*Zaniolepis latipinnis*) from the Southern California Bight, 1982-1985 (Brown *et al.* 1986, Thompson unpubl. data).

PCB levels in fishes analyzed by Pollock *et al.* (1991) were low for most species (Table 12-1). However, PCB levels in queenfish and white croaker were markedly elevated compared to the other fishes analyzed. Levels were particularly high in queenfish from Malibu Pier and in white croaker from Point Dume and Malibu and from Point Vicente and White Point. The HTP and JWPCP outfalls are the most likely sources of PCBs in northern Santa Monica Bay and Palos Verdes, respectively, but the more uniform distribution of PCBs (compared to DDT) in fishes throughout the Bay suggests that there are probably several sources of this contaminant.

It should be mentioned that the levels of chlordane were very low in most fishes throughout the study area (Pollock *et al.* 1991). Only white croaker, surfperches, California corbina, and queenfish had total chlordane levels above the method detection limit.

In 1992, the SMBRP conducted a study on the contamination of seafood in Santa Monica Bay (SCCWRP *et al.* 1992). Although not a risk assessment, the study was designed to provide information for management decisions regarding subsistence, recreational, and commercial fisheries in the area. White croaker was most extensively analyzed because of the historically high levels of chlorinated hydrocarbons found in this species (Table 12-1) and because it is one of the most commonly caught seafood species in Santa Monica Bay (Wine 1979). White croaker were collected from 11 sites along the southern California coast in September 1990 and tissue composites were analyzed for lead, selenium, and several chlorinated hydrocarbons including PCBs, DDT, and chlordane.

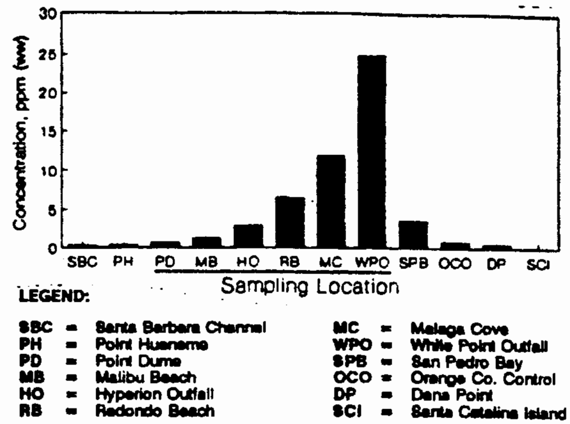


Figure 12-12. Regional variation in concentrations of total DDT in muscle tissue of Dover sole (*Microstomus pacificus*) from the Southern California Bight, 1970-1971 (Young *et al.* 1976b).

The distribution of PCBs in white croaker tissue (Figure 12-13) (SCCWRP *et al.* 1992) suggest that the most heavily contaminated area in 1990 was off the Palos Verdes Peninsula. At all three Palos Verdes stations (Palos Verdes North, South, and White Point), the mean concentration of total PCBs was two to three times higher than at any other station in Santa Monica Bay and more than 30 times higher than the Dana Point reference site. This is similar to the DDT distribution pattern in white croaker tissue in which DDT levels in fish collected from the Palos Verdes sites were as much as 85 times higher than those collected from Santa Monica Bay. Thus, in 1990 the distribution of PCBs and DDT in white croaker were highly elevated in fish taken from Palos Verdes, but in contrast to the 1987 survey (Pollock *et al.* 1991) contaminant levels were not elevated in white croaker from northern Santa Monica Bay. Both these studies confirmed the results of Young *et al.* (1976a) and Gossett *et al.* (1983b), that the JWPCP outfall area is the primary source of DDT and PCB contamination in fishes in the Southern California Bight.

TEMPORAL TRENDS

Metals. The temporal distribution of metals in Santa Monica Bay fishes has not been extensively studied, and long term trends are available for only a few species. One of the best surveys in recent years was conducted by SCCWRP (1992) for Dover sole near the HTP outfall to study the effects of sludge abatement in 1987. Concentrations of zinc, copper, cadmium, and silver were all low at "contaminated" sites near the outfall from 1986 through 1988 and only silver concentration decreased following sludge abatement (Figure 12-14). The concentrations of all metals analyzed in Dover sole were equal to or less than the southern California average of the mainland shelf (SCCWRP 1992).

Organic Compounds. In general, the concentrations of DDT and PCBs in the muscle tissue of fishes collected in Santa Monica Bay and off the Palos Verdes Peninsula have decreased over the last 20 years (McDermott-Ehrlich *et al.* 1977, 1978; Sherwood *et al.* 1978; Smokler *et al.* 1979; LACSD 1988; Young *et al.* 1988b; Pollock *et al.* 1991; SCCWRP *et al.* 1992). Because of the historically high levels of these contaminants found in white croaker, and because of the extensive database that exists for this species, the temporal changes in DDT and PCB levels in white croaker are outlined below.

Between 1980 and 1990, DDT levels in white croaker from Santa Monica Bay have decreased or remained relatively constant, with the highest levels measured in 1981 from fish taken at Malibu (Figure 12-15) (SCCWRP *et al.* 1992). However, off the Palos Verdes Shelf, DDT levels have been consistently the highest of anywhere in the Southern California Bight (NOAA 1991b). Since the discharge of DDT was terminated in 1971-1972, the concentration of this contaminant in sediments surrounding the JWPCP outfall has declined (NOAA 1991a). The change in DDT levels in Palos Verdes sediments is reflected by the bioaccumulation in white croaker. For instance, in 1971, the mean DDT concentration in white croaker from the Palos Verdes Shelf averaged 39,000 ppb (Young *et al.* 1978), but had decreased to 7,629 ppb by 1980 (Schafer *et al.* 1984). There was no apparent change in DDT levels between 1981 and 1987 (Pollock *et al.* 1991). In 1990, DDT levels from white croaker collected at three sites on the Palos Verdes Peninsula averaged 11,580 ppb (Pollock *et al.* 1991), which was a significant increase from 1987 levels. This increase may have resulted from shifting sediments off the Palos Verdes Shelf, which could have exposed old reservoirs of DDT or possibly to differences in the biological condition of the fish at the time of

Species	Point Dume	Malibu Pier	Malibu	Santa Monica Pier	Venice Beach	Marina Del Rey	Redondo Pier	Redondo Beach	NW Palos Verdes	Point Vicente	White Point	Dana Point
DDT												
Pacific bonito	25	48	30	21	24	11	21	43	18	32	31	5
Chub mackerel	7	10	19	7	12	18	12	9	14	26	19	5
kelp bass	14	nd	16	nd	24	16	nd	nd	44	32	126	23
California scorpionfish	14	nd	nd	nd	9	8	11	12	33	41	154	nd
California halibut	4	16	7	7	nd	7	nd	8	nd	nd	nd	10
surfperches	14	9	nd	nd	nd	40	35	42	70	45	29	7
queenfish	114	191	164	139	93	37	90	43	95	70	141	62
white croaker	201	27	506	74	44	54	nd	nd	253	2641	2099	6
PCBs												
Pacific bonito	11	15	19	11	9	5	5	17	8	13	14	2
Chub mackerel	3	10	2	3	3	9	3	0	6	13	9	4
kelp bass	9	nd	5	nd	11	2	nd	nd	20	9	14	nd
California scorpionfish	7	nd	nd	nd	3	1	8	2	10	2	41	nd
California halibut	2	0	2	0	nd	0	nd	2	nd	nd	nd	5
surfperches	9	3	nd	nd	nd	10	20	21	16	17	29	0
queenfish	25	294	38	10	34	16	11	15	14	19	24	17
white croaker	236	23	757	64	53	45	nd	nd	61	498	252	1

nd = No data

Table 12-1 Geometric mean concentrations of total DDT and PCB (ppb wet weight) in edible tissue of several fish species in 1987 at sites throughout Southern California (complied from Pollock *et al.* 1991).

analysis. Since PCBs and DDT tend to accumulate in the fatty tissue, differences in reproductive condition or annual migrations of white croaker may have contributed to the apparent increase from 1987 to 1990, but it is unlikely that there has been any "new" source of DDT to the area.

PCB levels in white croaker from Malibu and Point Dume have decreased since 1987, which may reflect the termination of sludge disposal from the HTP outfall in 1987 (SCCWRP 1992). However, PCB levels in white croaker at other locations throughout Santa Monica Bay have changed little since 1981. On the Palos Verdes Shelf, PCB levels decreased markedly in white croaker tissue from 1975, when the average concentration was 2,780 ppb (Young *et al.* 1978), to 1980 when tissue levels averaged 383 ppb (Figure 12-16) (Schafer *et al.* 1982). These results reflect the decrease of PCB in Palos Verdes sediments (NOAA 1991a). In 1987, PCB levels in white croaker muscle (Pollock *et al.* 1991) were similar to

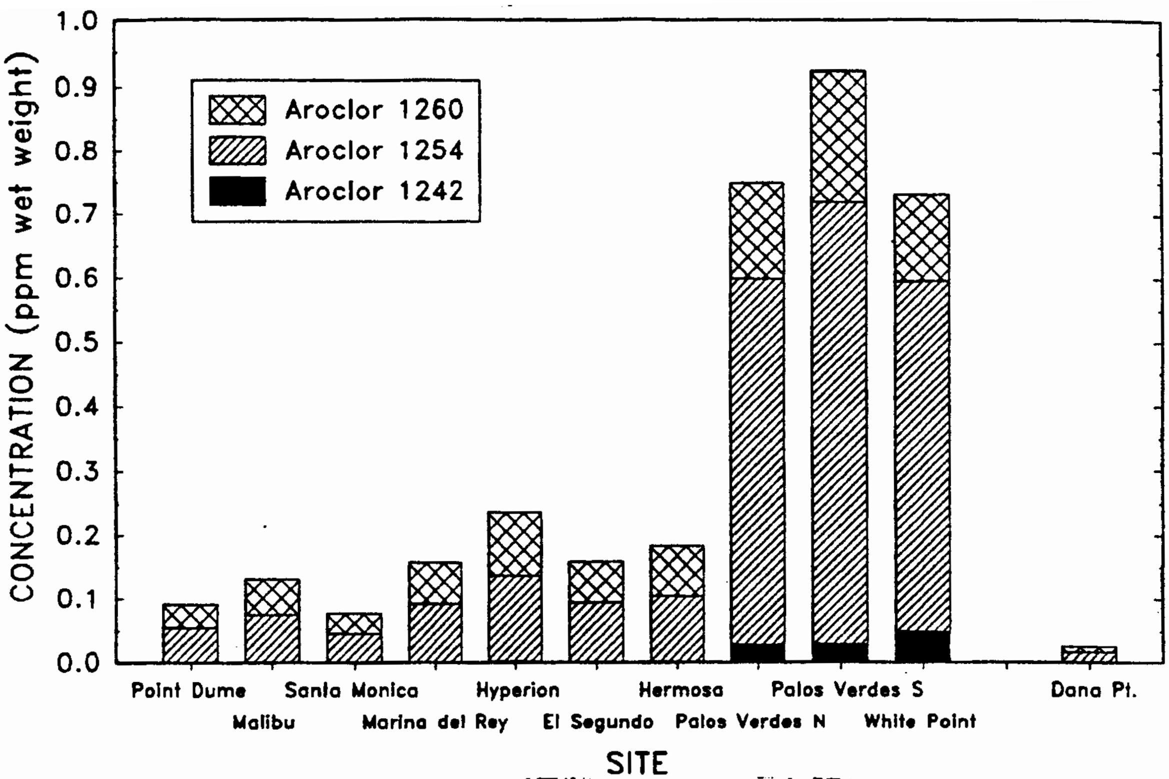


Figure 12-13. Mean concentrations of total PCB (Aroclors 1242 + 1245 + 1262) in composites of muscle tissue to white croaker (Genyonemus lineatus) collected from coastal sites in Southern California, 1990 (SCCWRP *et al.* 1992).

those in 1980, but by 1990 levels at several locations had increased to approximately 1,500 ppb (SCCWRP *et al.* 1992). The apparent increase in white croaker PCB levels from 1987 through 1990 may have been due to seasonal differences in lipid content of white croaker or perhaps to the shifting of sediments on the Palos Verdes Shelf, which may have exposed old beds of the contaminant. The fact that PCB levels have not decreased since the early 1980s reflects the persistence of this contaminant over time and suggests that the Palos Verdes sediments act as a source.

SEAFOOD CONSUMPTION

Because of the persistence of contaminants in some fishes caught in Santa Monica Bay and the Palos Verdes Shelf, and because of the growing public concern over the consumption of seafood from the area, the SMBRP funded a seafood consumption study, which was conducted in 1991 and 1992 (MBC in prep.) to determine the amount and type of seafood that is being eaten from the Bay. The last seafood consumption study of Santa Monica Bay was conducted in 1980 (Puffer *et al.* 1981, 1982). However, since that time the health risks of consuming seafood from the Bay may have changed due to changes in seafood availability, species preference, and ethnic composition of the fishing population.

RECREATIONAL FISH CATCH

In the 1992 study (MBC in prep.), surveyors identified 72 seafood species that were caught by recreational anglers during the summers of 1991 and 1992. The species caught in greatest abundance were chub mackerel, barred sand bass, kelp bass, white croaker, and Pacific barracuda. Chub mackerel was the most abundant fish caught from piers, private boats, and party boats, accounting for 51.9, 24.0, and 23.3% of the total catch, respectively. Of the fish caught from piers, white croaker was the second most abundant species, accounting for

18.2% of the total catch, followed by jacksmelt, and surf-perches. Barred sand bass was the second most abundant species caught from party boats, accounting for 20.2% of the total, followed by kelp bass (16.4%) and Pacific barracuda (13.2%). Of the species caught from private boats, white croaker was the second most abundant species (16.6%) followed by barred sand bass (8.8%), kelp bass (8.5%), and Pacific barracuda (5.9%). Many fewer species were caught by beach anglers, but of these, sea mussels and Pacific purple urchin together accounted for nearly 90% of the total catch.

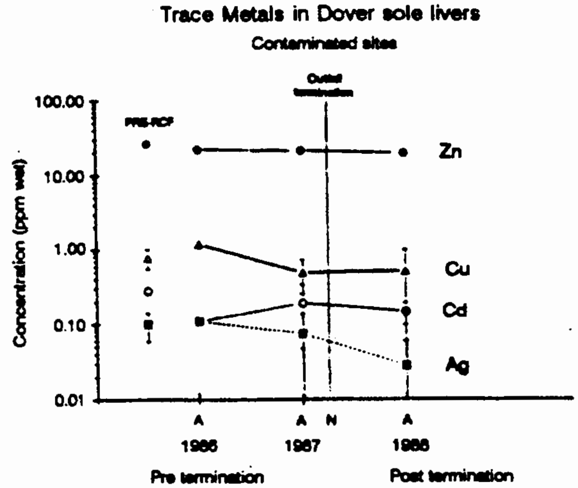


Figure 12-14. Concentrations of trace metals in liver tissue of Dover sole (Microstomus pacificus) from contaminated sites near the HTP 7-mile outfall, 1986-1988 (SCCWRP 1992).

DEMOGRAPHIC PROFILE OF SANTA MONICA BAY ANGLERS

The demographic profile of the anglers that catch and consume seafood species from the Bay is used to determine the relative risks of different ethnic groups of eating contaminated seafood. In 1980, Puffer *et al.* (1981, 1982) found that the anglers in the Los Angeles area consisted mainly of caucasians (42%), followed by blacks (24%), Mexican-Americans (16%), Oriental/Samoans (13%), and "others" (5%). Of these 88% were male, primarily

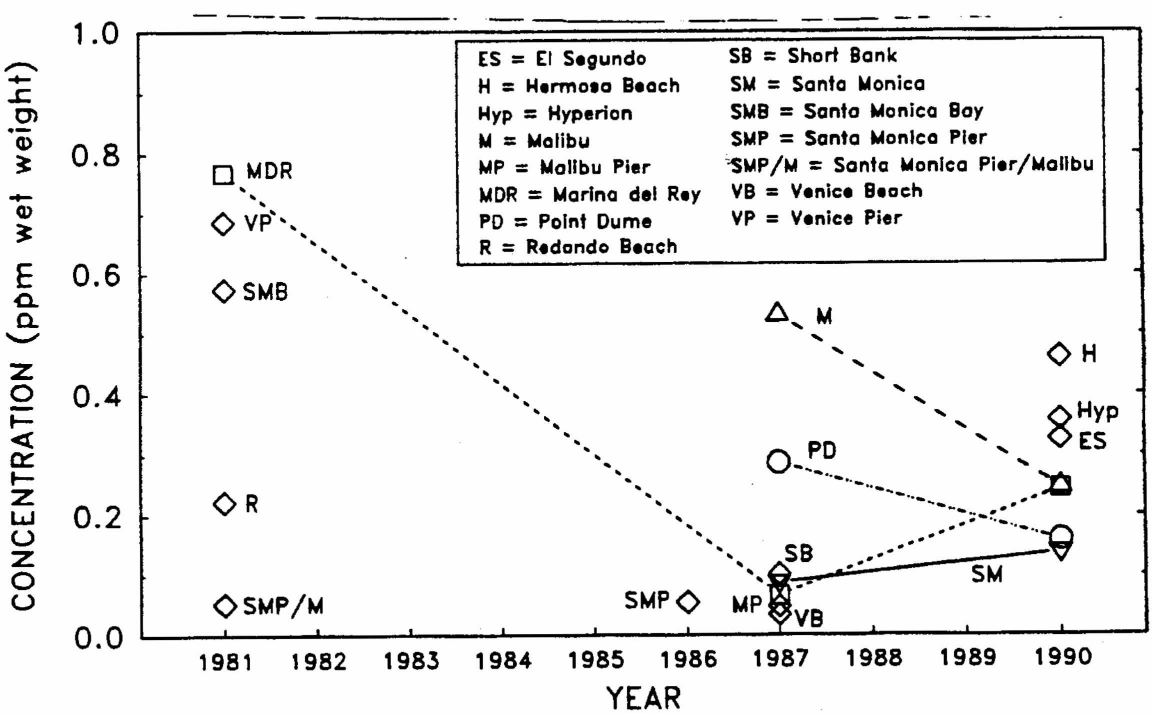


Figure 12-15. Mean concentrations of total DDT in muscle tissue of white croaker (*Genyonemus lineatus*) collected from Santa Monica Bay, 1981-1990 (data from Gossett *et al.* 1983, Risebrough 1987, Pollock *et al.* 1991, SCCWRP *et al.* 1992).

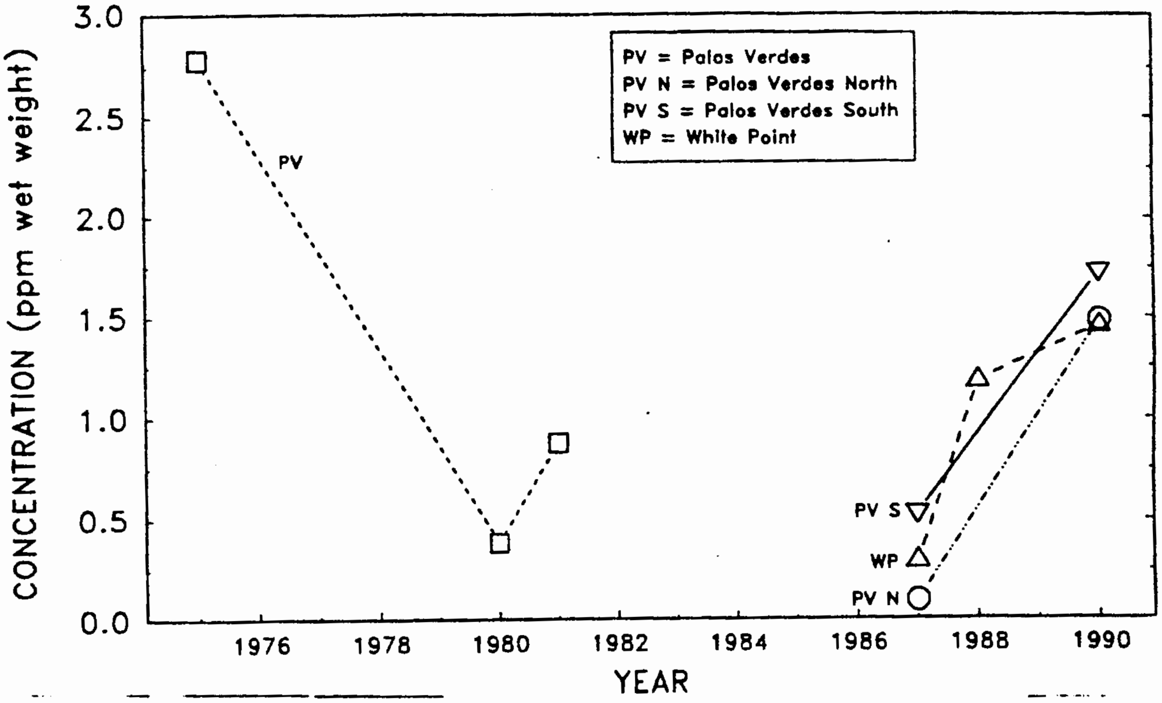


Figure 12-16. Mean concentrations of total PCB in muscle tissue of white croaker (*Genyonemus lineatus*) collected from Palos Verdes Shelf, 1975-1990 (data from Young *et al.* 1978a, Schafer *et al.* 1984, Gossett *et al.* 1983, Risebrough 1987, Pollock *et al.* 1991, SCCWRP *et al.* 1992.

between the ages of 18 and 40. Similar to 1980, the majority (44%) of the anglers in 1991 and 1992 were white. However, the second most abundant anglers were hispanic (25%), followed by blacks (10%); Filipinos, Koreans, Chinese, Vietnamese, and "others" each accounted for less than 7% of the total fishing population in the Bay. In 1991 and 1992, 86% of the anglers were male and most were between the ages of 25 and 45.

SEAFOOD CONSUMPTION RATES

The health risks of consuming contaminated seafood from the Bay depends on the frequency and magnitude of food consumed and on the level of contaminants present in the consumed species. In 1980, seafood consumption study, Puffer *et al.* (1981) found that, of the species caught by recreational anglers, California halibut, Pacific bonito, chub mackerel (listed as Pacific mackerel in Puffer *et al.* 1991, 1982), and opaleye were consumed the most. On average, anglers consumed 4.3, 1.9, 1.1, and 0.5 kg/person/month, respectively. White croaker was the fifth most abundantly consumed species, with anglers consuming an average of 0.4 kg of white croaker per person per month (Puffer *et al.* 1981).

The surveys conducted in 1991 and 1992 (MBC in prep.) suggest that the consumption habits of recreational anglers that fish in the Santa Monica Bay area have changed little in the last ten years and that the differences that do exist probably reflect species availability. In 1991 and 1992, the species that anglers consumed the most were chub mackerel, Pacific barracuda, barred sand bass, and Pacific bonito. The "other" group, which consisted of Middle Easterners, Samoans, and Cambodians had the highest consumption rates, followed by Filipinos and whites; Koreans consumed the most white croaker.

Warnings Effect	Black	Korean	Filipino	Vietnamese	Chinese	Hispanic	Japanese	White	Other	Total
	Racial/Ethnic Category									
Total "No"	52	10	20	2	12	97	25	214	12	457
Total "Yes"	43	14	36	5	9	78	34	243	6	468
Eat Less of All Fish	16	4	11	2	1	22	8	50	1	115
Eat Less of Some Fish	3	3	3	1	1	8	1	29	0	49
Stopped Eating All Fish	8	0	6	0	1	14	6	51	1	87
Stopped Eating Some Fish	16	7	16	2	6	34	19	113	4	217
Total	95	24	56	7	21	175	59	457	18	925

Table 12-2. Responses of recreational anglers to seafood consumption warnings posted in Santa Monica Bay, 1991-1992 (MBC in prep).

Health Warning Awareness. To determine the effectiveness of health warnings posted by the Department of Health Services concerning the consumption of fish from Santa Monica Bay, recreational anglers in Santa Monica Bay were asked whether they were aware of the health warnings, and if so, what effect have they had on seafood consumption (MBC in prep.). Of the 925 individuals questioned in the 1991 and 1992 surveys, nearly 50% said that they were not aware of the health warnings (Table 12-2). Of the anglers that were aware of the warnings (468 individuals), 46% (217 individuals) said they had stopped eating some fish, 25% (115 individuals) said they ate less of all fish, 19% (87 individuals) said they stopped eating all fish, and 10% (49 individuals) said they ate less of some fish.

RISK ASSESSMENT

APPROACH

The first step in the risk assessment process is to define toxic hazards posed by the chemical contaminants in selected seafoods of Santa Monica Bay. The hazard and dose-response assessments result in the choice of the critical health effects on which to base the subsequent steps in the risk analysis. For example, the health effect of concern may be selected because it is the most severe adverse effect identified in the hazard assessment. Because cancer is a severe disease that may be initiated by relatively low levels of exposure to toxic chemicals, it is usually the health effect chosen for evaluating risks of any potentially cancer-causing chemical.

CONTAMINANTS OF CONCERN

Information on concentrations of toxic chemicals in tissues of invertebrates and fishes of Santa Monica Bay was presented in previous chapters. The contaminants of greatest concern relative to potential human health effects are DDT and PCBs. These contaminants exhibit the following characteristics (MBC 1988):

- High persistence in the aquatic environment
- High bioaccumulation potential
- Suspected as potential cause of cancer in humans based on mammalian bioassays
- Known sources of contaminant within Santa Monica Bay
- High concentrations in previous samples of both fish and invertebrates from various locations within the Bay.

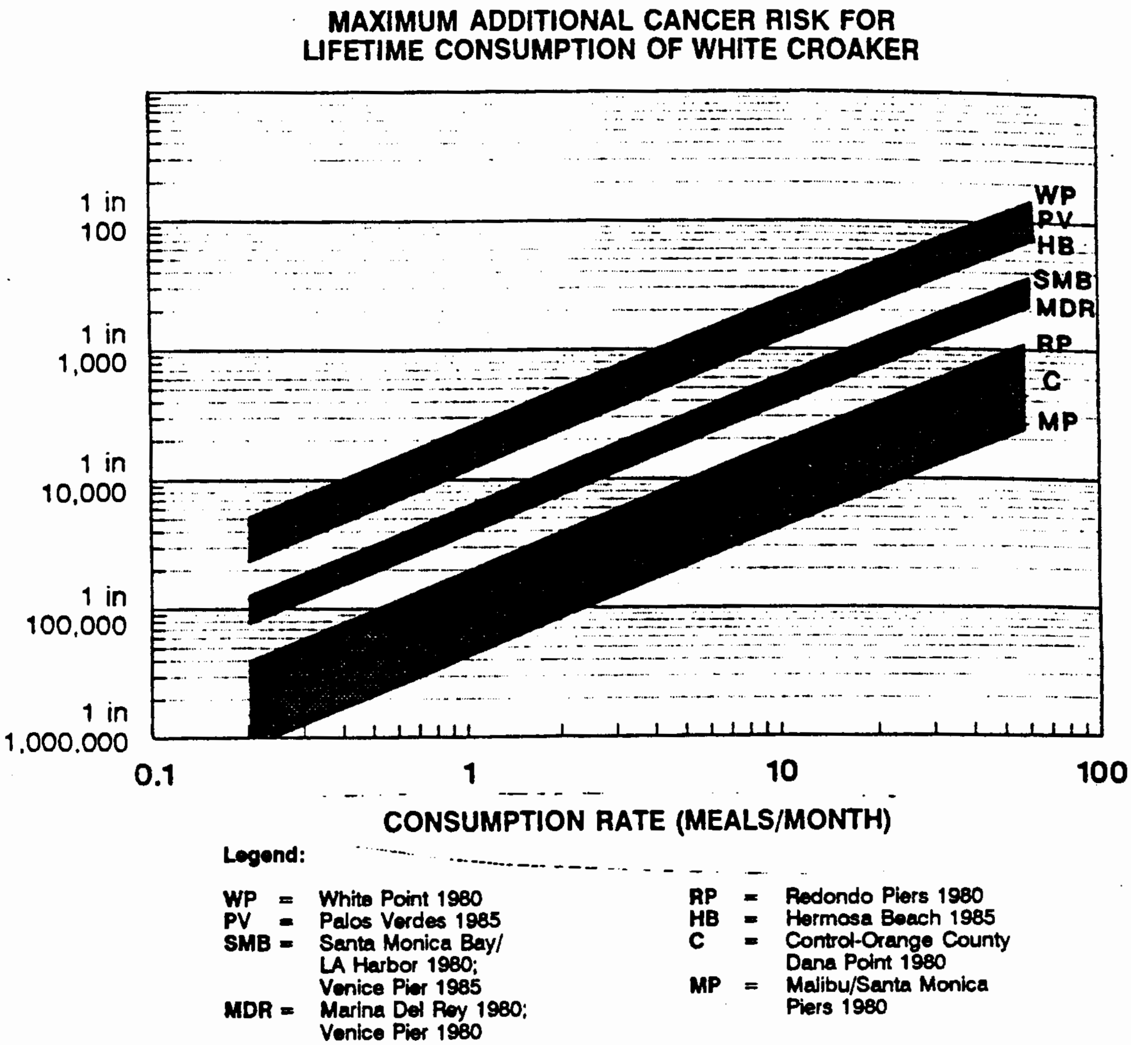


Figure 12-17. Upper-limit estimates of lifetime cancer risk (based on average lifetime of 70 years) from total DDT plus total PCB in white croaker (*Genyonemus lineatus*) from Southern California. One meal - 0.25 lb = 114 g (MBC 1988).

Based on the data presented earlier, concentrations of metals in samples of fish muscle tissue from Santa Monica Bay are not sufficiently high to pose a problem. Chlordane and selected metals (lead, silver, cadmium, chromium, and mercury) in shellfish may pose a human health hazard, but data for edible tissues of harvested species are very limited. Therefore, subsequent steps in this risk assessment focus on PCBs and DDT (and related compounds).

CHEMICAL INTAKE FROM SEAFOOD CONSUMPTION

Because the seafood consumption study of Santa Monica Bay (MBC in prep.) has not yet been completed and because catch/consumption patterns undoubtedly vary over time, precise estimates of exposure to contaminated seafood have not yet been made. However, two studies (MBC 1988, Pollock *et al.* 1991) have analyzed the potential risks of eating seafood from Santa Monica Bay. In MBC (1988), a range of estimates of consumption was used to derive a range of contaminant doses for each of the selected seafood species and geographic locations. Risk estimates presented in a later section are related to a range of consumption values.

The calculated doses of total DDT and total PCBs from consumption of contaminated seafood correspond to selected consumption rates as follows (MBC 1988): a low estimate equal to the national average consumption of estuarine fish and shellfish (6.5 g/d = about 2 meals/mo), the 90th percentile value for each species (85.2 g/d = 22 meals/mo for white croaker, 334 g/d = 88 meals/mo for Pacific bonito; Puffer *et al.* 1981, 1982), and the 90th percentile value for all species combined (225 g/d = 59 meals/mo). The average serving of fish was assumed to be 0.25 lb (= 114 g). These consumption values were selected only for illustration purposes, and to develop the relationships between risk and consumption presented below. Estimates of average per capita consumption of fish and shellfish by the U.S.population generally range from 6.5 to 20.4g/day (Pastorok 1988). Most estimates include fish and shellfish (mollusks and crustaceans) in marine, estuarine, and fresh waters, but marine species form the bulk of consumed items. Most estimates also include commercially harvested fisheries products. Also, estimates of average U.S. consumption do not account for subpopulations in coastal areas that may consume large quantities (>20 g/day) of locally caught fish or shellfish.

RISK CHARACTERIZATION

Estimates of excess cancer risk associated with long-term consumption of seafood from Santa Monica Bay (MBC 1988) were derived from estimates of toxic potencies for the selected contaminants (i.e., PCBs, total DDT) and chemical intake by sport fish consumers. It should be noted that consumption of fish and shellfish (including commercial products) is the major route of exposure of humans to PCBs (USFDA 1984, Humphrey 1987). In contrast, exposure of humans to DDT and related compounds occurs through a variety of foods and, in some subpopulations (e.g., farmers, pesticide applicators), through use of pesticides. When interpreting the risk estimates presented below, remember that they represent approximate (order of magnitude) estimates of a plausible upper limit to lifetime cancer risk for the specific chemicals and exposure conditions (i.e., a selected seafood species, harvest location, and consumption rate). The real health risks may be much lower than those shown. Because an individual's chance of having cancer is influenced by factors other than PCB and DDT exposure via seafood consumption (e.g., cigarette smoking, hereditary factors), the risk estimates presented below represent additional risks associated only with the exposure route of concern (i.e., ingestion of seafood from Santa Monica Bay).

CANCER RISK ESTIMATES

The potential upper-limit risks of cancer associated with consuming selected seafood species from some areas of Santa Monica Bay (MBC 1988) are shown in Figures 12-17 and 12-18. Actual cancer risks are unknown and may be much lower than the levels indicated in the figure. The plausible-upper-limit risk is shown as a function of consumption rate to illustrate the relative importance of consumption rate and to allow evaluation of risks based on various consumption rates. Each shaded area in the figure is based on the range of total concentration of PCBs and DDT (including DDD and DDE) in muscle tissue for the species and locations noted. Data on contaminant concentrations in edible fish tissue were available for several locations (Figures 12-17 and 12-18), including frequently used fishing piers and several offshore areas in Santa Monica Bay; a party boat fishery; the Palos Verdes Peninsula (PV); trawl transects T-3 and T-5 within three miles of the JWPCP outfall sampled by Los Angeles County Sanitation District; and the JWPCP outfall area (WP), which may not normally be used by recreational anglers. Each shaded area (Figures 12-17 and 12-18) represents information for two or more locations with the same general range of risk (i.e., high, medium, or low). A separate line is not shown for each location because the risk estimates are not precise and individual replicate data to test for statistical differences among areas were not available.

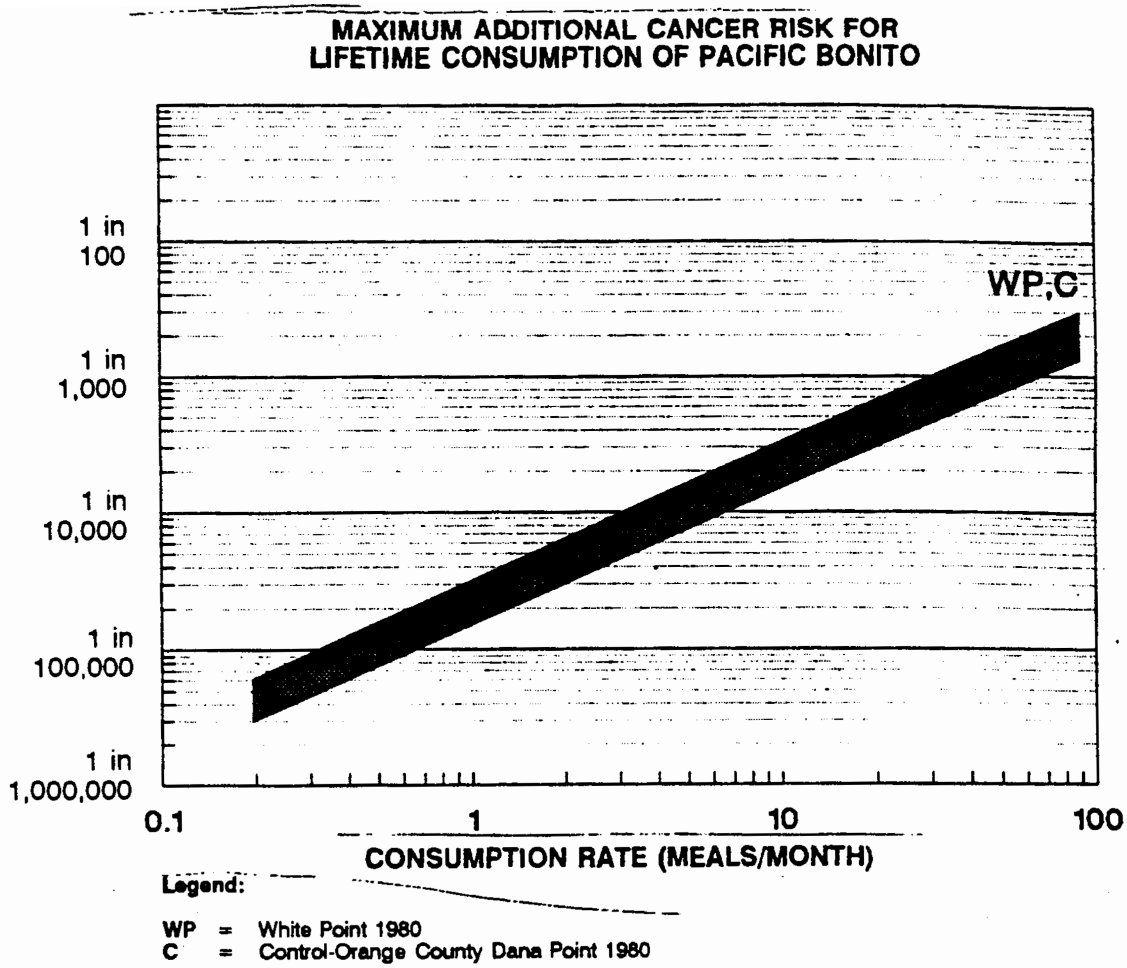
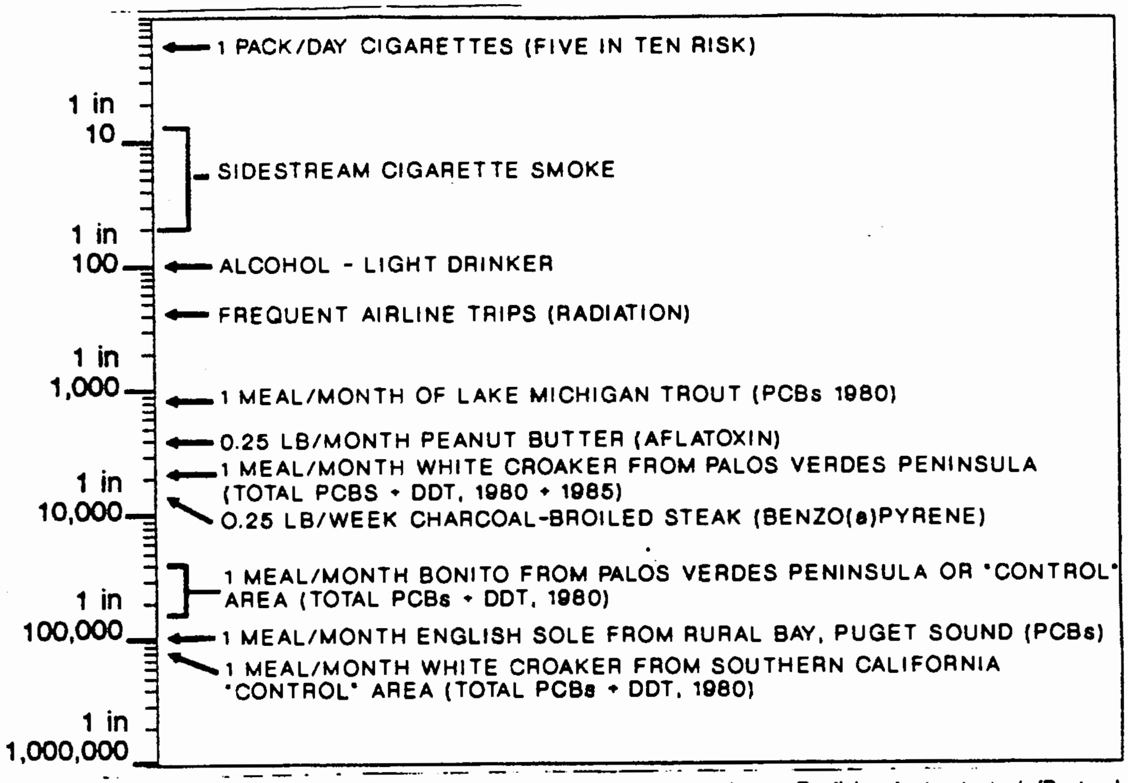


Figure 12-18. Upper-limit estimates of lifetime cancer risk (based on an average lifetime of 70 years) from total DDT plus total PCB in Pacific bonito (*Sarda chiliensis*) from Southern California. One meal = 0.25 lb = 114 g (MBC 1988).

To interpret Figures 12-17 and 12-18, choose a consumption level (on the horizontal axis) that corresponds to the average frequency of the seafood species in the diet. The consumption rate is the average consumption rate for a 70-year lifetime, but exposures for less than 70 years can easily be calculated. For example, if it is assumed that the seafood of interest is eaten once per month (i.e., one 0.25-lb serving per month) for only seven years, then the average lifetime (70 years) consumption rate is one-tenth (seven divided by 70) the short-term rate, or 0.025 lb/month. Find the region of the shaded area for the fishing location of interest that corresponds to the consumption rate selected. Then read the range of risk estimates (on the vertical axis) that corresponds to the selected consumption rate and harvest area. Comparisons with health risks from other foods and common activities can be made using Figure 12-19 (also refer to the section, Comparison of Santa Monica Seafood Risks with Other Risks).

Based on the risk analysis by PTI in MBC (1988), consumption of seafood from the JWPCP outfall area and the surrounding areas of the Palos Verdes Peninsula poses the greatest risk of cancer from total DDT and PCBs combined. Total DDT accounted for more than about 35% of the total cancer risk associated with total DDT and PCBs in white croaker at only the Palos Verdes Peninsula area. Consumption of white croaker from areas offshore of Hermosa Beach also posed a relatively high risk. Cancer risks associated with consuming white



All risk estimates were taken from Wilson and Crouch (1987) except: peanut butter, English sole, trout, steak (Pastorok *et al.* 1986); sidestream cigarette smoke (Papanek 1988, pers. comm.); white croaker and bonito (present study).

Average annual risk estimates from Wilson and Crouch (1987) were multiplied times the uncertainty factor given by the authors to convert them to upper-limit estimates and by a factor of 70 years to convert them to lifetime risks. Data were not available to calculate cancer risk estimates associated with swimming in Santa Monica Bay.

Figure 12-19. Upper-limit estimates of lifetime cancer risk (based on an average lifetime of 70 years) for various activities (MBC 1988).

croaker from offshore Santa Monica Bay (Figure 12-17) were moderate relative to other study areas; nevertheless, they were about the same as risks associated with the consumption of white croaker representing the average contamination at six Los Angeles Harbor sites combined [including party boat samples analyzed by Gossett *et al.* (1983a)]. Marina del Rey and the Venice and Redondo Piers also presented moderate risk levels relative to other areas. The lowest risk levels for croaker occurred at the Malibu/Santa Monica Piers, which exhibited risk estimates slightly lower than the control areas at Orange County and Dana Point.

The relative risk of consuming Santa Monica Bay seafood as estimated by PTI in MBC (1988) is similar to that estimated by Pollock *et al.* (1991). For instance, Pollock *et al.* (1991) estimated that the excess lifetime risk of consuming white croaker from White Point was one in 1,000 (1.0 x 10-3), which is the same as that estimated by MBC 1988 (Figure 12-17). However, the two risk assessments cannot be compared directly because of differences in PCB and DDT contaminant levels, the PCB carcinogenic potency factors, and theoretical seafood consumption rates.

The Pollock *et al.* (1991) study included many more species and locations than the MBC, 1988, study. Pollock *et al.* (1991) developed site and species-specific recommendations for seafood consumed from several areas in Santa Monica Bay and the Palos Verdes Shelf (Table 12-3). The existing fish consumption advisory published in the California Department and Fish and Game's sportfishing regulations is based on these recommenda-

Site	Species	Recommendation*
Santa Monica Pier Venice Pier Marina Del Rey Redondo Beach Dana Point	All species	No restrictions
Redondo Pier	California corbina	One meal every two weeks
Malibu Pier	queenfish	One meal a month
Short Bank	white croaker	One meal every two weeks
Point Dume Malibu Point Vicente Palos Verdes-Northwest	white croaker	Do not consume
White Point	white croaker	Do not consume
	California scorpionfish rockfishes kelp bass	One meal every two weeks+

* One meal is about six ounces (170 g).
\+ Consumption recommendation is for all the listed species combined.

Table 12-3 Site-specific seafood consumption recommendations for several locations in Santa Monica Bay, based on 1987 contaminant levels (Pollock *et al.* 1991).

tions. More species-specific recommendations for the most frequently caught and consumed fishes in the area (are shown in Table 12-4); recommendations were based on contaminant levels in fishes collected in 1987 (Pollock *et al.* 1991), where one meal consists of six oz (170 g) of fish. The recommendations are meant to provide guidance to anglers as an indication of how often to fish in an area and how often to eat a specific fish species caught at a site (Pollock *et al.* 1991).

SUMMARY OF ASSUMPTIONS AND UNCERTAINTIES

Faced with the many uncertainties and assumptions in risk assessment, an estimate of the plausible upper-limit to cancer risk was derived above to evaluate potential human health effects related to consumption of contaminated fish. A similar approach is commonly used by EPA and other agencies as the basis for environmental regulations. This ensures that health risks will not be underestimated. Although the absolute risk may often be overestimated by as much as 1,000 times (or even 10,000 times in some circumstances), the plausible-upper-limit approach is appropriate to ensure adequate protection of human health. Assumptions inherent in this risk assessment are summarized in MBC (1988).

Because of the differences in habitat, feeding habits, and trophic position, white croaker and Pacific bonito were selected in MBC (1988) to represent a wide range in assessing the health risks associated with consuming seafood from the Bay. White croaker are probably more indicative of specific areas of the Bay because of their limited movements and benthic feeding habits. In contrast, Pacific bonito are highly mobile species. Consequently, major differences in contamination of white croaker among areas are found, whereas little spatial variation in contamination of Pacific bonito is expected.

In the analyses on which Figures 12-17, 12-18, and 12-19 were based, the effect of cookingon contaminant concentrations was not taken into account. The effect of cooking on the ultimate health risk from amixture of chemicals (including any transformation or degradation products produced by heating) is not completely understood. Some studies have shown decreases in concentrations of lipid-soluble organic compounds such as DDT and PCBs following pan-frying, broiling, or baking of fish fillets (Smith *et al.* 1973, Skea *et al.* 1981, Puffer and Gossett 1983).

RISK GROUP / Species	Recommendation*
HIGH	
white croaker	Avoid consumption
MODERATE	
California corbina	Consume not more than one meal every two weeks
queenfish	
surfperches	
California scorpionfish	
LOW	
black croaker	Consumption not restricted
barred sand bass	
rockfishes	
kelp bass	
LOWEST	
Pacific bonito	Consumption not restricted
chub mackerel	
Pacific sanddab	
Pacific barracuda	
opaleye	
halfmoon	
California halibut	

* One meal is about six ounces (170 g).

Table 12-4. Species-specific seafood consumption recommendations for several fish species of Santa Monica Bay, based on 1987 contaminant levels (Pollock *et al.* 1991).

Because of the limitations of risk assessment, emphasis should be placed on relative risk comparisons. For example, comparisons among fishing areas are valuable for developing perspectives for environmental advisories such as guidance on choices of fishing location and target species by individual anglers. Statistical differences in PCB and DDT concentrations in fish tissue among fishing areas were demonstrated by Gossett *et al.* (1983a) and Pollock *et al.* (1991). Nevertheless, caution should be exercised in interpreting upper-limit risk estimates presented in Figures 12-17 and 12-18. Contaminant concentration differences on the order of those between Hermosa Beach and the JWPCP outfall area or between the Redondo Piers and the offshore Santa Monica Bay station are likely to be nonsignificant. Thus, risk estimates for these pairs of areas (and other pairs of areas differing by a similar magnitude of contamination) in Figure 12-17 should be considered as roughly equal.

COMPARISON OF SANTA MONICA BAY SEAFOOD RISK WITH OTHER RISKS

Are Santa Monica Bay seafoods hazardous to your health? Although this question is on the minds of many scientists, environmental managers, and anglers, it is impossible to provide a simple answer. The answer to this question depends on five factors: 1) the location of interest (e.g., outer bay vs. the outfall areas vs. fishing piers), 2) the species of interest (open-water species vs. bottom species), 3) the chemicals responsible for contamination, 4) seafood consumption rate, and 5) the risk level considered "acceptable" or tolerable by an agency or the individual consumer. Despite our best efforts, society will never achieve a world of "zero-risk," especially relative to food quality (e.g., see Ames 1983).

Despite the limitations of risk assessment, the data are adequate to support the conclusion that significant risks of potential health effects may result from relatively high consumption of bottomfish and lipid-rich species harvested from certain locations within the study area (MBC, 1988; Pollock *et al.*1991). Concentrations of total DDT and PCBs in fish from within the study area are clearly elevated above "background" concentrations at control sites.

To aid interpretation of the risk estimates presented above, health risks from consumption of other foods and from other common activities are presented in Figure 12-19 [based mainly on data in Pastorok *et al.* (1986) and Wilson and Crouch (1987)]. Against a background of an average lifetime risk on the order of two to three in ten (20 to 30%) per individual for all cancers from all causes, an additional lifetime cancer risk of one in a million or less is generally considered tolerable by environmental regulatory agencies (Travis *et al.* 1987). An additional lifetime cancer risk above about one in a thousand is generally considered unacceptable. Risk levels on the order of one in ten thousand to one in one-hundred thousand have often led to development of environmental regulations on chemical releases and exposure of humans. Regulatory decisions regarding contamination of food products have sometimes been based on risk levels up to one in 1,000 to one in 100.

Although the potential health risks of eating fish from Santa Monica Bay are high in some cases (Table 12-4), other foods and activities may pose substantial risks (greater than one in 1,000). Considering that the usable protein content of Santa Monica Bay fish, steak, and peanut butter are roughly similar, substitution of the latter two protein sources for locally harvested fish may not substantially reduce cancer risk.

SUMMARY, STATUS AND TRENDS

13

CHAPTER 13
SUMMARY, STATUS AND TRENDS

The information presented in Chapters 1 through 12 describes in detail the sources of contamination to and the nature of developments in the study area; the distribution of contaminants over space and time; and the actual impacts which are known or suspected to have resulted from the contamination, development, and use of Santa Monica Bay.

This chapter emphasizes the major trends of concern and those issues which have given rise to the Action Plan Elements being developed by the Santa Monica Bay Restoration Project (Table 13-1). Like the body of the report, this chapter includes three major topics (sources, distribution, and impacts of contamination) which are arranged in that order. The sources of contaminants will be addressed by Action Plan Elements IA, IB, and ID of Table 13-1. These elements deal with mass emissions, pollution prevention, and municipal and industrial discharges.

POINT SOURCES

Point sources relate primarily to Action Plan Element ID of Table 13-1, Municipal and Industrial Discharges. Seven facilities operate point sources of contamination to Santa Monica Bay under NPDES permits. These facilities represent potential impacts to the Bay.

GENERATING STATIONS

The three generating stations use seawater to cool condensers, discharging it back to the Bay at somewhat elevated temperatures. Redondo, Scattergood, and El Segundo Generating Stations have all been operating for more than 20 years. No long-term, widespread impacts have been attributed to their thermal waste, individually or collectively. The small amounts of contaminants which originate in the plant are generally well below the NPDES-permitted limitations and do not constitute a threat to the local biota.

Each year a seemingly large number of plankton (one to two billion) are entrained into the cooling water flow, where they are usually assumed to suffer in excess of 99% mortality. However, despite the large numbers, there is no indication that these losses have affected the local population size even though individual units at the plants have been operating for 20 to 40 years. White croaker generally suffer the greatest entrainment losses and yet they are also among the most abundant offshore species.

Adult fishes are also impinged and killed on protective screens across the intake conduit. These losses, as much as 78,000 individuals per year at El Segundo, also seem high; but the most commonly impinged species - queenfish - is also among the most common species offshore; thus no population-level impact can be ascribed to the stations.

OIL REFINERY

Chevron USA operates an NPDES-permitted ocean outfall from its El Segundo refinery which discharges an average of about eight million gallons of wastewater to the Bay each day. Chevron's on-site treatment facility became operational in the 1970s and has been upgraded several times since then. At present operational wastes are fully treated before being discharged; storm runoff is treated in oil/water separators with induced air flotation units.

The most abundant constituents in the present effluent are COD, BOD, and TSS, with annual mass emissions of about 1,800, 125, and 100 MT, respectively. The effluent has only exceeded permitted limitations on three occasions in the last seven years. At present the wastewater outfall discharges in about 20 feet of water, less than 200 feet from shore. However, Chevron is in the process of relocating the outfall to a point 3,500 feet from shore in approximately 60 feet of water.

Action Plan Element
I. REDUCE SOURCES OF POLLUTION
A. Mass Emission Policy
B. Pollution Prevention Program
C. Comprehensive Stormwater/Urban Runoff Management Program
D. Municipal and Industrial Discharge
E. Prevention and Response to Oil and Hazardous Materials Spills
F. Remediate Contaminated Sediments
II. PROTECT THE PUBLIC FROM HEALTH RISKS ASSOCIATED WITH SWIMMING AND CONSUMING SEAFOOD FROM THE BAY
A. Ensure that Bay Seafood is Safe to Consume
B. Reduce Human Health Risks Associated with Swimming in Bay Waters
III. RESTORE, PROTECT AND MANAGE HABITATS AND WATERSHEDS
A. Marine Ecosystem
B. Wetlands
C. Beaches and Intertidal Zones
D. Watersheds

Table 13-1. Draft Action Plan Elements of the Comprehensive Conservation and Management Plan for Santa Monica Bay.

WASTEWATER TREATMENT PLANTS

Hyperion Treatment Plant (HTP) and Joint Water Pollution Control Plant (JWPCP) are among the four largest municipal wastewater treatment plants in southern California; both discharge treated domestic and industrial sewage to the study area. In the past these discharges were unquestionably the major point sources of contamination to Santa Monica Bay. However, effluent concentrations and mass emissions from both facilities have declined significantly since the early 1970s, following the creation of the USEPA and enactment of the Clean Water Act.

HYPERION TREATMENT PLAN

HTP treats wastewater from most of the City of Los Angeles' 3.5 million persons and tens of thousands of businesses and industries.

The flow from HTP's 5-mi outfall has generally increased over the years, from about 200 million gallons per day (mgd) in 1950 to over 400 mgd in 1983. However, the flow has declined steadily since 1983, to just under 300 mgd in 1992 (Figure 13-1). Between 1974 and 1987, (when it was discontinued) an average of 4.4 mgd of mixed secondary effluent and digested sewage sludge was discharged to the head of Santa Monica Submarine Canyon through HTP's 7-mi outfall.

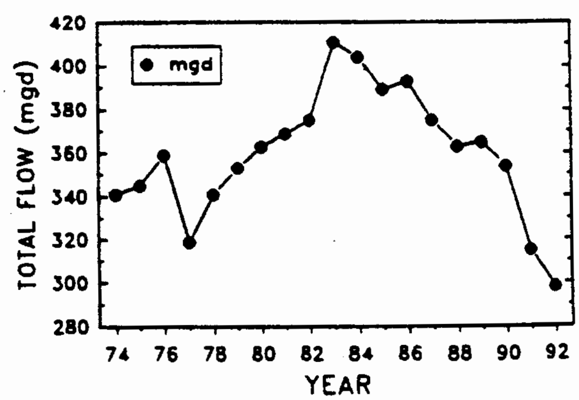


Figure 13-1. Average flow from the HTP 5-mile outfall, 1974-1992. (Data from Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; CLA,DPW 1987, 1988, 1989, 1990, 1991, 1992).

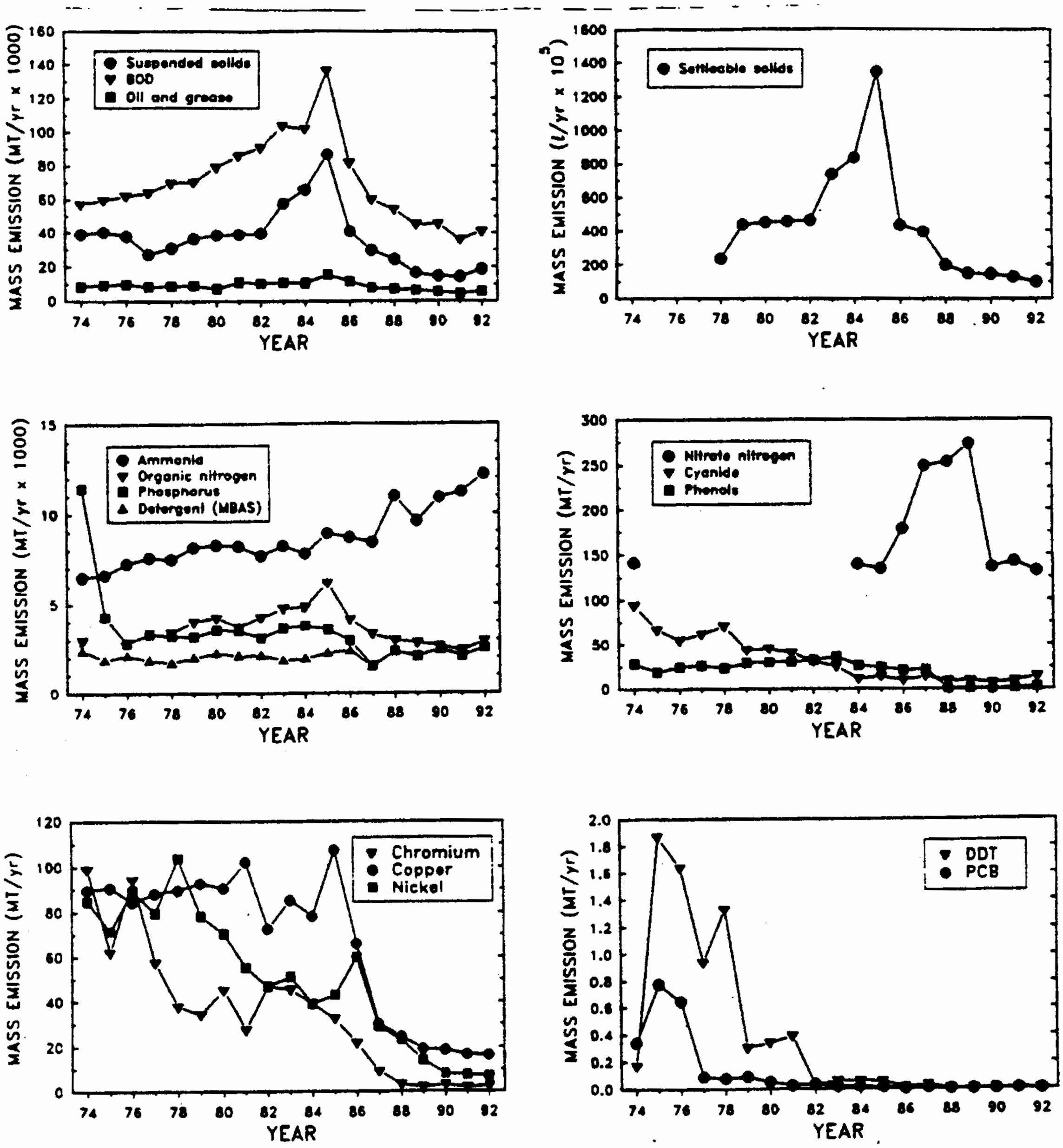


Figure 13-2. Annual mass emission rates of selected contaminants discharged from HTP 5-mile outfall from 1974-1992. (Data from Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; CLA, DPW 1987, 1988, 1989, 1990, 1991, 1992).

Mass emissions of organic matter (suspended solids, BOD, and settleable solids) through the 5-mi outfall also increased steadily through the mid-1980s, peaked in 1985 and have declined since then (Figure 13-2). The mass emission of BOD, for example, was about 140,000 metric tons (MT) in 1985 but has been below 50,000 MT since 1988.

Mass emissions of nutrients were relatively stable from the mid-1970s to the mid-1980s, at which time they decreased sightly (Figure 13-2). The increase in ammonia is attributed to treatment improvements, digestion which converts nitrates to ammonia.

Mass emissions of most trace metals declined between 1974 and 1986, although the annual variability was great (Figure 13-2). Since 1988, mass emissions have been consistently low, in some cases not detectable.

The mass emissions of DDT and PCBs declined dramatically in the late 1970s, displaying a three to five year lag behind legislative source control which limited their use and manufacture (Figure 13-2). Mass emissions have been very low (sometimes undetected) since 1982.

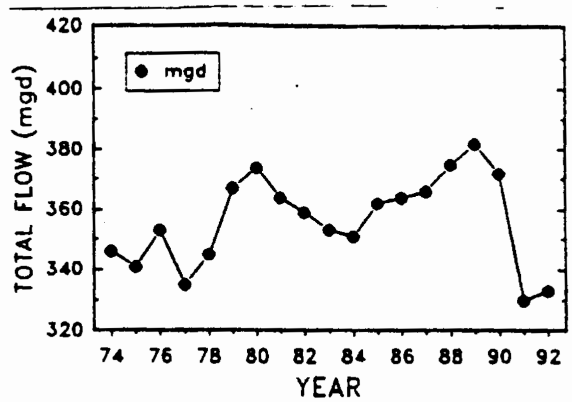


Figure 13-3. Average flow from JWPCP outfall, 1974-1992. (Data from Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982

The general decline in the mass emissions of most contaminants between 1974 and 1986-87 reflect source control of various sorts; the dramatic decreases in 1987-1988 coincide with better solids removal (suspended and settleable solids) to which the contaminants bind.

JOINT WATER POLLUTION CONTROL PLANT

JWPCP treats wastewater from a population of about five million people and 70,000 businesses and industries, including most of Los Angeles county which is not serviced by HTP.

Flow from JWPCP to the Palos Verdes Shelf generally increased from about 340 mgd in the mid-1970s to about 370 mgd in the late 1980s (Figure 13-3). In 1991 and 1992, the flow declined and averaged 330 mgd.

Mass emissions of organic matter (suspended solids, BOD, and settleable solids) from JWPCP decreased steadily from 1974 to 1982, exhibited a spike in 1983 during construction, declined greatly in 1984, and continued to decline gradually from 1984 to 1990. Mass emissions increased slightly in 1991 and 1992 (Figure 13-4).

Mass emissions of ammonia remained almost unchanged from 1974 to 1992, whereas organic nitrogen and phosphorus declined steadily from the mid-1970s to 1985, and have been stable since then (Figure 13-4).

Mass emissions of most trace metals declined steadily between 1974 and the late 1980s. There are indications that the mass emission rates have reached a plateau (Figure 13-4).

The mass emissions of DDT from JWPCP decreased 80% between 1974 and 1975, reflecting a lag with respect to the cessation of its disposal to the treatment system in 1971 (Figure 13-4). DDT levels have been very low since 1985 and often are not detected. The mass emissions of PCBs declined steadily between 1974 and 1985; PCBs have been undetected since 1986.

The very gradual, but steady, decline in mass emissions of most contaminants from JWPCP in the last 20 years reflect better source control as well as improved treatment technology, especially solids removal.

TAPIA WATER RECLAMATION FACILITY (TWRF)

TWRF provides primary, secondary, and tertiary treatment for as much as 10 mgd. Sludge is treated by aerobic digestion and either pumped to land-injection farms, or dewatered and disposed at land-fills.

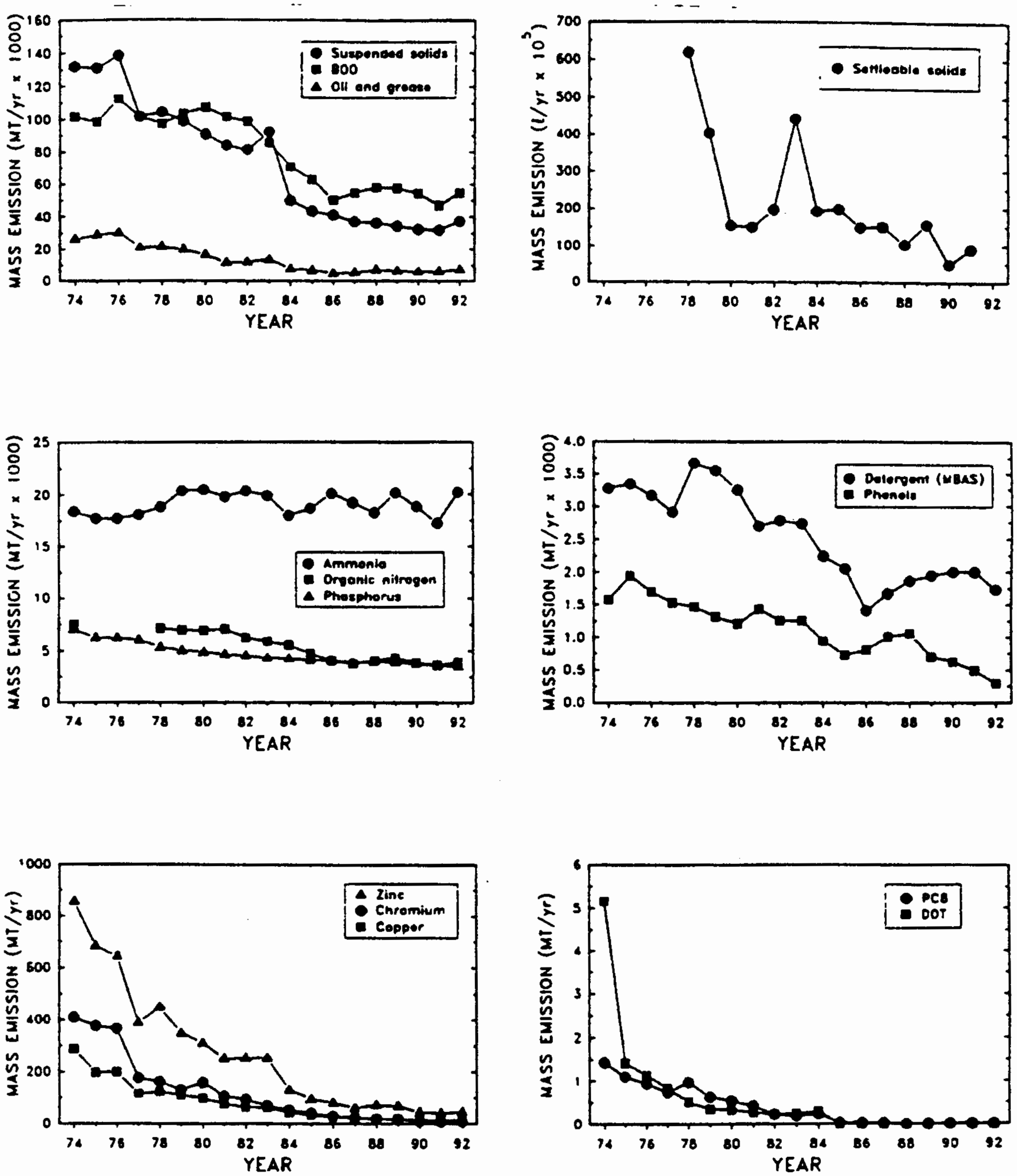


Figure 13-4. Annual mass emission rates of selected contaminants from JWPCP outfall 1974-1992. (Data from Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; Stull 1988 pers. comm.; Horvath 1992 pers. comm.).

TWRF's NPDES permit allows only tertiary-treated and completely pathogen-free wastewater to be discharged to Malibu Creek. The flow to Malibu Creek has averaged 2.7 mgd since 1974 and 2.5 mgd over the last five years.

NONPOINT SOURCES OF CONTAMINANTS

Nonpoint sources relate primarily to Action Plan Element I-A and I-B of Table 13-1, mass emission and pollution prevention measures. Nonpoint sources of contamination are, by definition, diffuse, unpredictable, and difficult to quantify. In the past runoff was strictly considered a nonpoint source, However, recent legislation now treats storm drains as point sources in the sense that they require NPDES permits. Although effluent does enter the receiving waters at a single point, they will always be nonpoint in the sense that contaminants enter the storm drain in a diffuse, irregular, and unpredictable (i.e. nonpoint) manner.

MARINE VESSEL ACTIVITIES

Contaminants which enter the waters of Santa Monica Bay through the operation of marine vessels includes oil and refined petroleum products; antifouling paint additives (zinc, chromium, copper, mercury, arsenic, PCBs, and tributyl tin); trace metals from sacrificial anodes; lead from leaded marine fuel; PAHs from the combustion of fuel; and human enteric wastes.

The most remarkable fact about this potential contamination is that it is nonpoint and virtually impossible to quantify. Except for the enteric bacteria which result from illegal discharges of holding tanks or toilets, most derive from normal operation of the source vessels. Stricter enforcement of regulations will help reduce the input, as will careful evaluation of the use and effects of specific substances. Thus, TBT was banned from use on small vessels which are moored in confined marinas for long periods of time. TBT is still being released as old paint is scraped or sloughed off, but new sources are not being added.

OIL & HAZARDOUS MATERIALS SPILLS

This section relates directly to Action Plan Element IE, prevention of and response to oil and hazardous waste spills to Santa Monica Bay. Because there are no large, commercial ports and few large commercial vessels in the study area, the risk of oil spills from tankers or ruptured fuel tanks in the study area is relatively low.

Spills are required to be reported to the US Coast Guard, which recorded an average of 6 spills per year from 1973 to 1987. These totaled less than 2,000 gallons, and were primarily fuel oil and crude oil. The largest spill in that period of time was 1,000 gallons of crude oil from a tanker offshore El Segundo and most of it was recovered. In 1991, approximately 9,000 gallons of diesel-based cutting oil spilled from a ruptured pipeline off El Segundo; some of this product reached shore in Malibu, although no serious impacts were reported.

For comparison, it has been estimated that an average of about ten barrels (420 gal) of oil from natural submarine oil seeps off Redondo Beach and Manhattan Beach reach the surface each day. Additional amounts do not reach the surface, either deteriorating or forming tarballs.

In 1990, the Lempert/Keene/Seastrand Oil Act (SB2040) was passed. Among other things the Act established an Oil Spill Prevention and Response (OSPR) group within the California Department of Fish and Game. OSPR is now engaged in establishing baseline data and enforcing development of contingency plans by every oil facility, transporter, and vessel in State waters.

DREDGING & DUMPSITES

The dumping of unwanted and hazardous waste materials at sea has been largely prohibited since 1972, although some illegal activities have taken place since then. However, none of the 15 formerly permitted dumpsites in Southern California is in the study area. It is virtually impossible to estimate what kinds and amounts of materials have accumulated on-bottom, much less what fraction may some day be resuspended or dissolved and enter the ecosystem.

At present dredged materials from Los Angeles and Long Beach Harbors are dumped at a permitted site (LA-2) which is just outside the study area. From 1978 to 1988, an average of about 180,000 cubic yards per year of dredged material was disposed of at LA-2. LA-2 was recently re-opened for use, but no contaminated materials will be permitted to be dumped. Theoretically materials from LA-2 could move into Santa Monica Bay, but no estimates have been made of this potential.

AERIAL FALLOUT

Aerial fallout is probably the most diffuse contaminant source and the most difficult to quantify. Studies in the 1960s and 1970s, indicated that the mass emissions of lead, mercury, and manganese from aerial fallout might exceed those from point sources. However, only a few studies of aerial fallout have been conducted locally in the last 15 years.

Knowledge of the emission rates in aerial fallout is academic, however, since the only way to regulate aerial fallout is by the application of source control measures at the site(s) where the contaminants enter the atmosphere. The levels of lead in aerial fallout undoubtedly decreased after the use of leaded gasoline was restricted, just as the mass emissions of DDT to Santa Monica Bay decreased after DDT process wastes were no longer disposed of at landfills on Palos Verdes Peninsula.

STORM & URBAN RUNOFF

Material in this section relates to Action Plan Element IC of Table 13-1, comprehensive stormwater and urban runoff management program. Unlike some metropolitan areas, the City and County of Los Angeles have separate sewage and storm drain systems. The sewage system is too small to handle the uncommon, but sometimes torrential rains, although storm runoff does infiltrate and overload the sewage system on occasion. Overflows of sewage caused by storm runoff may result in raw, untreated sewage entering Santa Monica Bay through storm drains.

Legislation now treats storm drains as point sources (the effluent does enter at a single point), but they will always be nonpoint in the sense that contaminants enter the storm drain in a diffuse, irregular, and unpredictable (nonpoint) manner. Thus, until the flow in major storm drains is retained and treated, there is no effective way to control contaminant levels except by upstream source control — i.e., policing all sites where contaminants enter the drainage.

The kinds and amounts of contamination in storm/urban run-off to Santa Monica Bay were estimated for the major drainages in 1983, 1984, and 1989 (Table 13-2). However, it is not possible to accurately extrapolate the results of just a few surveys (usually conducted during periods of high runoff) to the many small drains and various flow conditions which prevail through the year and study area.

Above all else, these studies confirm that many contaminants remain high in storm/urban runoff. Thus, as wastewater treatment becomes more effective and mass emissions decrease, the relative contribution of contaminants via runoff have become greater, even though the absolute amounts have not increased.

Storm/urban runoff is somewhat unique in that it contributes indicator bacteria to the nearshore of Santa Monica Bay (Table 13-2). Bacteria from HTP and JWPCP do not ordinarily reach shore, where the potential threat to humans engaged in direct body-contact activities is greatest. However, numerous studies have confirmed that bacteria are abundant in stormwater and are most concentrated in the vicinity of stormdrains and the mouths of streams to the Bay.

	Malibu Creek				Ballona Creek				
	Total 83	Total 84	Total 89	Mean 83-84, 89	Total 83	Total 84	Total 89	Mean 83-84, 89	Grand Mean
Flow (billion l/yr)	114	16	9	46	112	27	21	53	50
Flow (mgd)	82	12	6	33	81	20	15	39	36
<u>High Emission Constituents (MT)</u>									
Calcium Carbonate	35672	9038	-	22355	31290	7376	-	19333	20844
Bicarbonate	20920	3423	-	12172	22913	4427	-	13670	12921
Sulfate	15100	6808	4091	8666	10952	4317	4076	6448	7557
COD	8500	346	-	4423	6167	1456	-	3812	4117
Chloride	7946	1484	1092	3507	8678	2118	2144	4313	3910
Calcium	8033	1945	1145	3708	6830	1520	2131	3494	3601
Sodium	6308	1802	1205	3105	7215	2048	2045	3769	3437
Magnesium	3779	1002	624	1802	3449	858	872	1726	1764
TOC*	3228	98	2	1109	1824	347	91	754	932
BOD**	478	44	-	261	1145	198	28	457	316
Potassium	354	85	94	178	358	97	162	206	192
Oil & Grease	-	-	9	9	383	-	29	206	105
Iron	544	0.5	0.5	182	71	12	2.16	28	105
Nitrate	247	101	3	117	155	24	30	70	93
Phosphate	164	40	18	74	119	6	4	43	59
Ammonia	25	1	0.4	9	221	3	1	75	42
Flouride	57	10	5	24	79	12	10	34	29
Boron	-	-	3	3	15	-	5	10	8
<u>Low Emission Constituents (MT)</u>									
Barium	25.29	0.6	0.21	8.70	8.15	2.07	1.05	3.76	6.23
Manganese	29.19	0.16	0.08	9.81	5.06	0.99	0.22	2.09	5.95
Nitrite	18.06	0.33	3.00	7.13	6.64	-	7.00	6.82	4.82
Zinc	10.04	0.13	0.09	3.42	9.33	2.62	0.51	4.15	3.79
Hexavalent chromium	5.69	0.82	0.13	2.21	5.62	1	0.21	2.28	2.25
Nickel	10.09	0.18	0.12	3.46	1.77	0.33	0.21	0.77	2.12
Chromium	5.33	0.16	0.13	1.87	1.82	0.55	0.29	0.89	1.38
Copper	2.68	0.18	0.05	0.97	3.67	0.76	0.12	1.52	1.24
Lead	1.14	0.16	0.69	0.66	1.22	1.09	0.51	0.94	0.80
Silver	0.45	0.02	0.05	0.17	0.61	0.07	0.10	0.26	0.22
Cadmium	0.23	0.02	0.04	0.10	0.15	0.05	0.11	0.10	0.10
Mercury	0.11	0.02	-	0.07	0.12	0.02	-	0.07	0.07
<u>Bacteria (trillion cells/yr (cell x 10^{12}))</u>									
Total Coliform	13991	132	146	4756	103163	84120	5295	64193	34474
Fecal Streptococcus	17747	49	19	5938	48985	-	523	24754	13465
Fecal Coliform	1384	7	13	468	16297	1800	490	6196	3332

Source: Modified from LAC, DPW, unpubl. data; M. Stenstrom, UCLA, unpubl. data

Note: Mass emissions for 1989 was calculated by adding monthly mass emissions. When parameter was not detected during a particular month, half the minimum detection level was used. Selenium, aldrin, lindane, dieldrin, Heptachlor, heptachlorepoxide, Endosulfan, and Endrin were all not detected at Ballona Creek and not analyzed at Malibu in 1989.

BOD was not analyzed throughout 1989 at Malibu.
Data not available for DDE, DDD, and DDT in 1989.

* TOC - Total Organic Carbon
** BOD - Biochemical Oxygen Demand

Table 13-2. Mass emissions for Malibu and Ballona Creeks for 1983-1984 and 1989.

As in the case of aerial fallout, the only effective way to reduce contaminant input via storm/urban runoff is to impose stricter upstream source control measures. While the upstream sources of some contaminants have been identified (at least generally) the exact upstream sources of bacterial contamination have not.

DISTRIBUTION OF CONTAMINANTS

This section contains material which relates to Action Plan Element I-F of Table 13-1, remediation of contaminated sediments. Most contaminants reach Santa Monica Bay in an aqueous medium; a few are dissolved in water but most are attached to particulates which are suspended in water. Once in the Bay the organic or inorganic particulates are redistributed to some extent, but tend to settle out of suspension and accumulate on the seafloor according to two basic criteria: close to their point of entry, and in depositional environments (quiet water where contaminant-bearing particulates settle out of suspension). The so-called "hotspots" of contamination reflect these criteria.

In Santa Monica Bay hotspots are found in the vicinity the HTP and JWPCP outfalls, in embayments such as Marina del Rey, King Harbor, and Ballona Lagoon, and at the mouths of streams and storm drains during periods of runoff. Hotspots began to develop around wastewater outfalls as soon as the outfalls became operational: in 1937 at the JWPCP outfalls on the Palos Verdes Shelf; in 1951 at the HTP 5-mi outfall; and in 1957 at the HTP 7-mi sludge outfall to Santa Monica Submarine Canyon.

High levels of DDT and PCBs were discharged through the JWPCP outfalls until the 1970s, several years after the discharge of process wastes to the sewage system was discontinued. However, JWPCP has continued to discharge less-than-secondary treated effluent since then and solids in the (cleaner) effluent have settled out of suspension to cover the highly contaminated sediments. DDT and PCB levels are now highest six to 12 inches beneath the sediment surface within one mile of the outfalls. While this may have temporarily sequestered the contaminants and kept them from being incorporated into the food web, they remain in the area and are potentially available to be resuspended and reintroduced into the ecosystem.

Fortunately, hotspots of chemical degradation can recover once the input of contaminants is curtailed or reduced. This has been observed world-wide and in the study area, as the contaminated sediments are resuspended through bioturbation or water motion and are carried by ocean currents out of the area.

In 1987, HTP ceased discharging sludge into Santa Monica Submarine Canyon and in 1988 the sludge field was as much as 4.6 feet deep. Indicators of organic enrichment and contaminant levels were elevated over an area of 20 mi^2 However, sediment sulfide levels decreased within nine months after the discharge was terminated and were only slightly above background values. Within a year organic carbon values decreased 23%, nitrogen 29%, PCBs and PAHs about 48%, and trace metals from 53 to 59%. DDT concentrations actually increased, however, perhaps as surface materials were removed, exposing underlying deposits. By 1990, approximately 0.5 inches of cleaner sediment had covered the sludge.

The mouths of streams and storm drains into Santa Monica Bay constitute point sources which probably create temporary hotspots of contamination. Although appropriate time-series studies have not been conducted just offshore of drains to confirm this, it is expected that the hotspots in the Bay itself would only last for a few days after the input has ceased. The concentrations of organic and inorganic substances (for example, oil and grease from roads and parking lots) would be reduced through dilution and dispersion, aided by the stream flow itself as well as the wave energy and currents in the nearshore environment. The reduction in bacterial concentrations would accelerate because of the natural die-off of the organisms in seawater.

Marina del Rey, King Harbor, and Ballona Lagoon are not only depositional locales, but include the mouths of streams or drains which discharge runoff. Thus contamination levels are affected by both criteria for hotspots. Fortunately, they are all relatively small and contaminated sediments can theoretically be dealt with readily; in fact some accumulations of toxic substances have probably been removed during maintenance dredging at Marina del Rey and King Harbor.

Contaminant levels in Marina del Rey have fluctuated in recent years, possibly because they derive from nonpoint, and therefore unregulated, sources. Even though its use is banned, for example, the insecticide chlordane is highly concentrated; it may be leeching out of previously treated wooden structure. The limited exchange with the Bay proper reduces the likelihood that existing levels will be reduced by dilution or dispersion.

HABITAT IMPACTS

The impacts summarized in this section provide information which relates to Action Plan Elements IIIA-IIID of Table 13-1, to restore, protect, and manage habitats and watersheds.

SUBTIDAL BENTHOS

Infaunal assemblages were used to evaluate the "health" of the seafloor even before analytical chemistry was used to monitor contaminant levels directly. Both scientists and lay persons are usually more interested in the effects of pollution on the living resources than in the chemical concentrations themselves. Because the contaminants can be passed up the food web to humans, there is also concern for their own well-being.

The infaunal assemblages which have inhabited the sediments around HTP and JWPCP outfalls reflect the contamination levels in those sediments. They also reflect the improvements in sediment quality which have taken place during the last 20 years.

As early as 1952, the area around HTP's 1-mi outfall supported infaunal assemblages which were progressively degraded with proximity to the discharge. The assemblage was unaffected eight miles from it; enrichment characterized the infauna at 1.9 to 4.5 miles away; and within 0.3 miles of the outfall was an impoverished zone. In 1957, the bottom near JWPCP outfalls on the Palos Verdes Shelf was described as "foul" and lacking several important animal groups.

In 1977, benthic communities throughout the study area were characterized using the "Infaunal Index" as being normal, changed, or degraded (Figure 13-5). Eighteen and a half mi^2 of bottom surrounding the HTP outfalls were considered changed, and within this area, 1.2 mi^2 (around the HTP 7-mi outfall) were considered degraded; no degraded communities were observed near the 5-mi outfall. Approximately 33 mi^2 around the JWPCP outfalls on the Palos Verdes Shelf and extending north past Redondo Submarine Canyon were changed, 3.5 mi^2 immediately adjacent to the outfalls were degraded.

By 1991, only nine mi^2 of bottom in the vicinity of the HTP outfalls were considered "affected" and less than one mi2 next to the (now unused) 7-mi sludge outfall was considered degraded. These represent a 50% reduction in the total area affected by HTP effluents. From 1985 to 1991, diversity of the infauna had improved throughout the area. All these improvements are attributed to the reduction of mass emissions from HTP, abatement of

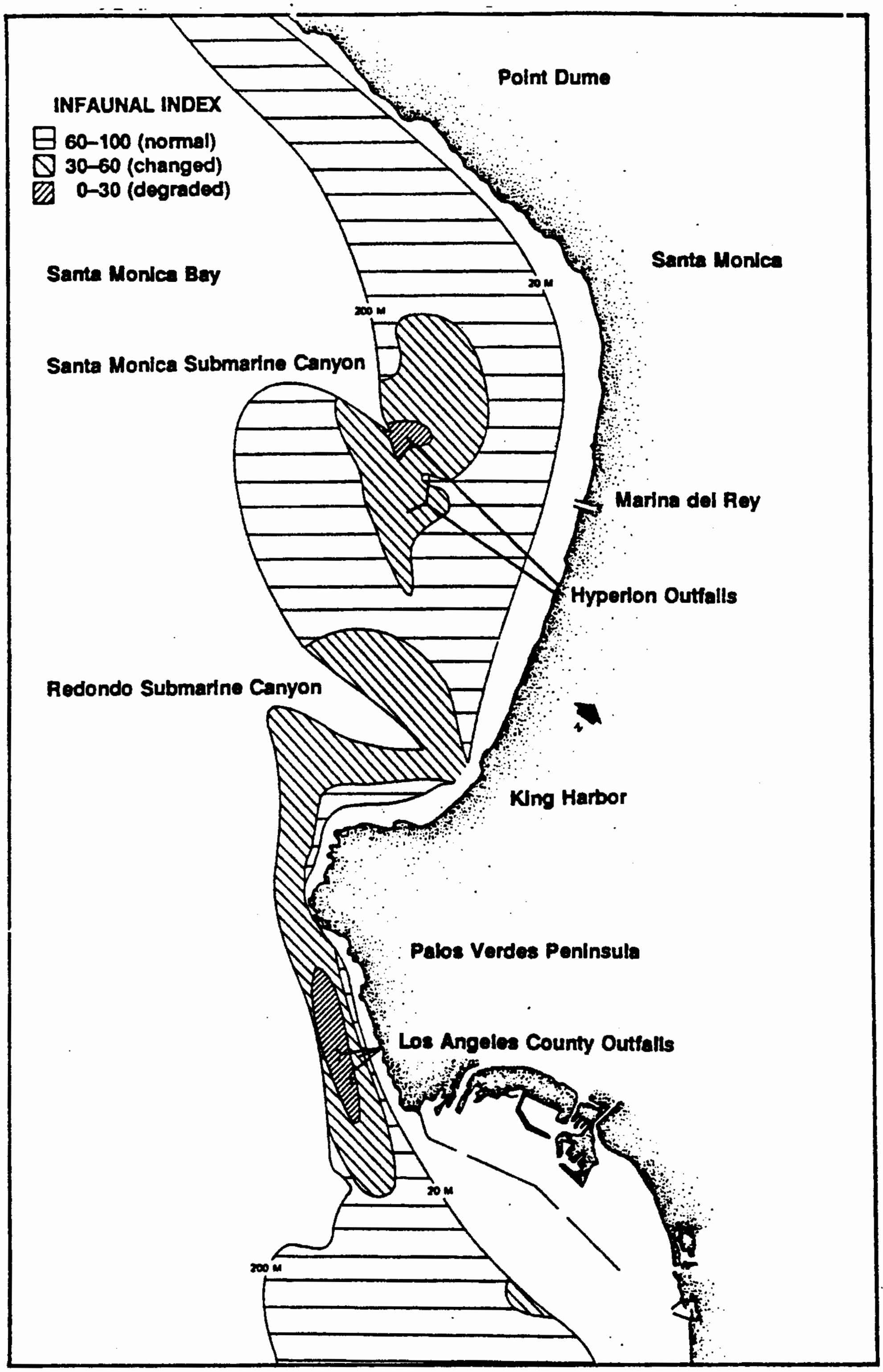


Figure 13-5. Location of normal, changed, and degraded areas in the study area as defined by changes in infaunal index, 1977 (Bascom 1978).

improvements are attributed to the reduction of mass emissions from HTP, abatement of sludge disposal from the 7-mi outfall, and improved effluent quality from the 5-mi outfall. With the improvement in JWPCP effluent, infauna on the Palos Verdes Shelf continued to increase in diversity, sediment quality improved, and outfall related gradients declined.

DEMERSAL FISH ASSEMBLAGES

Between 1957 and 1975, the abundance and diversity of demersal fishes were low near both HTP outfalls, but from 1976 to 1979 species richness, biomass, and the size of individual fish were all greater in the 7-mi sludge field than in reference areas. From 1984 to 1986, biomass and abundance were generally high near the outfalls and white croaker was the dominant species, although it was not elsewhere in the Bay. In 1989 and 1990, the numbers of species and individuals were both depressed in the vicinity of the outfalls.

Although the above community-wide measures do not indicate clear recovery at either outfall, examination of individual species suggests that replacement often takes place according to individual species prey preferences. Crustaceans, the preferred prey of most common demersal fish, are uncommon near outfalls and so also are species which feed on them. Hornyhead turbot and English sole feed primarily on infaunal polychaetes and mollusks, which dominate near outfalls, and those fish species are also often dominant near outfalls.

Between 1970 and 1976, the abundance and diversity of demersal fishes near the JWPCP outfalls on the Palos Verdes Shelf were severely depressed, however, by 1985 and 1986 the assemblage was showing marked signs of recovery. Previously rare or uncommon species were becoming common while previously abundant species (indicators of outfalls) were becoming less common. These changes coincided with improvement in JWPCP's effluent quality and in changes in the availability of infaunal prey (crustaceans vs. polychaetes) which the fish consumed.

BEACHES & ROCKY INTERTIDAL HABITATS

Prior to development, the coast between Santa Monica and the Palos Verdes Peninsula consisted primarily of sand dunes and sandy beaches, which were moved around by air and water currents. Beach sand is naturally moved offshore by longshore currents; sediment needed to replenish the beach sand lost down submarine canyons was replenished by rivers and creeks flowing into Santa Monica Bay. Dunes behind the beach also supplied sand and provided a buffer between the shoreline and inland development.

The development of coastal structures impacted longshore sediment transport and channelization of drainages reduced the sediment input. These factors, along with rising sea level, have combined to redistribute the available material and erode local beaches to the point that recreation and coastal development are threatened.

Beach nourishment has ameliorated the condition in some places: more than 30 million yds^3 of material have been placed on beaches in Santa Monica Bay since 1938, much excavated from nearby dunes and construction projects or dredged from Marina del Rey. Recently, however, sediments in Marina del Rey were found to be too contaminated with lead and other metals for beach nourishment. Therefore, dredged material has been dumped offshore, to be distributed by longshore currents. Shoreline erosion and accretion continue to be studied in search for methods to protect and restore the beaches of Santa Monica Bay.

Beaches provide habitat for certain species which are of special concern specifically because of the loss of habitat in Southern California. The Federal government lists the California least tern and the El Segundo Blue (butterfly) as endangered and the Western snowy plover as threatened. California least terns and Western snowy plovers both nest on beaches and salt flats which have been heavily developed and used for recreation. The El Segundo Blue is severely imperiled, as it is restricted to sand dunes where its host plant is found. Other species are being studied because their numbers are declining: the wandering skipper butterfly is another dune inhabitant while the black abalone is found on rocky shores.

Projects underway to protect the California least tern include providing appropriate and undisturbed nesting habitat near suitable foraging areas. One such site at Venice Beach has been very successful, even though it is located on a well used beach. Other potential nesting sites are being identified to further expand the least tern population, including one in the Ballona Wetlands and one at Dockweiler Beach. No projects have been implemented or proposed for Western snowy plover; however, since its nesting requirements are similar to those of the California least tern, future restoration projects may be designed for both.

Efforts to protect the El Segundo Blue have included preserving a small dune area near the western end of LAX and maintaining the population of the butterfly's host plant, the coastal wild buckwheat. Restoration of additional dunes and halting the spread of invasive plants (which displace the buckwheat) will help survival of this species.

More than 50 million people visit the beaches of Santa Monica Bay each year. The beaches between Santa Monica and Redondo Beach receive the heaviest use, as they are most accessible to inland populations. Beaches and rocky intertidal tidepools are used as classrooms by students and naturalists; they also provide bait for fishermen and food for some ethnic groups.

As human use of the beaches and waters of Santa Monica Bay increases, so does trash and the need for beach clean-up, including (unfortunately) the removal of natural debris such as drift kelp which is a natural part of the marine nutrient cycle. The increase in the user population has also meant more marine vessel spills and greater contamination from urban runoff. Floatable materials may impact intertidal species such as California grunion which lay their eggs on beaches. Contaminants may also find their way into the food web, potentially impacting the entire ecosystem.

KELP BEDS

Kelp beds along the Palos Verdes Peninsula began to decrease in size shortly after the first JWPCP outfall became operational in 1937; degeneration began near the outfall site at White Point and spread outward from there. There has been a strong inverse relationship between kelp coverage and mass emissions of total suspended solids (TSS) from JWPCP, and when TSS levels declined between the mid-1970s and mid-1980s, kelp coverage increased. However, the impact of large, destructive storms cannot be discounted as a major factor, as was clear in 1983 and 1988 (Figure 13-6).

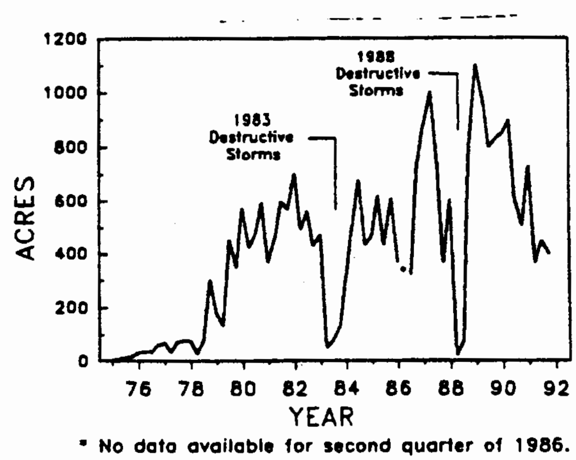


Figure 13-6. Changes in the Palos Verdes Peninsula kelp canopy 1974 to 1992 (modified from CDFG unpubl. data; LACSD unpubl. data).

WETLANDS

Wetlands are covered periodically or permanently with shallow water, and include freshwater, saltwater and brackish water marshes, swamps, and mudflats. Marine wetlands develop where streams enter the ocean across a low, flat coast and are modified by variable salinities and the tidal cycle. Wetlands help mitigate flooding, filter and recharge groundwater, and provide feeding and breeding habitat for fish and waterfowl. In the past, wetlands were considered useful only for more "constructive" purposes. Recently the ecological role and importance of wetlands has been recognized.

Ten brackish wetlands occur along the edge of Santa Monica Bay, the largest of which are the Ballona Wetlands Complex (Ballona Wetlands, Ballona Lagoon, Del Rey Lagoon, Oxford Flood Control Basin, and the Venice Canals) and Malibu Lagoon. At one time the Ballona Complex comprised 2,100 acres of wetlands. The development of Marina del Rey, the Venice Canals, and other residential and commercial properties; the draining for agricultural use and to control insect pests; and the channelization of Ballona Creek have reduced the wetlands to less than 160 acres. The 40-acre Malibu Lagoon, at the mouth of Malibu Creek, is also a remnant of a previously larger system. Most wetlands in the study area have reduced biological diversity and productivity because of their degraded condition.

Restricted water flow, which results in poor water quality (high levels of nutrients and/or contaminants), is the main concern at most sites. Additional adverse impacts include the lack of shallow water habitat, disruption of upstream flow, introduction of non-native plants and animals, debris and bacteria from urban runoff, human recreational over-use, and the presence of domestic pets.

The wetlands of Santa Monica Bay support a variety of marine and terrestrial biota; however, many of the species characteristic of pristine saltmarshes of Southern California are lacking. Vegetation is often sparse and includes or is dominated by introduced species which have little functional value. The salt-marsh bird's beak (a Federally- and State-listed endangered plant) is no longer found in the area. Belding's savannah sparrow (a State-listed endangered species) is a year-round resident of saltmarshes, foraging and nesting in pickleweed, a dominant plant of the upper marsh. The population of this sparrow was low but stable until 1990, when it began to decline, in part because of predation by introduced red foxes. Attempts to remove the foxes have met with limited success. Other "listed" birds which have not been seen for some time (due to the absence of cordgrass) are the light-footed clapper rail (Federally- and State-listed endangered) and the black rail (State-listed as threatened). The black-necked stilt, a species of concern, has not nested recently in the local wetlands.

Animal communities in the sediments, lagoons, and channels of local wetlands are also less diverse than in the past and some of the most abundant invertebrates found now are indicators of stressed conditions. Some fish species (for example rainbow trout) no longer occur although the tidewater goby was recently reintroduced to its original habitat at Malibu Lagoon. California least tern (State- and Federally-listed endangered) forage in the waters of several of the Bay wetlands.

Although several plans have been developed to preserve and restore the wetlands of Santa Monica Bay, prior attempts have often been confused by the complex issues and often conflicting goals of the regulatory agencies. The extant wetlands have been inventoried (for the Santa Monica Bay Restoration Project) to serve as a basis for a general approach to protection and enhancement. The Port of Los Angeles has developed a Local Wetland Mitigation Program which identifies those wetlands available for mitigation projects. Successful implementation of any of the plans will depend on dedicated individuals and adequate funding.

Restoration at Malibu Lagoon has begun with the regulation of freshwater flow and reintroduction of the tidewater goby. Future plans include reduction of nutrient inputs, recontouring and revegetation of the intertidal habitat, and restoration of former wetlands in the City of Malibu. Rehabilitation of the Venice Canals has also begun and plans have been approved to enhance Ballona Lagoon, including removal of debris and exotic vegetation and replacement with native species. Construction of the Playa Vista residential-marina complex depends on development of plans to restore the Ballona Wetlands. The plans are to include: restoration of tidal flow; construction of saltwater marsh, dunes, a freshwater marsh, and a riparian corridor; and fish habitat enhancement in the proposed marina. Suggestions for enhancement of Del Rey Lagoon include increased tidal flow to achieve better water quality.

SWIMMING RISKS

The material summarized below relates to Action Plan Element IIB of Table 13-1, concern for the human health risks associated with swimming in Santa Monica Bay. Concern about the health risks from hazardous chemicals and biological pathogens to swimmers in Santa Monica Bay derives primarily because beaches have been closed due to sewage spills and storm drain runoff. There are no documented (verified) cases of disease or illness which were caused by microbial pathogens or toxic chemicals in the Bay.

Bathers in Santa Monica Bay may be exposed to a variety of harmful chemicals which may produce acute and long-term health effects. However, because etiological relationships between chemical contamination and human health are difficult to establish, health risk analyses of swimming in Santa Monica Bay have focused primarily on biological pathogens.

Pathogenic bacteria that have been found in the Bay include Pseudomonas, Enterobacter/Citrobacter, Streptococcus, Escherichia coli, Klebsiella, and marine Vibrio. These can cause human illnesses ranging from skin infections, gastroenteritis, upper respiratory problems, and wound infections, to pericarditis and spinal meningitis. Human-specific viruses such as hepatitis A, poliovirus, and Norwalk virus have also been found in marine waters and recently Coxsackie B viruses were found in storm drains that discharge to Santa Monica Bay.

The primary source of most human-specific biological pathogens is human fecal waste from treated wastewater discharges, urban runoff, sewage spills, small boat waste discharges, and the bathers themselves. The risk of disease from human fecal contamination is paramount; the relative importance of pathogens from non-human sources is not known.

There has been no evidence (microbial indicator) that the waste fields from HTP or JWPCP have reached shore in the past ten years, a result of improved treatment and offshore discharges. The largest source of bacterial pathogens to nearshore bathers in Santa Monica Bay is probably urban runoff via storm drains and stormwater overflows into sewage lines (which force untreated sewage back into storm drains, then to the Bay). Because most storm drains discharge directly into the surf zone and because high indicator bacteria counts have been found in storm drain runoff, the surf zone near storm drains is a high risk area, especially during rain storms.

High indicator bacteria levels and human enteric viruses have also been found in storm drains during dry weather. Recent studies in Santa Monica Bay provide evidence of dry-weather biological contamination of urban runoff. Samples from the Pico-Kenter, Ashland, and Herondo Storm Drains and Malibu Lagoon were analyzed for densities of "indicator" bacteria (total and fecal coliforms and enterococcus) and human enteric viruses. Samples bacteria (total and fecal coliforms and enterococcus) and human enteric viruses. Samples were taken variously from inside the drains and from the nearby surf zone at ankle and chest depths. Densities of bacterial indicators were classified as exceeding "excessive limits" or "levels of concern".

In 1989, 1990, and 1991, all three bacterial indicators exceeded levels of concern in virtually all samples taken from the Pico-Kenter Storm Drain and densities of bacterial indicators generally decreased with water depth and distance from the Drain (Figure 13-7). In 1989, bacterial counts from Pico-Kenter Storm Drain were nearly one-hundred times greater than levels of concern.

All three indicator levels were approximately one order of magnitude lower in ankle-deep water than in storm drains and two orders of magnitude lower in chest-deep water than in the drains. A similar pattern was seen at the Ashland Storm Drain. Bacterial densities were markedly lower in the surf zone, but levels of concern were frequently exceeded up to distances of 150 yards from the Pico-Kenter Drain. In 1989, HTP recorded bacteria levels below levels of concern at a station 200 yards south of Pico-Kenter, suggesting that bacterial contamination may be limited to within 150 to 200 yards from the Storm Drain.

Bacterial densities near Pico-Kenter were much lower in 1991 than in 1990 (Figure 13-7), suggesting that the 600 feet extension to the Drain (which was added in August 1990) reduces bacterial densities in the surf zone.

Human enteric viruses were found in the Pico-Kenter and Herondo Storm Drains and in Malibu Lagoon, indicating that human fecal waste was present in the runoff even during dry weather. Possible sources of the human fecal contamination include leaky sewer lines and septic systems; overflows from blocked sewers; campers, picnickers, or the local homeless population; and illegal discharges from mobile homes or recreational vehicles.

The extent of contamination around storm drains depends on local rainfall, runoff from the surrounding area, and the interval between storms. Densities of all three bacterial indicators were highest during periods of peak rainfall in Los Angeles between July 1989 and June 1990 (Figure 13-8). Bacterial densities are usually highest during the first few months of the rainy season and during the first few hours of a single storm and tend to decrease thereafter.

These ongoing studies have established that the largest potential threat to swimmers in the Bay is from human pathogens in urban runoff, especially at the Pico-Kenter and Herondo Storm Drains and in the Malibu Creek/Malibu Lagoon drainage system.To assess the potential swimming risk quantitatively it is necessary to conduct an epidemiological study and there appears to be sufficient evidence from biological data to warrant one. Such a study has not been conducted for Santa Monica Bay, although one has been designed and proposed by Dr. Robert Haile, and approved and recommended by the Santa Monica Bay Restoration Project Management Committee.

CONTAMINATED SEAFOOD

The material summarized below relates to Action Plan Element IIA of Table 13-1, concern that seafood collected from Santa Monica Bay is safe to consume.

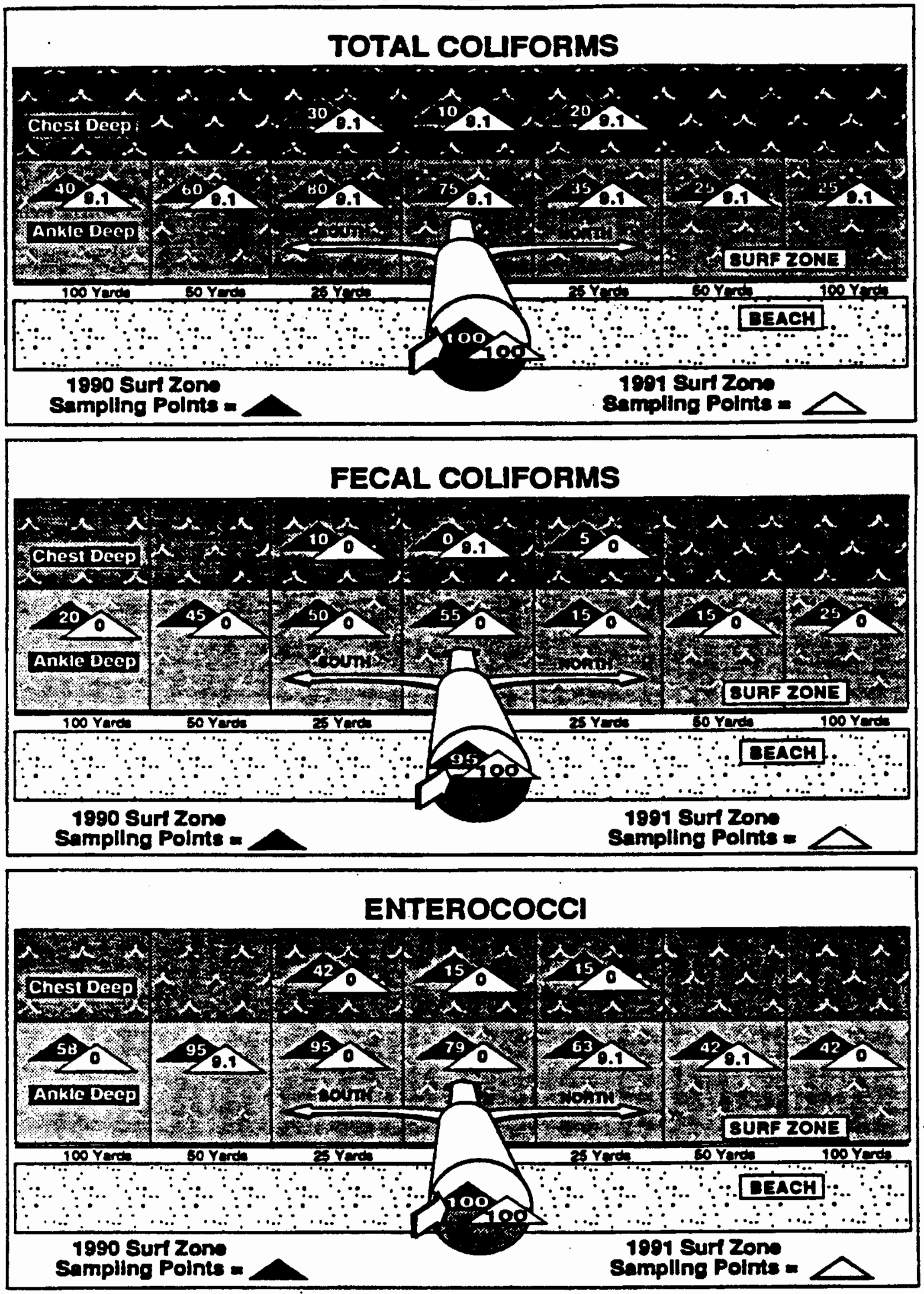


Figure 13-7. Percentage of sampling days where excessive levels of bacterial indicators were exceeded near the Pico-Kenter Storm Drain in 1990 and 1991 (excessive levels: total coliforms = 1,000 cfu/100 *ml*, fecal coliforms = 200 cfu/100 *ml*, enterococci - 24 cfu/100 *ml*). Gold *et al.* 1992).

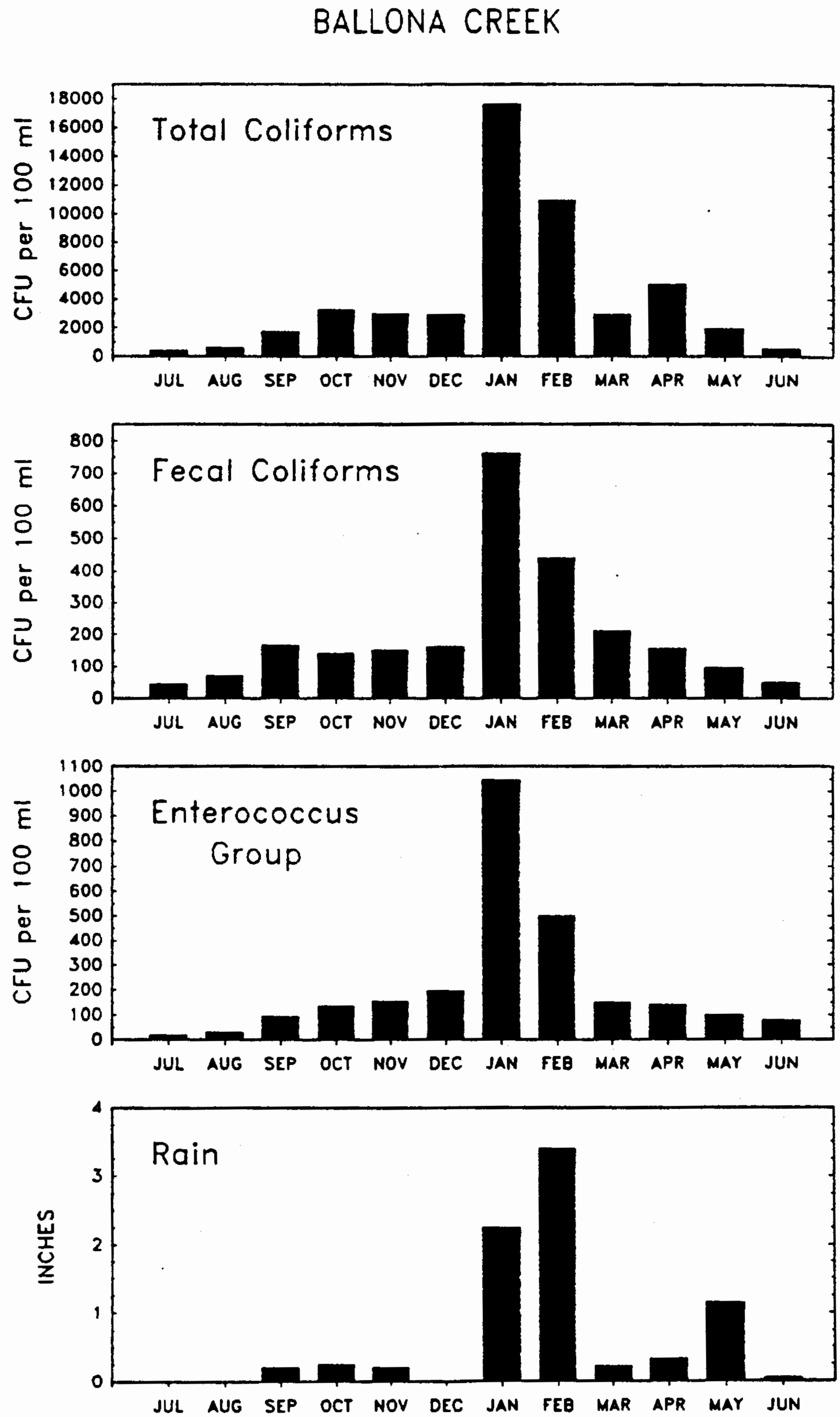


Figure 13-8. Monthly geometric means of indicator bacteria measured in Ballona Creed at Pacific Avenue, sampling year 1989-1990; rain data are in total inches per month (CLA,DPW 1991).

Marine environments adjacent to heavily populated areas may contain many chemical contaminants. Organisms (including humans) may contact these contaminants through direct water contact or through contact with contaminated sediments. Human health may be at risk through direct contact and by consuming contaminated species. The most extensively studied and tractable contaminants in Santa Monica Bay are heavy metals, PCBs, and DDT and its derivatives.

Historically wastewater outfalls were the principal source of contaminants to the Bay. Recent improvements in effluent quality may have changed this; however, the sediments contaminated previously may now constitute a principal source of contaminants along with urban runoff via storm drains, particularly during periods of heavy rainfall or sewage overflows. In general, metal levels in edible tissue of fishes and invertebrates from near the JWPCP and HTP outfalls in the last ten years have not been substantially elevated over those at reference sites elsewhere in southern California. Since sediments near the outfalls often contain high metal concentrations, actual bioaccumulation and biomagnification of metals in the species studied appear to be minor. Thus seafood consumption does not appear to pose an appreciable health risk from metals contamination.

Organic contaminants such as PCBs and DDT (and DDD and DDE) present the greatest risk to individuals that consume seafood from Santa Monica Bay. High levels of these contaminants in the sediments around the JWPCP and HTP outfalls reflect the massive discharges that occurred in the 1960s and early 1970s. Over the past 25 years several species (especially filter-feeding invertebrates and demersal fishes) from contaminated areas have exhibited very high body-burden levels of PCBs and DDT. Body-burden levels in the late 1970s were much lower than those in the late 1960s, reflecting the ban on dumping these contaminants in the early 1970s.

Body-burden levels of PCBs and DDT have been about the same (at particular sites) throughout the Bay since about 1982, reflecting the persistence of these contaminants over time and suggesting that historically contaminated sediments now constitute a source. The PCBs and DDT discharged to the Palos Verdes Shelf in the 1960s and 1970s, continue to bioaccumulate in the tissues of fishes and invertebrates in the area.

Because of the persistence of PCBs and DDT in fishes from the Palos Verdes Shelf and northern Santa Monica Bay, the Office of Environmental Health Hazard Assessment (OEHHA) conducted a comprehensive study and risk assessment in 1991. OEHHA measured body burden levels of several contaminants (including PCBs and DDT) in fishes from the Bay and assessed the potential health hazards of consuming the contaminated species.

White croaker is generally the most contaminated fish in the Bay, especially those from highly-contaminated areas such as the Palos Verdes Shelf. The theoretical excess lifetime cancer risk from consumption of white croaker from the Palos Verdes Shelf is approximately one in 1,000, based on a theoretical consumption rate of about one six ounce (170 g) meal per week (23 g/day). Other relatively contaminated species are California corbina, queenfish, surfperches, and California scorpionfish. Pacific bonito, chub mackerel, Pacific sanddab, Pacific barracuda, opaleye, halfmoon, and halibut are less contaminated.

OEHHA also developed (on the basis of 1987 data) site-specific recommendations for seafood consumption from areas of Santa Monica Bay and the Palos Verdes Shelf (Table 13-3) and species-specific recommendations for the most frequently caught and consumed fishes (Table 13-4). OEHHA points out that the inclusion of seafood in the diet is strongly encouraged as a general recommendation. Tables 13-3 and 13-4 reference fishes caught locally and are meant to indicate how often to fish an area and how often to eat specific species from each site.

Site	Species	Recommendation*
Santa Monica Pier Venice Pier Marina Del Rey Redondo Beach Dana Point	All species	No restrictions
Redondo Pier	California corbina	One meal every two weeks
Malibu Pier	queenfish	One meal a month
Short Bank	white croaker	One meal every two weeks
Point Dume Malibu Point Vicente Palos Verdes-NW	white croaker	Do not consume
White Point	white croaker	Do not consume
	California scorpionfish rockfishes kelp bass	One meal every two weeks+

* One meal is about six ounces (170 g).
+ Consumption recommendation is for all the listed species combined.

Table 13-3. Site-specific seafood consumption recommendations for several locations in Santa Monica Bay, based on 1987 contaminant levels (Pollock *et al.* 1991).

RISK GROUP Species	Recommendation*
HIGH	
white croaker	Avoid consumption
MODERATE	
California corbina queenfish surfperches California scorpionfish	Consume not more than one meal every two weeks
LOW	
black croaker barred sand bass rockfishes kelp bass	Consumption not restricted
LOWEST	
Pacific bonito chub mackerel Pacific sanddab Pacific barracuda opaleye halfmoon California halibut	Consumption not restricted

* One meal is about six ounces (170 g).

Table 13-4. Species-specific seafood consumption recommendations for several fish species of Santa Monica Bay, based on 1987 contaminant levels (Pollock *et al.* 1991).

A recent SMBRP-funded study to determine seafood consumption patterns of anglers that fish in Santa Monica Bay will describe consumption patterns by ethnic group and fish species. This information will ultimately be used to calculate the potential health risks, rather than those formulated from theoretical consumption rates, of consuming Santa Monica Bay seafood.

LOS ANGELES COUNTY BEACH CLOSURES
1986 - 1992

Date Closed	No. of Days	Location	Cause
03/20/86	2	Redondo Pier to ¼ mile southward.	Sewage discharge under Redondo Pier.
09/26/87	2	Temescal Storm Drain to Sunset Storm Drain.	Sewage discharge due to sewage pump failure.
10/07/87	1	100 yds. north and south of Santa Monica Canyon Storm Drain.	Sewage discharge due to blocked sewer line. 100 gallons.
10/22/87	6	½ mile north of Sunset Storm Drain to ½ mile south of the Bel Air Bay Club.	Sewage discharge due to pump failure.
10/22/87	6	Ventura County border to Long Beach City border.	Sewage discharge at North Outfall Treatment Facility, due to heavy rains. 2.7M gallons.
10/22/87	42	Marina Del Rey Beach.	Excessive bird population leading to elevated bacterial levels.
10/30/87	13	Temescal Storm Drain to Sunset Storm Drain.	Unknown.
10/31/87	12	Ventura County border to Long Beach City border.	Sewage discharge at North Outfall Treatment Facility, due to heavy rains. 4.11M gallons.
11/25/87	5	Temescal Storm Drain to Sunset Storm Drain.	Unknown.
12/01/87	3	Temescal Storm Drain to Sunset Storm Drain.	Sewage discharge due to unknown sewer system failure. Approximately 2K gallons.
12/30/87	3	Pulga Canyon Storm Drain to Santa Monica Canyon Storm Drain.	Unknown.
06/03/88	1	¼ mile either side of Pulga Storm Drain.	Sewage discharge due to sewage pump failure.
07/06/88	1	¼ mile either side of Sunset Storm Drain.	Sewage discharge due to line blockage.
09/15/88	2	Santa Monica Pier south to Pico/Kenter Storm Drain.	Suspected sewage discharge from Santa Monica Pier Storm Drain.
10/07/88	1	Pico/Kenter Storm Drain to ¾ miles southward.	Possible diesel fuel flow from Pico/Kenter Storm Drain.
11/10/88	3	Venice Pier to Grand Ave. Storm Drain.	Sewage discharge into Ballona Creek due to sewer line blockage.

LOS ANGELES COUNTY BEACH CLOSURES
1986 - 1992

Date Closed	No. of Days	Location	Cause
12/12/88	3	Sunset Storm Drain to Temescal Storm Drain.	Sewage discharge due to sewage pump failure.
01/23/89	3	200 yds. north and south of Santa Monica Pier.	Small sewage discharge under Santa Monica Pier.
03/06/89	3	King Harbor south ¼ mile to Ainsworth Court.	Sewage discharge due to restaurant sewer line blockage.
05/02/89	2	Venice Pier to Imperial Ave. Storm Drain.	Sewage discharge into Ballona Creek due to sewage pump failure, 100K gallons.
09/26/89	3	¼ mile either side of Ashland Storm Drain.	Sewage discharge of unknown origin into Ashland storm drain. Est. less than 500 gallons.
11/20/89	1	½ mile either side of Pulga Storm Drain.	Sewage discharge due to pump failure caused by tripped circuit breaker. Est. 1.5K gallons.
12/13/89	2	Sunset Storm Drain to Temescal Storm Drain.	Sewage discharge due to pump failure caused by faulty air check valve at pump station 639. Approximately 6.5K gallons.
02/17/90	4	Entire Los Angeles County coastline from Topanga Canyon Storm Drain to Palos Verdes Point.	Discharge of primary treated sewage from North Outfall Treatment Facility, due to heavy rains. Approximately 7.6M gallons.
9/19/90	9	Santa Monica Pier south to Ashland storm drain. Reopened Ashland to Hart St. on 9/21/90.	Possibly caused by construction on the Pico/Kenter storm drain. Release of accumulated debris. Not sewage related.
12/10/90	4	King Harbor south to Pearl Street extended (appx. ¼ mi. north and south of Redondo Pier)	Small sewage leak from 12" main.
02/28/91	14	Topanga Canyon Blvd. south to Palos Verdes Point. Closure reduced to Marina Del Rey entrance channel south to the El Segundo city line and Marina Del Rey on 3/5/91.	Discharge of 2.31M gallons partially treated sewage at the North Outfall Treatment Facility due to heavy rains.
03/01/91	13	Topanga Canyon to the Ventura County border. Closure reduced to Topanga Canyon to Malibu Creek on 3/6/91.	Washout of private sewage treatment systems due to heavy rains.

LOS ANGELES COUNTY BEACH CLOSURES
1986 - 1992

Date Closed	No. of Days	Location	Cause
03/24/91	1	Surfrider Beach, Malibu.	Diesel fuel spill.
03/29/91	2	Grand Ave. north to Imperial Highway.	Diesel fuel spill.
11/21/91	4	Imperial Highway storm drain, one mile north and south.	Sewer line break at Hyperion Treatment plant resulting in flow of sewage into Imperial Hwy. storm drain and 2K gallons of sewage into ocean. Partially reopened 11/22/91.
02/10/92	11	Entire L.A. County coastline, from Ventura County of Long Beach City.	Discharge of 66.12M gal. partially treated sewage at the North Outfall Treatment Facility due to heavy rains. Partially reopened 2/19/92 from MDR entrance channel to Cabrillo Beach.
05/02/92	3	Dockweiler Beach, ½ mile north to 1 mile south of Marina Del Rey entrance channel and Marina Del Rey Beach.	High Bacteria counts detected in Ballona Creek, most likely caused by a small sewage discharge which occurred when a contractor accidently drilled into a sewer line. This coincided with civil disturbances in Los Angeles and as a precautionary measure beaches were closed.
05/16/92	1	Redondo Beach Pier, south to Ruby St. (appx. ¼ mile).	Leaking sewer line under the Redondo Beach Pier. Quantity unknown.
07/29/92	1	Redondo Beach Pier, south to Ruby St. (appx. ¼ mile).	Leaking sewer line under the Redondo Beach Pier. Quantity 50 - 75 gallons.
08/15/92	3	Rose Ave. south to Imperial Highway (appx. 4 miles).	High bacteria counts originating from sewage in upper Ballona Creek, source unknown. Coastline reopened 8/18/92 and Marina Del Rey Beach reopened 8/19/92.
08/17/92	3	Redondo Beach Pier, south to Knobhill Ave. (appx. ¾ mile)	Leaking sewer line under the Redondo Bch. Pier due to vandalism. Amount and duration unknown.
09/04/92	1	Avenue 23, Los Angeles, south to Imperial Highway. (appx. 2½ miles).	High bacteria counts detected in Ballona Creek, source unknown, with the potential to affect adjacent beaches.

LOS ANGELES COUNTY BEACH CLOSURES
1986 - 1992

Date Closed	No. of Days	Location	Cause
09/16/92	1	Pico Blvd. south to Windward Ave. (appx. 2 miles).	Collapsed sewer line discharging into Ashland Storm Drain.

APPENDIX A

List of Acronyms

Appendix A. List of Acronyms. Santa Monica Bay Characterization Study, 1993.

AHF	University of Southern California, Allan Hancock Foundation
BHC	Benzene hexachloride
BLM	United States Department of Interior, Bureau of Land Management
BMPS	Best Management Practices
BOD	Biochemical oxygen demand
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CCC	California Coastal Commission
CCMP	Comprehensive Conservation and Management Plan
CDFG	California Department of Fish and Game
CDFG,MRO	California Department of Fish and Game, Marine Resources Division
CDFG,OSPR	California Department of Fish and Game, Oil Spill Prevention and Response
CDHS	California Department of Health Services
CDPR	California Department of Parks and Recreation
CEG	Coastal Ecology Group
CEPA	California Environmental Protection Agency
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CLA,BE	City of Los Angeles, Bureau of Engineering
CLA,DA	City of Los Angeles, Department of Airports
CLA,DPW	City of Los Angeles, Department of Public Works
CLA,DWP	City of Los Angeles, Department of Water and Power
CLA,EMD	City of Los Angeles, Environmental Monitoring Division
CLTRT	California Least Tern Recovery Team
CNPS	California Native Plant Society
COD	Chemical oxygen demand
CPFV	Commercial Passenger Fishing Vessel
CPUE	Catch per unit effort
CRWQB,LAR	California Regional Water Quality Control Board, Los Angeles Region
CSCC	California State Coastal Conservancy

CSG,MAP	California Sea Grant, Marine Advisory Program
CSM,PPD	City of Santa Monica, Program and Planning Department
CSM,SMPPD	City of Santa Monica, Program and Planning Department
CSWPCB	California State Water Pollution Control Board
CSWQCB	California State Water Quality Control Board
CSWRCB	California State Water Resources Control Board
CWA	Clean Water Act (of 1972)
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved oxygen
EIS	Environmental impact statement
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
EQA	Environmental Quality Analysts, Inc.
FDA	Food and Drug Administration
FWS	Fish and Wildlife Service (see also USFWS)
HCH	Hexachlorocyclohexane
HERS	Hyperion Energy Recovery System
HTP	Hyperion Treatment Plant
IRC	Intersea Research Corporation
JWPCP	Joint Water Pollution Control Plant
kg	Kilogram
km	Kilometer
LAC,A-C	Los Angeles County, Auditor-Controller
LAC,DBH	Los Angeles County, Department of Beaches and Harbors
LAC,DPW	Los Angeles County, Department of Public Works
LAC,DRP	Los Angeles County, Department of Regional Planning
LAC,MNH	Los Angeles County Museum of Natural History

Appendix A (Cont).

LAC,OCAO	Los Angeles County, Office of Chief Administrative Officer
LACSD	Los Angeles County Sanitation Districts
LAX	Los Angeles Airport
LFCRRT	Lightfooted Clapper Rail Recovery Team
m	Meter
MBAS	Methylene blue activated substance (e.g. detergent)
mgd	Million gallons per day
ml	Milliliters
MMS,OCSNC	Minerals Management Service, Outer Continental Shelf National Compendium
MMS,POCSR	Minerals Management Service, Pacific Outer Continental Shelf Region
MOA	Memorandum of Agreement
MPN	Most probable number
MT	Metric ton (1000 kg)
MTP	Maguire Thomas Partners
MTP-PV	Maguire Thomas Partners-Playa Vista
NAS	National Audubon Society
NEP	National Estuary Program
NEPA	National Environmental Protection Act
NFSP	National Marine Fisheries Service, National Fishery Statistics Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAEL	"No Observed Adverse Effect Level"
NOEL	"No Observed Effects Level"
NPDES	National Pollutant Discharge Elimination System
NRC,COWT	National Research Council, Committee on Ocean Waste Transportation
NWP	Nation Wide Permits
OCS	Outer continental shelf
PAC	Port Area Committee
PAH	Polycyclic (or polynuclear) aromatic hydrocarbon
PCB	Polychlorinated biphenyl
POLA	Port of Los Angeles

Appendix A (Cont).

ppb	Parts per billion
ppm	Parts per million
ppt	Parts per thousand, also 0/00
PSP	Paralytic shellfish poisoning
RfD	Reference dose
RWQCB,LAR	Regional Water Quality Control Board, Los Angeles Region (see CRWQCB)
SCAG	Southern California Association of Governments
SCCWRP	Southern California Coastal Water Research Project
SCE	(The) Southern California Edison Company
SCE,SGD	Southern California Edison, Steam Generation System
SCUBA	Self-contained underwater breathing apparatus
SDWG	Sediment Dynamics Workshop Group
SL	Standard length; in fish, from the snout to the base of the tail
SMB	Santa Monica Bay
SMBRP	Santa Monica Bay Restoration Project
SMNRA	Santa Monica National Recreation Area
SMW	State Mussel Watch
SWCP	State Wetlands Conservation Plan
TBT	Tributyl tin
THUMS	Texaco Humble Union Mobile Standard
TICH	Total identifiable chlorinated hydrocarbon
TLVRCO	Topanga-Las Virgines Resources Conservation District
TOC	Total organic carbon
tpd	Tons per day
TSCA	Toxic Substance Control Act
TSS	Total suspended solids
TVS	Total volatile solids
USACE	United States Army Corps of Engineers
USACOE/LAHD	United States Army Corps of Engineers/Los Angeles Harbor Department
USEPA	United States Environmental Protection Agency

Appendix A (Cont).

UCLA & WCC	University of California at Los Angeles and Woodward-Clyde Consultants
USCB	United States Census Bureau
USFWS	United States Fish and Wildlife Service
WCC	Woodward-Clyde Consultants
WSED	Wastewater Systems Engineering Division
ww	Wet weight

APPENDIX B

Glossary

Appendix B. Glossary. Santa Monica Bay Characterization Study, 1993.

208 PLANNING	Authorized under Section 208 of the 1972 amendments to the Federal Water Pollution Control Act to control non-point source pollution.
AEROBIC	Living, active, or occurring only in the presence of oxygen.
ALDRIN	A cyclodiene insecticide which is extremely toxic from skin absorption.
ALGAE	A group of chiefly aquatic nonvascular plants which lack flowers and produce organic compounds by the process of photosynthesis. Includes one-celled algae such diatoms and dinoflagellates as well as multicellular seaweeds and kelps.
AMPHIPOD	A small (most are well under an inch long) shrimp-like crustacean of the order Amphipoda. Sand fleas are a common example.
ANAEROBIC	Living, active, or occurring in the absence of oxygen. Some bacteria live only in the absence of oxygen and in the course of normal respiration produce the hydrogen sulfide which is characteristic of anoxic sediments.
ANNELID	Any of a phylum (Annelida) of segmented worms, including polychaetes.
ANOXIC	Lacking oxygen; said of water or sediment.
ANTHROPOGENIC	Made or caused by man; said of substances such as DDT or effects such as elevated water temperatures.
AQUIFER	An underground rock, sand, or gravel formation that yields water.
AROMATIC	A class of (often persistent) organic compounds characterized by at least one benzene ring.
ASSEMBLAGE	A group of species that occur together. See Community.
ADVECTION	The horizontal movement of air.
BACTERIOPLANKTON	Planktonic bacteria
BAITFISH	Small, schooling pelagic fish (such as anchovy) which are preyed upon by larger game fish and hence are used as bait by sport fishermen.
BENEFICIAL USE	Water protected under the Porter-Cologne Act including domestic, municipal, agricultural and industrial water; power generation; recreation; navigation; and preservation of fish, wildlife, and aquatic resources.
BENTHIC	Living on or in the sea floor.

BENTHOS	The bottom of the ocean; also, collectively, the biota living on or in the bottom.
BEST MANAGEMENT	Steps by which water quality is protected, usually from nonpoint sources such as agriculture, construction, mining, logging or urban runoff. These steps can also be applied to point source waste discharges.
BIOACCUMULATION	The accumulation of a substance (usually a contaminant) in the tissues of an organism.
BIOASSAY	A test which measures the lethal or sub-lethal effects of a substance (or composite mixture) on living organisms or tissues.
BIOCHEMICAL OXYGEN DEMAND (BOD)	The amount of oxygen used by organic matter in water. High levels of BOD can remove oxygen needed to support fish and aquatic life.
BIODEGRADATION	A biochemical (i.e. conducted by living organisms) process by which complex substances are broken down into simpler ones; said especially of toxic substances which are detoxified by the process.
BIOMAGNIFICATION	The accumulation of a substance (usually a contaminant) at greater tissue concentrations in successively higher-level consumers with increasingly higher contaminant levels as prey are consumed up the food chain.
BIOMASS	The weight of living tissue, of an organism or a group of organisms. Often includes the weight of non-living material (such as a snail's shell) which was produced by the organism(s).
BIOTA	The plants and animals found in a particular environment.
BIOTURBATION	Disruption of sediment caused by animal activity.
BIVALVE	A mollusk having two shells hinged together, as the oyster, clam, or mussel.
CARBON DIOXIDE (CO_2)	A colorless, odorless, incombustible gas present in the atmosphere and formed during respiration.
CARCINOGENIC	Having the capacity to cause cancer.
CATCH PER UNIT EFFORT (CPUE)	The numbers or pounds of organisms which are collected in a standard sampling or fishing effort.
CETACEAN	Whales, dolphins, and porpoises, all of which are sometimes placed in the order Cetacea.
CHLORDANE	An insecticide and fumigant (for termites) which is toxic by ingestion, inhalation, and skin absorption.
CHLORINATED HYDROCARBONS	Organic compounds that contain chlorine and have toxic properties in varying amounts; pesticides and solvents such as DDT, DDD, DDE, and PCB.

CHLOROPHYLL	The pigment which makes most plants green and enables them to produce organic substances in the process of photosynthesis.
CLEAN WATER ACT	The federal water quality control law governing surface waters establishing water quality objectives, waste discharge standards, and the NPDES permit process; also called the Federal Water Pollution Control Act, amended.
CLEAN WATER GRANT	Apportioned under Clean Water Act for upgrading or constructing publicly-owned and operated sewage treatment facilities.
COLIFORM	Relating to, resembling, or being the colon bacillus bacteria.
COMMUNITY	All plants and animals living in a particular place or habitat and which interact with one another. Some scientists use the term assemblage to denote a community when interactions among the species cannot be defined.
CONDUCTIVITY	A measure of salinity in water determined by conduction of electricity; generally related to the chloride ion concentration (or chlorinity).
CONTAMINANT	An unnatural (man-made) substance found in the environment or a naturally occurring substance or compound which is found in unnaturally high concentrations; a health hazard; a pollutant.
CORALLINE	Consisting of or containing deposits of calcium carbonate which would include any of the various corallike animals or calcareous algae.
CRUSTACEAN	An animal belonging to a class or phylum of organisms (Crustacea) which have a hard exoskeleton and jointed legs and body; includes crabs, lobster, amphipods, and shrimp.
CUBIC FEET PER SECOND (cfs)	The flow of water past a given point over time at the equivalent of 449 gal/min or 1.98 acre-ft/day.
DBCP (dibromo-chloropropane)	A pesticide and fungicide extensively used until banned in 1977 as a suspected carcinogen.
DDT (dichlorodiphenyl-trichloroethane)	A toxic insecticide banned in 1970 but still widely found in water and fish samples.
DEMERSAL	On or near the sea floor.
DETRITUS	Fine, disaggregated particles of inorganic and organic material (i.e. dead plant and animal matter), either in suspension on settled on the bottom of a water body. Forms the basis of an extensive food web in the ocean.
DIATOM	Any of a class (Bacillariophyceae) of minute planktonic unicellular or colonial algae with silicified skeletons.

DIELDRIN	An insecticide toxic by ingestion, inhalation, and skin absorption. It is carcinogenic. Its use is now restricted to nonagricultural applications.
DINOFLAGELLATES	Important plantlike elements of plankton having two flagella.
DIOXIN	2,3,7,8-tetrachlorodibenzo-p-dioxin, a contaminant of a herbicide, banned by the FDA for most purposes after ten years of use. It was also a contaminant in defoliants used in Vietnam (agent orange). It is a carcinogen, a teratogen, and a mutagen.
DISINFECTION	Process where effluent is treated with a disinfectant (e.g. chlorine) to kill bacteria and viruses.
DISSOLVED OXYGEN (DO)	Oxygen (parts per million) which is dissolved in water; the source of most oxygen used by plants and animals in their normal respiration. The dissolved oxygen in seawater replenished by exchange with the air or produced by plants during photosynthesis.
DIVERSITY	A parameter of ecological communities which describes the relationship between the number of species and their abundance.
ECHINODERM	An invertebrate animal having radial symmetry and belonging to the phylum Echinodermata. Includes starfish and sea urchins.
ECOSYSTEM	The sum of all plants, animals, and non-living components of a particular defined area. A given kelp bed may be viewed as an ecosystem, but it is also part of the larger coastal or Bay ecosystem.
EFFLUENT	The material which flows out of a pipe or facility into a water body (or another larger pipe). Wastewater which has undergone treatment to remove pollutants.
EL NIÑO	An aperiodic change in the oceanic climate of the Pacific whereby warm, low-nutrient water flows east along the Equator, north along the west coast of North America and south along South America. The condition lasts for several months or 2-3 years, causing a change in the biota and climate of an area.
EMBAYMENT	A body of water forming an indentation of the shoreline, larger than a cove but smaller than a gulf.
ENDOSULFAN	An insecticide which is toxic by ingestion, inhalation, and skin absorption. Use is restricted.
ENDRIN	A stereoisomer of dieldrin, used as an insecticide to control crop insects and mites. It is a carcinogen, and toxic by inhalation and skin absorption.
ENTERIC	Relating to the intestines.
ENTEROCOCCUS	Any of a genus (*Streptococcus*) of nonmotile, usually parasitic, gram-positive bacteria occurring in the intestine that divide only in one plane and which occur in pairs or chains.

EPIBIOTA	Organisms living on the surface of the seafloor.
EPIDERMAL TUMORS	Tumors located in the outer, nonvascular, layer of the skin.
EPIFAUNA	Benthic animal living on the surface of bottom material.
EROSION	Deterioration of earth or rock by water, glaciers, winds, and waves.
ERYTHROCYTE	One of the red cells of the blood.
ESTUARY	The coastal portion of a river mouth where the fresh, river water mixes with the saltwater of the ocean. The degree of mixing and layering (fresh water tends to float on top of the sea water) depends on tidal conditions, river flow, and local currents. Estuaries typically support a biota which can tolerate varying salinities and therefore differ from marine and freshwater biotas.
EUPHAUSIID	Any of an order (Euphausiacea) of usually luminescent, shrimp-like crustaceans which are important components of plankton; also known as krill.
EUTROPHIC	Describing a situation in which excess nutrients have led to excessive plant growth; when the plants die and decompose, dissolved oxygen is used up, making the water uninhabitable by animals. Erosion, sewage discharges, fertilizers and detergents speed the process.
FAUNA	The animal life of a community, habitat, or ecosystem.
FECAL COLOFORM (bacteria)	A class of bacteria which are found in the intestinal tracts of mammals, including man. Fecal coliform bacteria are not dangerous themselves, but their abundance is measured in water as an indication of raw sewage and thus the potential for the presence of pathogenic organisms.
FEDERAL WATER POLLUTION CONTROL ACT, as amended	Original title of Clean Water Act.
FLOOD CONTROL BASIN	An area to temporarily hold water to prevent flooding of lands downstream.
FLORA	The plant life of a community, habitat, or ecosystem.
FOLIOSE	Describes having leaves of a specified number or type, or a thin leaflike stratum or layer.
FORB	Any herb that is not a grass or grasslike.
FOOD WEB	A symbolic description of the interdependence of the organisms of a community, based on who eats whom.
GENOTOXIC	Any substance that is toxic to a specific plant or animal as a group.
GEOCHRONOLOGICAL	Relating to the chronology of the earth as indicated by geological data.

GEOSTROPHIC	Current flow resulting from the deflective forces caused by the rotation of the earth.
GILLNET	A curtainlike net, suspended vertically in the water for the purpose of entrapping fish by their gills.
GROIN	A small jetty extending from the shore to prevent beach erosion.
GROUNDWATER	Water in the spaces between soil and rock particles; water under the subsurface from which wells and springs are fed.
HABITAT	A particular place or environment which supports a particular assemblage of organisms. Most habitats are described in terms of physical parameters such as sediment type and water depth, but the concept also includes chemical attributes of the water column and living components (a mussel, for example, provides a place for other organisms to attach).
HAZARDOUS WASTE	A waste or combination of wastes, which may cause or contribute to death or serious illness or pose a potential hazard to human health or the environment.
HEPATOPANCREAS	A glandular organ of a crustacean that combines the digestive functions of the vertebrate liver and pancreas.
HEPTACHLOR	A persistent cyclodiene chlorinated hydrocarbon insecticide, toxic by ingestion, inhalation, and skin absorption. Use has been restricted and discontinued except for termite control.
HEPTACHLOREPOXIDE	Insecticide, a degradation product of heptachlor.
HERBICIDE	A substance which is capable of killing or stunting the growth of plants.
HERBIVORE	An animal that eats plants.
HYDROCARBON	An organic compound composed of the elements hydrogen and carbon; natural gas, coal, and petroleum are important naturally occurring hydrocarbons.
INDICATOR	An organism or ecological community so strictly associated with particular environmental conditions that its presence is indicative of the existence of these conditions.
INDIGENOUS	Native, or belonging to a particular region or local ecosystem; said of plants and animals as well as of humans.
INFAUNA	Collectively, the invertebrates that live in, beneath, and just at the surface of unconsolidated soft sediments.
INSECTICIDE	A substance which is capable of killing insects, either by direct application or by ingestion.
INSOLATION	Solar radiation.

INTERTIDAL	That portion of the shore or structures in the ocean which is between high and low tide levels; the substrate and organisms in the intertidal are alternately covered by seawater and exposed to the air.
KILOGRAM (kg)	A standard metric unit of weight (mass) equivalent to 1,000 grams or about 2.2 pounds.
KILOMETER (km)	A standard metric unit of length (distance) equivalent to 1,000 meters or about 0.6 mile.
LARVA	A young or juvenile stage (of some species) which differs in basic body form from that of the adult; the plural is larvae.
LINDANE	A pesticide (hexachlorocyclohexane) consisting chiefly of the gamma isomer of BHC, which is toxic by ingestion, inhalation, and skin absorption. Its use is restricted.
LIPID	Substances that are soluble in nonpolar organic solvents and includes fats and oils; along with proteins and carbohydrates are major structural components of living cells.
LITER (*l*)	A standard metric unit of volume, equivalent to 1,000 cubic centimeters or 0.26 gal.
MEIOFAUNA	Very small (less than about 0.5 mm) organisms found in sediments.
MEROPLANKTON	Planktonic eggs and larvae of invertebrates and fish.
METABOLISM	The sum total of all chemical processes which go on in an organism and give it life; the major kinds of metabolism include the breakdown of some substance and the synthesis of others.
METER (m)	A standard metric unit of length or distance, the equivalent of about 3.3 feet or 1.1 yard.
METRIC TON (MT)	A standard metric unit of weight (mass), the equivalent of 1,000 kilograms, 2,200 pounds, or 1.1 English tons.
MICROGRAM (μg)	A metric unit of weight which equals one millionth of a gram.
MICROLAYER (Sea Surface)	The very thin, upper surface layer of the ocean, at which organic substances, toxicants, and pathogens accumulate at greater concentrations than in the water column itself.
MILLIGRAM (mg)	A metric unit of weight which equals one thousandth of a gram.
MILLIGRAMS PER LITER (mg/*l*)	Concentration of a substance in water equaling 0.001 g in 1,000 *ml* of water. Approximate equivalent - parts per million.
MILLION GALLONS PER DAY (mgd)	Measure of water or wastewater flow equal to about 0.5 cubic feet per second or 3.78 million liters per day.

MOLLUSC(K)	An invertebrate animal which belongs to the phylum Mollusca and which has an unsegmented body and usually with a hard outer shell. Includes clams, mussels, snails, chitons, squid, and nudibranchs.
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)	Standards for waste discharges from point sources to surface waters (rivers, lakes, bays, oceans, etc.) controlled by state or federal agencies under provisions of Clean Water Act.
NEKTON	Free-swimming aquatic animals, independent of wave and current action.
NEMATODE	Elongated cylindrical worms (round worms) of the phylum Nematoda parasitic in animals or plants or free-living in soil sediments or water.
NEOPLASM	A tumor-like area of (abnormal) cell growth; a new growth of tissue serving no physiological function.
NERITIC	Relating to the region of shallow water (over the continental shelf) adjoining the seacoast.
NITRATE	Ion containing nitrogen and oxygen; its excess in water will stimulate the growth of algae.
NONPOINT SOURCE	A widespread, diffuse, or unidentifiable source of contaminants that comes from more than one point which cannot be controlled or easily monitored; it therefore does not involve an NPDES permit.
NUISANCE WATER	A component of surface runoff which includes street runoff from domestic washdown and irrigation water but not rainfall.
NUTRIENTS	Elements necessary for plant growth. Nitrogen and phosphorous are the most common. Excess nutrients in surface waters stimulate plant and algae growth.
OLIGOCHAETE	An annelid worm of the class Oligochaeta; these are more common on land (e.g. earthworms) than in the sea.
OMNIVORE	A consumer which eats many types of foods, including both plants and animals.
ORGANIC	In the chemical sense, a compound that contains one or more atoms of the element carbon (not applied to simple carbon compounds such as carbon dioxide or cyanide); more generally, produced by, derived from, or having to do with organisms.
PAPILLOMA	A benign tumor due to overgrowth of the epithelial tissue on papillae of vascular connective tissue.
PARTS PER BILLION (ppb)	Number of units per billion units. (e.g. μg/kg)
PARTS PER MILLION (ppm)	Number of units per million units. (e.g. mg/kg)
PELAGIC	Of, in, or pertaining to the water column as opposed to the bottom of the ocean.

PERCOLATION	Movement of water through rock or soil.
PESTICIDE	Any substance which is used to control (usually by killing) pests, including insecticides, herbicides, algicides etc.
pH	A measure of the acidity or alkalinity of a fluid which ranges from 1 to 14. A pH of 7.0 is neutral, while 3 is very acidic and 12 is very alkaline (basic).
PHENOL	Aromatic organic compounds in which one or more hydroxy groups are attached directly to the benzene ring.
PHYTOPLANKTON	Small (generally one-celled) drifting plants including blue-green algae, flagellates and diatoms.
PINNIPEDS	A seal or sea lion, both of which are sometimes placed in the order or suborder Pinnipedia.
PLANKTON	Generally relatively small organisms which drift passively with currents, and are unable to swim against them.
POINT SOURCE	A single source from which contaminants enter the receiving water body; usually a discharge pipe or structure which is regulated under an NPDES permit.
POLLUTANT	In general, the same as a contaminant, i.e. some substance present in an environment at unnatural concentrations or levels. Some persons define a pollutant as a contaminant which has an adverse impact on the environment or which comes from an anthropogenic source.
POLYCHAETE	An annelid worm of the class Polychaeta; these are found only in the ocean.
POLYCHLORINATED BIPHENYLS (PCBs)	An extremely toxic group of industrial chemicals used in capacitors, transformers, and carbonless paper. Manufacture of this product was banned in 1976 and its use discouraged.
PORTER-COLOGNE WATER QUALITY CONTROL ACT	1970 California law defining water rights and pollution control programs.
PRELIMINARY TREATMENT	Initial stage of sewage treatment which includes screening, pulverization, and grit removal.
PRIMARY TREATMENT	Sewage treatment which includes the removal of much of the suspended solids by sedimentation but not colloidal and dissolved matter. It does not include biological oxidation and usually consists of clarification with or without chemical treatment.
PRIMARY CONSUMER	Animals that eat plants.
RAW SEWAGE	Untreated sewage.
REGIONAL WATER QUALITY CONTROL BOARDS	Nine regional boards in California that plan and enforce water quality standards within their boundaries.

RESIDENCE TIME	The estimated, average time that a water parcel spends in a confined or semi-confined region before being exchanged with the open ocean.
RESPIRATION	The collective metabolic processes by which an organism converts stored chemical energy into physical energy in order to remain alive; involves the use of oxygen and the production of carbon dioxide.
RIPARIAN	Area next to a river; bank of a stream.
RUNOFF	Water that is not absorbed into the ground and hence which flows into streams or other bodies of water, or into a drain or sewer.
SALINITY	The standard measure of the "saltiness" of seawater; measured as the weight of salts (primarily sodium chloride) per unit of water and expressed as parts per thousand or grams per liter. The salinity of normal seawater is between 33 and 35 ppt.
SEAWATER INTRUSION	A condition that occurs when seawater enters an aquifer near the coast, generally resulting from the removal of freshwater via wells.
SECONDARY CONSUMER	Animals that eat other animals, particularly primary consumers.
SECONDARY TREATMENT	Sewage treatment that includes the reduction of organic material and solids by bacterial decomposition; about 85% of the BOD and suspended solids are removed. It consists primarily of clarification followed by a biological process to produce sludge.
SEDIMENTATION	Deposition or settlement of suspended matter in water, wastewater, or other liquids.
SESSILE	Permanently attached; not free to move about.
SHELLFISH	Molluscs (such as oysters, clams, and abalone) and crustaceans (such as crab and lobster) which have a hard outer shell or exoskeleton and are of sport or commercial interest.
SLUDGE	The solid material which settles, or is precipitated, out of sewage during the treatment process.
SPOROPHYTE	A young plant developed from a spore
STATE WATER RESOURCES CONTROL BOARD	State agency responsible for water rights and pollution control.
STRATIFIED	Occurring in distinct layers, separated by a sharp difference in some parameter. In the ocean, where the layers are of different densities, the boundary is called a pycnocline. If the difference is in temperature, the sharp difference, the pycnocline, is also a thermocline; if in salinity, it is also a halocline. Freshwater tends to float on top of saltwater and warm water on top of cold water.

SUCCESSION	Unidirectional change in the composition of an ecosystem or ecological community as the competing organisms modify the environment.
SUSPENDED SOLIDS	Organic and inorganic material which is in suspension in seawater or in a waste effluent.
SYNERGISTIC	Having the capacity to work together such that the total effect is greater than the sum of the individual effects.
TEMPERATE	The region between the Tropic of Cancer and the Arctic Circle or between the tropic of Capricorn and the Antarctic Circle; the biota associated with this region.
TERTIARY TREATMENT	Sewage treatment that includes the removal of nutrients (e.g. nitrogen and pholphorus compounds) and most of the remaining suspended solids.
THERMOCLINE	A boundary layer in a thermally stratified body of water that separates upper, warmer, less dense water from lower, colder, denser water.
TOTAL DISSOLVED SOLIDS (TDS)	Solids that are able to pass through a filter but which remain following evaporation; generally consist of salts.
TOXAPHENE	A chlorinated camphene insecticide, toxic by ingestion, inhalation, and skin absorption. Most uses are prohibited; widely used and persistent; used on cotton, tomatoes, and many field crops.
TOXIC	Lethal or damaging to humans or other living animals such as plants, pets, fish, and wildlife.
TRACE METAL	Metallic elements such as cadmium, chromium, lead, nickel, silver, and zinc which occur naturally in "trace" amounts in ocean water. They are of concern because 1) their concentrations may be increased through man's activities; 2) they do not degrade; 3) their concentration may be biomagnified through the food chain; and 4) they may be toxic at high concentrations, even though many are required for the normal functioning of organisms.
TRACER	A chemical (or bacterium) used to track the transport and fate of contaminants from a particular source.
TUNICATE	Any marine chordate having a saclike body enclosed in a thick membrane or tunic.
TURBIDITY	Water cloudiness; determined by the amount of material (living and non-living) which is suspended in a parcel of water. High turbidity reduces the penetration of light.
WASTE DISCHARGE REQUIREMENTS	Waste discharge conditions adversely affecting waters of state and regulated by the Regional Water Quality Control Board and sometimes the State Water Resources Control Board.
WASTEWATER RECLAMATION	A process where pollutants are removed so that the water can be reused.
WASTESHED	The land area encompassing the service area of a municipal wastewater treatment plan.

WASTEWATER	Sewage; a combination of water-carried wastes and liquid from industrial plants, residences, and commercial buildings.
WATERSHED	The total land from which rain water drains into a particular stream, drain, or body of water; the drainage basin.
WETFISH	Fish that are packed in a can first and then cooked; pelagic wetfish in southern California include small schooling species such as Pacific sardine, northern anchovy, chub (=Pacific) mackerel, and jack mackerel, all of which are harvested by purse seine.
WETLANDS	A collective term which describes areas where permanently or frequently wet conditions produce particular plant and animal communities; includes saltmarshes, freshwater marshes, and tidal mudflat habitats.
ZOOPLANKTON	Small drifting animals. See plankton.

APPENDIX C

List of Common and Scientific Names.

Appendix C. List of Common and Scientific Names. Santa Monica Bay Characterization Study.

Common Name	Scientific Name
abalone	*Haliotis spp.*
American kestrel	*Falco sparverius*
amphipod	Amphipoda
anemone	Anthozoa
annelid	Annelida
armed box crab	*Mursia gaudichaudii*
arrow goby	*Clevelandia ios*
arrow worms	Chaetognatha
auklet	Alcidae, unid.
barnacle	Balanus spp.
barnacle	*Chthamalus spp.*
barnacle	Cirripedia
barred sand bass	*Paralabrax nebulifer*
barred surfperch	*Amphistichus argenteus*
basking shark	*Cetorhinus maximus*
bat ray	*Myliobatis californica*
bay shrimp	*Crangon spp.*
beach bloodworm	*Euzonus mucronata*
beach hopper	Talitridae
beach morning glory	*Convolvulus soldanella*
beach primrose	*Camissonia (Oenothera) cheiranthifolia*
bean clam	*Donax gouldi*
Belding's savannah sparrow	*Passerculus sandwichensis beldingi*
bigmouth sole	*Hippoglossina stomata*
black abalone	*Haliotis cracherodii*
black oystercatcher	*Haematopus bachmani*
black perch	*Embiotoca jacksoni*
black rail	*Laterallus jamaicensis*
black turnstone	*Arenaria melanocephala*
blacksmelt	*Bathylagus spp.*
blackspotted bay shrimp	*Crangon nigromaculata*
blacktail jackrabbit	*Lepus californicus*
black-necked stilt	*Himantopus mexicanus*
blood worm	*Glycera dibranchiata*
blue shark	*Prionace glauca*
blue whale	*Balaenoptera musculus*
blue (= bay) mussel	*Mytilus edulis*
bluefish	*Pomatomus saltatrix*
bocaccio	*Sebastes paucispinis*
Bonaparte's gull	*Larus philadelphia*
Botta's (valley) pocket gopher	*Thomomys bottae*
bottlenose dolphin	*Tursiops truncatus*
brittle star	*Amphiodia urtica*
brittle star	Ophiuroidea, unid.
broadtail isopod	*Paracerceis spp.*
brokenspine brittle star	*Ophiura lutkeni*
brown algae	Phaeophyta
brown pelican	*Pelecanus occidentalis occidentalis*
brown rockfish	*Sebastes auriculatus*
bryozoan	Ectoprocta
cabezon	*Scorpaenichthys marmoratus*
California brown pelican	*Pelecanus occidentalis californicus*
California buckwheat	*Eriogonum fasciculatum*
California clingfish	*Gobiesox rhessodon*
California corbina	*Menticirrhus undulatus*

Appendix C (Cont).

Common Name	Scientific Name
California gnatcatcher	*Polioptila californica*
California ground squirrel	*Spermophilus (= citellus) beecheyi*
California grunion	*Leuresthes tenuis*
California gull	*Larus californicus*
California halibut	*Paralichthys californicus*
California killifish	*Fundulus parvipinnis*
California least tern	*Sterna antillarum browni*
California lizardfish	*Synodus lucioceps*
California mussel	*Mytilus californianus*
California poppy	*Eschscholzia californica*
California sagebrush	*Artemisia californica*
California sandstar	*Astropecten verrilli*
California scorpionfish	*Scorpaena guttata*
California sea cucumber	*Parastichopus californicus*
California sea lion	*Zalophus californiensis*
California sea slug	*Pleurobranchaea californiensis*
California sheephead	*Semicossyphus pulcher*
California smoothtongue	*Leuroglossus stilbius*
California spiny lobster	*Panulirus interruptus*
California tonguefish	*Symphurus atricauda*
carinate (= keeled) dovesnail	*Alia carinata*
cattail	*Typha latifolia*
chaparral candle yucca	*Yucca whipplei*
chilipepper	*Sebastes goodei*
chiton	Polyplacophora
chub (= Pacific) mackerel	*Scomber japonicus*
cladoceran	Cladocera
comb jellies	Ctenophora
common dolphin	*Delphinus delphis*
common murre	*Uria aalge*
conejo buckwheat	*Eriogonum crocatum*
copepod	*Calanus pacificus*
cordgrass	*Spartina foliosa*
cormorant	*Phalacrocorax spp.*
cowcod	*Sebastes levis*
crustacean	Crustacea
cumacean	Cumacea
curlfin sole	*Pleuronichthys decurrens*
Dall's porpoise	*Phocoenoides dallii*
damselfish	Pomacentridae, unid.
date mussel	*Lithophaga spp.*
diatoms	Bacilliophycea
Dover sole	*Microstomus pacificus*
dudleya	*Dudleya cymosa marcescens*
eastern brown pelican	*Pelecanus occidentalis carolinensis*
eastern Pacific bobtail squid	*Rossia pacifica*
echinoderm	Echinodermata
eelgrass	*Zostera marina*
El Segundo blue butterfly	*Euphilotes battoides allyni*
encrusting bryozoan	*Membranipora spp.*
English sole	*Pleuronectes (= Parophrys) vetulus*
euphausiid	Euphausiacea, unid.
fantail sole	*Xystreurys liolepis*
feather-boa kelp	*Egregia menziesii*
fine-lined lucine (clam)	*Parvilucina tenuisculpta*
flag rockfish	*Sebastes rubrivinctus*
flathead sole	*Hippoglossoides elassodon*
fragile sea urchin	*Allocentrotus fragilis*
frog	*Hylidae and Ranidae*
giant kelp	*Macrocystis angustifolia* *Macrocystis pyrifera*

Appendix C (Cont).

Common Name	Scientific Name
giant rock scallop	*Crassidoma gigantea*
gigantic plumose anemone	*Metridium gignteum*
Gould beanclam (coquina)	*Donax gouldii*
gray sandstar	*Luidia foliolata*
gray whale	*Eschrichtius robustus*
grebe	Podicipedidae, unid.
greenblotched rockfish	*Sebastes rosenblatti*
greenling	Hexagrammidae, unid.
greenstriped rockfish	*Sebastes elongatus*
Gulf sanddab	*Citharichthys fragilis*
gull	*Larus spp.*
halfblind goby	*Lethops connectens*
halfmoon	*Medialuna californiensis*
harbor porpoise	*Phocoena phocoena*
harbor seal	*Phoca vitulina*
Heermann's gull	*Larus heermanni*
hermit crab	Paguridea
hornyhead turbot	*Pleuronichthys verticalis*
Hottentot fig	*Mesembryanthemum edule*
ice cream cone worm	*Pectinaria californiensis*
ice plant	*Mesembryanthemum spp.*
jack mackerel	*Trachurus symmetricus*
jacksmelt	*Atherinopsis californiensis*
jaeger	*Stercorarius spp.*
jellyfish	Scyphozoa
kelp	*Macrocystis spp., Egregia menziesii*
kelp bass	*Paralabrax clathratus*
kelp clingfish	*Rimicola muscarum*
kelp flies	Coelopidae
kelp gunnel	*Ulivicola sanctarosae*
kelp perch	*Brachyistius frenatus*
kelp pipefish	*Syngnathus californiensis*
kelp rockfish	*Sebastes atrovirens*
kelp scallop	*Leptopecten latiauratus*
kelpfishes	*Gibbonsia spp.*
krill	Euphausiacea
large beach hopper	*Megalorchestia californiana*
laurel sumac	*Rhus larina*
light-footed clapper rail	*Rallus longirostris levipes*
limpets	*Acmaea spp.*
lingcod	*Ophiodon elongatus*
lizard	*Iguanidae, Scincidae, Teiidae, and Anguidae*
longspine combfish	*Zaniolepis latipinnis*
loon	*Gavia spp.*
Lyon's pentachaeta	*Pentacheata lyonli*
marbled godwit	*Limosa fedoa*
Memphill fileclam (file shell)	*Limatula hemphilli*
Mexican fiddler	*Uca crenulata*
Mexican lampfish	*Triphiturus mexicanus*
minke whale	*Balaenoptera acutorostrata*
mollusk	Mollusca
moonsnail	Naticidae, unid.
mysid	Mysidae, unid.
mysid shrimp	Mysidacea
nematode	Nematoda
nematode	Nematoda, unid.
northern anchovy	*Engraulis mordax*
northern elephant seal	*Mirounga angustirostris*
northern fulmar	*Fulmarus glacialis*
northern lampfish	*Stenobrachius leucopsarus*

Appendix C (Cont).

Common Name	Scientific Name
northern right whale dolphin	*Lissodelphis borealis*
ocean shrimp	*Pandalus jordani*
ocean whitefish	*Caulolatilus princeps*
ochre starfish	*Pisaster ochraceus*
octopuses	*Octopus spp.*
olive rockfish	*Sebastes serranoides*
opaleye	*Girella nigricans*
ostracod	*Euphilomedes spp.*
ostracod	Ostracoda
Pacific argentine	*Argentina sialis*
Pacific barracuda	*Sphyraena argentea*
Pacific bonito	*Sarda chiliensis*
Pacific electric ray	*Torpedo californica*
Pacific goose barnacle	*Pollicipes polymerus*
Pacific hake	*Merluccius productus*
Pacific littleneck	*Protothaca staminea*
Pacific purple urchin	*Strongylocentrotus purpuratus*
Pacific rock crab	*Cancer antennarius*
Pacific sand dollar	*Dendraster excentricus*
Pacific sanddab	*Citharichthys sordidus*
Pacific sardine	*Sardinops sagax*
Pacific spiny brittle star	*Ophiothrix spiculata*
Pacific staghorn sculpin	*Leptocottus armatus*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Palos Verdes blue butterfly	*Euphilotes battoides allyni*
pelagic red crab	*Pleuroncodes planipes*
pelagic snail	*Janthina spp.*
peregrine falcon (American)	*Falco peregrinus anatum*
periwinkle	*Littorina spp.*
pickleweed	*Salicornia spp.*
pickleweed	*Salicornia virginica*
piddock clam	Pholadidae, unid.
pile perch	*Rhacochilus (= Damalichthys) vacca*
pink abalone	*Haliotis corrugata*
pink seaperch	*zalemblus rosaceus*
pipefish	Syngnathidae, unid.
pismo clam	*Tivela stultorum*
plainfin midshipman	*Porichthys notatus*
polychaete	*Capitella capitata*
polychaete	*Mediomastus*
polychaete	*Schistomeringos*
polychaete	*Tharyx spp.*
polychaete worms	Polychaeta, unid.
puffin	*Fratercula spp.*
pygmy sperm whale	*Kogia breviceps*
queenfish	*Seriphus politus*
rainbow (= steelhead) trout	*Oncorhynchus mykiss (formerly Salmo gairdneri)*
red algae	Rhodophyta
red fox	*Vulpes fulva*
red sea urchin	*Strongylocentrotus franciscanus*
rex sole	*Errex (= Glyptocephalus) zachirus*
ridgeback rock shrimp (= ridgeback prawn)	*Sicyonia ingentis*
rock crab	*Cancer spp.*
rock lice	*Ligia spp.*
rockfish	*Sebastes spp.*
rockpool blenny	*Hypsoblennius gilberti*
rockweed	*Pelvetia spp.*
rotifer	Rotifera
roundworm	Nematoda, unid.
rubberlip seaperch	*Rhacochilus toxotes*

Appendix C (Cont).

Common Name	Scientific Name
ruddy turnstone	*Arenaria interpres*
sablefish	*Anoplopoma fimbria*
salt bush	*Atriplex spp.*
salt grass	*Distichlis spicata*
saltmarsh bird's beak	*Cordylanthus maritimus ssp. maritimus*
sand crab	*Emerita analoga*
sand flea	Talitridae
sand sole	*Psettichthys melanostictus*
sand verbena	*Abronia maritima*
sanderling	*Calidris alba*
sandflat elbow crab	*Heterocrypta occidentalis*
Santa Susana tarweed	*Hemizonia minthornii*
scale insect	*Haliaspis spartina*
scoter	*Melanitta spp.*
sculpin	Cottidae, unid.
sea bass	Serranidae, unid.
sea cucumber	Holothuroidea
sea fan	Gorgonacea, unid.
sea felt	*Enteromorpha spp.*
sea fig	*Mesembryanthemum chilense*
sea lettuce	*Ulva spp.*
sea moss	Bryozoan, unid.
sea rocket	*Cakile maritima*
sea slug	Nudibranchia
sea squirt	Ascidiacea, unid.
sea star (sand star)	*Astropecten armatus, A. verrilli*
sea urchin	*Strongylocentrotus spp.*
senorita	*Oxyjulis californica*
shark	*Elasmobranchiomorphi (= Chondrichthyes, Elasmobranchii)*
shearwater	*Puffinus spp.*
sheep crab	*Loxorhynchus grandis*
shiner perch	*Cymatogaster aggregata*
shortbelly rockfish	*Sebastes jordani*
shortfin pilot whale	*Globicephala macrorhynchus*
shovelnose guitarfish	*Rhinobatos productus*
shrimp	Natantia
silky axinopsid (clam)	*Axinopsida serricata arvilucina*
silver beachweed	*Ambrosia (Franseria) chamissionis*
slender sole	*Eopsetta (= Lyopsetta) exilis*
small beach hopper	*Traskorchestia traskiana*
speckled sanddab	*Citharichthys stigmaeus*
sperm whale	*Physeter macrocephalus*
spider crab	*Podochela lobifrons*
spiny dogfish	*Squalus acanthias*
spiny sandstar	Astropecten armatus
sponge	Porifera
spoonworm	*Listriolobus pelodes*
spot shrimp (= spot prawn)	*Pandalus platyceros*
spotted kelpfish	*Gibbonsia elegans*
spotted sandpiper	*Actitus macularia*
squid	Teuthoidea
starry flounder	*Platichthys stellatus*
stingray	Dasyatididae, unid.
storm-petrel	*Oceanodroma spp.*
striped shore crab	*Pachygrapsus crassipes*
stripetail rockfish	*Sebastes saxicola*
summer flounder	*Paralichthys dentatus*
surfbird	*Aphriza virgata*
surfgrass	*Phyllospadix spp.*

Appendix C (Cont).

Common Name	Scientific Name
swordfish	*Xiphias gladius*
tern	*Sterna spp.*
thresher shark	*Alopias vulpinus*
tidewater goby	*Eucyclogobius newberryi*
toad	*Pelobatidae and Bufonidae*
topsmelt	*Atherinops affinis*
toyon	*Heteromeles arbutifolia*
tuberculate pear crab	*Pyromaia tuberculata*
tule	*Scirpus spp.*
tunicate	Ascidiacea
turban	*Tegula spp.*
turkey vulture	*Cathartes aura*
vermilion rockfish	*Sebastes miniatus*
walleye surfperch	*Hyperprosopon argenteum*
wandering skipper	*Panoquina errans*
wandering tattler	*Heteroscelus incanus*
warty sea cucumber	*Parastichopus parvimensis*
weakfish	*Cynoscion regalis*
western fence lizard	*Sceloporus occidentalis*
western gull	*Larus occidentalis*
western meadowlark	*Sturnella neglecta*
western mosquitofish	*Gambusia affinis*
western snowy plover	*Charadrius alexandrinus nivosus*
western sycamore	*Platanus racemosa*
western (southern Pacific) rattlesnake	*Crotalus viridis helleri*
whale	Cetacea
whimbrel	*Numenius phaeopus*
white alder	*Alnus rhombifolia*
white croaker	*Genyonemus lineatus*
white sea bass	*Atractoscion nobilis*
white sea urchin	*Lytechinus pictus (= L. anamesus)*
white seaperch	*Phanerodon furcatus*
wild buckwheat	*Eriogonum parvifolium*
wild lilac	*Ceanothus spp.*
willet	*Catoptrophorus semipalmatus*
willow	*Salix spp.*
winter flounder	*Pleuronectes (= Pseudopleuronectes) americanus*
woolly sculpin	*Clinocottus analis*
wrasse	Labridae, unid.
yellow rock crab	*Cancer anthonyi*
yellowchin sculpin	*Icelinus quadriseriatus*
yellowtail	*Seriola lalandi*

APPENDIX D

Concentrations and Mass Emissions of Contaminants from Wastewater Treatment Plants.

Appendix D-1. Average concentrations of constituents in the HTP 5-mi effluent, 1974-1992.

Year	1974	1975[a]	1976	1977	1978[b]	1979	1980	1981	1982	1983	1984	1985
Flow (mgd)	341	345	359	319	341	353	363	369	375	411	404	389
liters/day x 10(6)	1291	1306	1359	1207	1291	1336	1374	1397	1419	1556	1529	1472
GENERAL CONSTITUENTS (mg/l)												
Total Suspended Solids	83	85	77	62	66	75	77	77	77	102	118	162
Settleable solids (ml/l)					0.5	0.9	0.9	0.9	0.9	1.3	1.5	2.5
BOD (5-day)	121	125	125	145	148	144	158	169	176	183	183	254
Oil and Grease	18	20	20	19	19	19	14	22	20	19.0	19	29
Nitrate Nitrogen	0.3										<0.5	<0.5
Ammonia Nitrogen	13.8	13.9	14.6	17.2	15.9	16.7	16.5	16.1	14.8	14.5	14.0	16.6
Organic Nitrogen	6.3				7.3	8.2	8.4	7.3	8.2	8.4	8.7	11.5
Total Phosphorus	24.3	9.0	5.7	7.6	6.8	6.5	7.1	6.9	6.0	6.5	6.8	6.7
Detergent (MBAS)	5.1	3.9	4.3	4.2	3.6	4.1	4.5	4.1	4.1	3.2	3.5	4.2
Cyanide (CN)	0.20	0.14	0.11	0.14	0.15	0.09	0.09	0.08	0.06	0.04	0.02	0.03
Phenols	0.06	0.04	0.05	0.06	0.05	0.06	0.06	0.06	0.06	0.064	0.047	0.045
TRACE METALS (mg/l)												
Silver	0.020	0.020	0.010	0.030	0.030	0.044	0.030	0.025	0.020	0.015	0.015	0.026
Arsenic	0.010	0.010	0.010	0.010	0.010	0.013	0.010	0.012	<0.005	0.007	0.010	0.012
Cadmium	0.020	0.020	0.020	0.020	0.018	0.020	0.020	0.017	0.010	0.013	0.009	0.011
Chromium	0.210	0.130	0.190	0.130	0.080	0.070	0.090	0.054	0.090	0.080	0.070	0.060
Copper	0.190	0.190	0.170	0.200	0.190	0.190	0.180	0.200	0.140	0.150	0.140	0.200
Mercury	0.0032	0.0020	0.0015	0.0210	0.0010	0.0025	0.0010	0.0007	0.0007	0.0006	0.0004	0.0005
Nickel	0.180	0.150	0.180	0.180	0.220	0.160	0.140	0.108	0.090	0.090	0.070	0.080
Lead	0.040	0.030	0.030	0.030	0.090	0.150	0.090	0.050	0.050	0.030	0.055	0.090
Selenium	0.020	0.020	0.020	0.010	0.030	0.002	0.010	0.001	<0.005	<0.005	<0.005	<0.005
Zinc	0.240	0.230	0.220	0.320	0.300	0.310	0.330	0.217	0.180	0.170	0.160	0.280
CHLORINATED HYDROCARBONS (ug/l)												
Total DDT	0.72	1.63	1.30	0.20	0.16	0.18	0.10	0.05	0.06	0.03	0.03	0.02
Total PCB	0.36	3.92	3.31	2.13	2.82	0.62	0.67	0.76	<0.1	<0.2	<0.2	0.1

Appendix D1 (Cont).

Year	1986	1987	1988	1989	1990	1991	1992[c]	Survey Totals n	Mean	Std. Dev.	C.V.
Flow (mgd)	393	375	363	365	354	315	298	19	360	29	8
liters/day x 10(6)	0	0	0	0	0	0	0	19	1361	112	8
GENERAL CONSTITUENTS (mg/l)											
Total Suspended Solids	76	58	49	33	30	33	38	19	73	32	44
Settleable solids (ml/l)	0.8	0.8	0.4	0.3	0.3	0.3	0.2	15	0.8	0.6	72
BOD (5-day)	151	116	108	90	93	83	83	19	140	43	31
Oil and Grease	21.3	15	14	13	11	10	12	19	18	5	26
Nitrate Nitrogen	0.3	0.5	0.5	0.5	0.3	0.3	0.3	10	0.3	0.2	62
Ammonia Nitrogen	16.0	16.2	21.9	19.0	22.3	25.8	24.7	19	17	4	21
Organic Nitrogen	7.6	6.4	5.9	5.6	5.4	5.5	5.9	16	7.3	1.6	22
Total Phosphorus	5.4	2.9	4.7	4.1	5.0	4.7	5.1	19	6.9	4.4	64
Detergent (MBAS)	4.4	2.8						14	4.0	0.6	14
Cyanide (CN)	0.02	0.03	0.02	0.02	0.01	0.02	0.03	19	0.07	0.06	83
Phenols	0.04	0.04	0.00	0.00	0.00	0.00	0.00	19	0.04	0.02	62
TRACE METALS (mg/l)											
Silver	0.017	0.010	0.007	0.007	0.006	0.006	0.006	19	0.018	0.011	59
Arsenic	0.009	0.008	0.008	0.006	0.004	0.005	0.005	19	0.008	0.003	38
Cadmium	0.009	0.007	0.001	0.0004	0.001	0.0003	0.0002	19	0.011	0.008	70
Chromium	0.040	0.017	0.006	0.004	0.006	0.004	0.005	19	0.070	0.061	87
Copper	0.121	0.058	0.049	0.038	0.038	0.038	0.033	19	0.132	0.067	50
Mercury	0.0003	0.0001	0.0003	0.0002	0.0002	0.0002	0.00004	19	0.002	0.005	246
Nickel	0.110	0.056	0.046	0.028	0.016	0.017	0.014	19	0.102	0.064	63
Lead	0.040	0.043	0.045	0.018	0.003	0.003	0.001	19	0.047	0.037	79
Selenium	0.001							13	0.009	0.010	119
Zinc	0.218	0.174	0.079	0.074	0.069	0.113	0.070	19	0.198	0.088	44
CHLORINATED HYDROCARBONS (ug/l)											
Total DDT	[d]	<0.02	0	0	0	0.003	0	19	0.24	0.47	198
Total PCB	0.02	<0.1	0	0	0	0	0	19	0.77	1.27	164

a. For Chlorinated Hydrocarbons Project Values: Analyses of two 1-week composite samples of each effluent.
b. Project value for DDT based on 52 weekly composites.
c. Values for 1992 based on data January to October extrapolated to 12 months.
d. DDD, DDE, and DDT (p,p and o,p) were all <0.02.
Source: Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; CLA, DWP 1987, 1988, 1989, 1990, 1991, 1992; Cressey, R. 1992 HTP, pers. comm.

Appendix D-2. Annual mass emissions of constituents in the HTP 5-mi effluent, 1974-1992.

Year	1974	1975[a]	1976	1977	1978[b]	1979	1980	1981	1982	1983	1984	1985
Flow (mgd)	341	345	359	319	341	353	363	369	375	411	404	389
liters/day x 10(6)	1291	1306	1359	1207	1291	1336	1374	1397	1419	1556	1529	1472
GENERAL CONSTITUENTS (MT/yr)[d]												
Total Suspended Solids	39101	40513	38189	27324	31092	36576	38615	39253	39891	57916	65860	87061
Settleable solids (l/yrx10(6))					236	439	451	459	466	738	837	1344
BOD (5-day)	57003	59578	61996	63902	69723	70225	79236	86153	91180	103908	102139	136502
Oil and Grease	8480	9532	9919	8373	8951	9266	7021	11215	10361	10788	10605	15585
Nitrate Nitrogen	141										140	134
Ammonia Nitrogen	6501	6625	7241	7580	7490	8144	8275	8207	7667	8233	7814	8921
Organic Nitrogen	2968				3439	3999	4213	3721	4248	4753	4856	6180
Total Phosphorus	11448	4290	2827	3349	3203	3170	3561	3517	3108	3668	3795	3601
Detergent (MBAS)	2403	1859	2133	1851	1696	1999	2257	2100	2124	1828	1948	2257
Cyanide (CN)	94.2	66.7	54.6	61.7	70.7	43.9	45.1	40.8	31.1	25.0	11.2	14.0
Phenols	28.3	19.1	24.8	26.4	23.6	29.3	30.1	30.6	32.1	36.3	26.2	24.2
TRACE METALS (MT/yr)												
Silver	9.4	9.5	5.0	13.2	14.1	21.5	15.0	12.7	10.4	8.5	8.4	14.0
Arsenic	4.7	4.8	5.0	4.4	4.7	6.3	5.0	6.1	1.3	4.0	5.6	6.4
Cadmium	9.4	9.5	9.9	8.8	8.5	9.8	10.0	8.7	5.2	7.4	5.0	5.9
Chromium	98.9	62.0	94.2	57.3	37.7	34.1	45.1	27.5	46.6	45.4	39.1	32.2
Copper	89.5	90.6	84.3	88.1	89.5	92.7	90.3	102.0	72.5	85.2	78.1	107.5
Mercury	1.5	1.0	0.7	9.3	0.5	1.2	0.5	0.4	0.4	0.3	0.2	0.3
Nickel	84.8	71.5	89.3	79.3	103.6	78.0	70.2	55.1	46.6	51.1	39.1	43.0
Lead	18.8	14.3	14.9	13.2	42.4	73.2	45.1	25.5	25.9	17.0	30.7	48.4
Selenium	9.4	9.5	9.9	4.4	14.1	1.0	5.0	0.5	1.3	1.4	1.4	1.3
Zinc	113	110	109	141	141	151	165	111	93	97	89	150
CHLORINATED HYDROCARBONS (MT/yr)												
Total DDT	0.339	0.777	0.646	0.088	0.075	0.088	0.050	0.025	0.031	0.017	0.017	0.011
Total PCB	0.170	1.868	1.640	0.939	1.330	0.300	0.336	0.387	0.026	0.057	0.056	0.054

Appendix D2 (Cont).

Year	1986	1987	1988	1989	1990	1991	1992 [c]	Survey Totals n	Mean	Std. Dev.	C.V.
Flow (mgd)	393	375	363	365	354	315	298	19	360	29	8
liters/day x 10(6)	1488	1420	1374	1382	1340	1192	1128	19	1361	112	8
GENERAL CONSTITUENTS (MT/yr) [d]											
Total Suspended Solids	41263	29845	24573	16640	14672	14361	18773	19	36922	18137	49
Settleable solids (l/yrx10(6))	434	395	201	151	147	131	99	15	435	332	76
BOD (5-day)	81984	60080	54161	45383	45482	36120	41005	19	70829	25226	36
Oil and Grease	11565	7779	7021	6555	5380	4352	5928	19	8878	2619	30
Nitrate Nitrogen	179	249	254	273	136	143	132	10	178	57	32
Ammonia Nitrogen	8687	8401	10983	9581	10906	11228	12203	19	8668	1606	19
Organic Nitrogen	4126	3321	2959	2824	2641	2393	2893	16	3721	999	27
Total Phosphorus	2948	1524	2349	2053	2457	2066	2530	19	3446	2060	60
Detergent (MBAS)	2400	1469						14	2023	269	13
Cyanide (CN)	9.2	14.0	9.0	9.1	6.6	9.4	14.5	19	33.2	26.3	79
Phenols	20.6	21.8	0.5	0.4	0.2	0.9	2.1	19	19.9	12.4	62
TRACE METALS (MT/yr)											
Silver	9.2	5.2	3.5	3.5	3.0	2.5	3.2	19	9.0	5.2	57
Arsenic	4.8	4.4	4.0	3.0	2.0	2.2	2.5	19	4.3	1.5	35
Cadmium	4.9	3.4	0.7	0.2	0.3	0.1	0.1	19	5.7	3.8	68
Chromium	21.7	9.0	3.0	2.0	2.9	1.8	2.5	19	34.9	29.3	84
Copper	65.7	30.1	24.6	19.2	18.6	16.5	16.3	19	66.4	33.1	50
Mercury	0.2	0.1	0.2	0.1	0.1	0.1	0.02	19	0.9	2.1	233
Nickel	59.7	28.9	23.1	14.1	7.8	7.4	6.9	19	50.5	30.1	60
Lead	21.7	22.4	22.6	9.1	1.2	1.1	0.7	19	23.6	18.3	78
Selenium	0.5							13	4.6	4.6	100
Zinc	118	90	40	37	34	49	34.6	19	99	43	43
CHLORINATED HYDROCARBONS (MT/yr)											
Total DDT	0	0.005	0	0	0	0.001	0.0	19	0.11	0.23	197
Total PCB	0.011	0.026	0	0	0	0	0.0	19	0.38	0.60	159

a. For Chlorinated Hydrocarbons Project Values: Analyses of two 1-week composite samples of each effluent.
b. Project value for DDT based on 52 weekly composites.
c. Mass Emmissions for 1992 based on data from January to October extrapolated to 12 months.
d. Less than values calculated at 1/2 minimum detection level.
Source: Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984, SCCWRP 1986c; CLA, DWP 1987, 1988, 1989, 1990, 1991, 1992; Cressey, R. 1992 HTP, pers. comm.

Appendix D-3. Average concentrations of constituents in the JWPCP effluent, 1974-1992.

Year	1974[a]	1975[b]	1976	1977	1978[c]	1979	1980	1981	1982	1983	1984	1985
Flow (mgd)	346	341	353	335	345	367	374	364	359	353.3	351	362
liters/day x 10(6)	1310	1291	1336	1268	1306	1389	1416	1378	1359	1337	1329	1370
GENERAL CONSTITUENTS (mg/l)												
Total Suspended Solids	276	278	284	220	219	195	176	167	164	189	103	87
Settleable solids (ml/l)					1.3	0.8	0.3	0.3	0.4	0.9	0.4	0.4
BOD (5-day)	213	209	231	220	204	204	208	202	199	176	146	126
Oil and Grease	55	61	63	46	46	40	32	23	25	28	16	14
Nitrate Nitrogen (NO3-N)	0.15										<0.10	0.48
Ammonia Nitrogen	39	38	36	39	40	40	40	39	41	41	37	37
Organic Nitrogen	15.7				14.9	13.7	13.4	14.0	12.5	12.0	11.4	9.4
Total Phosphorus	14.7	13.2	12.8	13.0	11.2	9.9	9.4	9.2	9.1	8.8	8.8	8.2
Detergent (MBAS)[d]	6.85	7.10	6.50	6.30	7.70	7.00	6.29	5.37	5.61	5.60	4.63	4.10
Cyanide (CN)	0.43	0.33	0.32	0.24	0.18	0.17	0.12	0.08	0.06	0.04	0.04	0.02
Phenols	3.31	4.13	3.48	3.30	3.08	2.60	2.33	2.85	2.53	2.57	1.95	1.46
TRACE METALS (mg/l)												
Silver	0.012	0.013	0.013	0.008	0.014	0.019	0.010	0.008	0.011	0.010	0.009	0.010
Arsenic	0.025	<0.011	0.007	0.009	0.011	0.010	0.005	0.005	0.007	0.006	0.020	0.013
Cadmium	0.041	0.036	0.026	0.025	0.030	0.027	0.020	0.016	0.011	0.015	0.008	0.005
Chromium	0.86	0.80	0.75	0.38	0.34	0.26	0.31	0.21	0.19	0.14	0.11	0.08
Copper	0.60	0.42	0.41	0.25	0.26	0.22	0.19	0.15	0.13	0.13	0.09	0.07
Mercury	0.001	0.001	0.001	0.001	0.001	0.001	0.0008	0.0018	0.0008	0.0009	0.0006	0.0004
Nickel	0.31	0.28	0.32	0.24	0.27	0.21	0.20	0.15	0.15	0.15	0.11	0.08
Lead	0.26	0.25	0.22	0.19	0.19	0.15	0.12	0.09	0.08	0.08	0.05	0.05
Selenium	0.012	<0.013	0.011	0.016	0.010	0.013	0.010	0.029	0.012	0.013	0.013	0.011
Zinc	1.79	1.45	1.32	0.84	0.94	0.69	0.60	0.50	0.51	0.52	0.27	0.19
CHLORINATED HYDROCARBONS (ug/l)												
Total DDT	3.01	2.33	1.92	1.58	2.04	1.25	1.05	0.84	0.45	0.38	0.48	0.07
Total PCB	10.8	10.95	2.93	2.46	1.76	1.02	0.65	0.54	0.47	0.51	0.63	0.02

Appendix D3 (Cont).

Year	1986	1987	1988	1989	1990	1991	1992 [f]	Survey Totals n	Mean	Std. Dev.	C.V.
Flow (mgd)	364	366	375	382	372	330	333	19	356	15	4
liters/day x 10(6)	1378	1385	1419	1446	1408	1249	1260	19	1349	57	4
GENERAL CONSTITUENTS (mg/l) [e]											
Total Suspended Solids	82	73	70	65	63	70	68	19	150	80	53
Settleable solids (ml/l)	0.3	0.3	0.2	0.3	0.1	0.2		14	0.4	0.3	75
BOD (5-day)	100	108	112	109	106	103	99	19	162	50	31
Oil and Grease	10	11	14	12	12	13	14	19	28	18	65
Nitrate Nitrogen (NO3-N)	0.52	0.50						5	0.3	0.2	72
Ammonia Nitrogen	40	38	35	38	37	38	37	19	38	2	4
Organic Nitrogen	8.0	7.4	7.8	8.2	7.4	7.9	7.0	16	10.7	3.1	29
Total Phosphorus	8.1	7.5	7.6	7.3	7.2	7.9	6.2	19	9.5	2.4	25
Detergent (MBAS) [d]	2.80	3.30	3.60	3.70	3.90	4.40	3.14	19	5.2	1.5	30
Cyanide (CN)	0.02	<0.02	0.03	0.01	0.01	0.01	<0.012	19	0.11	0.13	118
Phenols	1.60	2.00	2.04	1.33	1.21	1.07	0.54	19	2.3	0.9	41
TRACE METALS (mg/l)											
Silver	0.008	0.008	0.007	0.008	0.008	0.008	<0.007	19	0.010	0.004	39
Arsenic	0.007	0.007	0.006	0.005	0.009	0.004	0.003	19	0.008	0.006	69
Cadmium	0.004	0.002	0.003	0.002	0.001	0.002	<0.001	19	0.014	0.013	91
Chromium	0.06	0.05	0.04	0.03	0.02	0.02	<0.035	19	0.24	0.27	112
Copper	0.05	0.04	0.04	0.04	0.03	0.03	0.03	19	0.17	0.16	97
Mercury	0.0004	0.0003	0.0005	0.0004	0.0004	0.0005	<0.0005	19	0.001	0.000	58
Nickel	0.06	0.05	0.05	0.05	0.04	0.04	0.03	19	0.15	0.10	68
Lead	0.06	0.05	0.036	0.025	0.012	0.008	<0.009	19	0.10	0.08	83
Selenium	0.014	0.013	0.012	0.013	0.013	0.014		18	0.013	0.005	41
Zinc	0.16	0.12	0.14	0.13	0.09	0.09	0.08	19	0.55	0.51	93
CHLORINATED HYDROCARBONS (ug/l)											
Total DDT	0.07	0.06	0.004	0.002	0.002	0.009	0.009	19	0.82	0.94	115
Total PCB	0	0	nd	nd	nd	nd	nd	19	1.72	3.34	194

a. For Total PCB, the average concentration for January to September was 4.72; for October to December, 29.1.
b. For Chlorinated hydrocarbons Project values: Analyses of two 1-week composite samples of each effluent.
c. Project value for DDT based on 52 weekly composites.
d. MBAS is Methylene blue active substances.
e. Less than values calculated at 1/2 minimum detection level.
c. Values for 1992 based on data January to October extrapolated to 12 months.
Sources: Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; Stuil 1988, pers. comm.; Horvath 1992, pers. comm.

Appendix D-4. Annual mass emissions of constituents in the JWPCP effluent, 1974-1992.

Year	1974[a]	1975[b]	1976	1977	1978[c]	1979	1980	1981	1982	1983	1984	1985
Flow (mgd)	346	341	353	335	345	367	374	364	359	353.3	351	362
liters/day x 10(6)	1310	1291	1336	1268	1306	1389	1416	1378	1359	1337	1329	1370
GENERAL CONSTITUENTS (MT/yr)												
Total Suspended Solids	131930	130966	138501	101818	104381	98869	90938	83980	81339	92054	49946	43510
Settleable solids (l/yrx10(6))					620	406	155	151	198	443	194	200
BOD (5-day)	101816	98460	112507	101818	97232	103432	107472	101581	98698	85660	70798	63014
Oil and Grease	26338	28926	30480	21336	21925	20230	16637	11717	12151	13637	7759	7002
Nitrate Nitrogen (NO3-N)	72										24	240
Ammonia Nitrogen	18403	17713	17703	18050	18827	20331	20461	19763	20335	19870	17942	18654
Organic Nitrogen	7505				7102	6946	6924	7040	6200	5867	5528	4701
Total Phosphorus	7027	6219	6242	6017	5338	5019	4857	4626	4508	4285	4267	4101
Detergent (MBAS)[d]	3274	3345	3170	2916	3670	3549	3250	2700	2782	2733	2245	2050
Cyanide (CN)	206	155	156	111	86	86	62	40	30	19	19	10
Phenols	1582	1946	1697	1527	1468	1318	1204	1433	1255	1256	946	730
TRACE METALS (MT/yr)												
Silver	5.7	6.1	6.3	3.7	6.7	9.6	5.2	4.0	5.6	5.1	4.4	5.0
Arsenic	12.0	2.6	3.4	4.2	5.2	5.1	2.6	2.5	3.5	3.1	9.7	6.5
Cadmium	19.6	17.0	12.7	11.6	14.3	13.7	10.3	8.0	5.5	7.4	3.9	2.5
Chromium	411	377	366	176	162	130	160	106	94	70	53	40
Copper	287	198	200	116	124	112	98	77	63	62	43	34
Mercury	0.5	0.5	0.7	0.5	0.7	0.5	0.4	0.9	0.4	0.4	0.3	0.2
Nickel	148	132	156	111	129	106	103	74	74	75	53	40
Lead	124	118	107	88	91	74	62	45	40	41	24	25
Selenium	5.7	3.1	5.4	7.4	4.8	6.6	5.2	14.6	6.1	6.5	6.3	5.5
Zinc	856	683	644	389	448	350	310	251	253	254	131	95
CHLORINATED HYDROCARBONS (MT/yr)												
Total DDT	1.44	1.10	0.94	0.73	0.97	0.63	0.54	0.42	0.22	0.18	0.23	0.04
Total PCB	5.16	5.16	1.43	1.14	0.84	0.52	0.34	0.27	0.23	0.25	0.31	0.01

Appendix D4 (Cont).

Year	1986	1987	1988	1989	1990	1991	1992[f]	Survey Totals n	Mean	Std. Dev.	C.V.
Flow (mgd)	364	366	375	382	372	330	333	19	356	15	4
liters/day x 10(6)	1378	1385	1419	1446	1408	1249	1260	19	1349	57	4
GENERAL CONSTITUENTS (MT/yr)											
Total Suspended Solids	41236	36912	36265	34303	32377	31913	37540	19	73620	37735	51
Settleable solids (l/yrx10(6))	151	152	104	158	51	91		14	220	158	72
BOD (5–day)	50288	54609	58024	57524	54476	46958	54654	19	79948	23655	30
Oil and Grease	5029	5562	7149	6386	6064	6109	7453	19	13784	8594	62
Nitrate Nitrogen (NO3–N)	261	253						5	170	113	66
Ammonia Nitrogen	20115	19164	18236	20160	18810	17233	20216	19	19052	1072	6
Organic Nitrogen	4023	3742	4036	4327	3803	3588	3870	16	5325	1457	27
Total Phosphorus	4073	3792	3948	3874	3711	3588	3439	19	4681	1038	22
Detergent (MBAS)[d]	1408	1669	1865	1953	2004	2006	1733	19	2543	709	28
Cyanide (CN)	10	5	16	5	5	5	3	19	54	62	115
Phenols	805	1011	1057	702	622	488	297	19	1123	441	39
TRACE METALS (MT/yr)											
Silver	4.0	4.0	3.6	4.2	4.1	3.6	1.8	19	4.9	1.6	33
Arsenic	3.5	3.5	3.1	2.6	4.6	1.8	1.9	19	4.3	2.6	61
Cadmium	2.0	1.0	1.6	1.1	0.5	0.9	0.3	19	7.0	6.3	89
Chromium	30	26	19	16	9	7	10	19	119	131	110
Copper	26	21	19	18	16	13	15	19	81	77	95
Mercury	0.2	0.2	0.3	0.2	0.2	0.2	0.1	19	0.4	0.2	54
Nickel	30	26	26	26	22	17	19	19	72	48	66
Lead	30	25	19	13	6	4	3	19	49	40	80
Selenium	7.0	6.6	6.2	6.7	6.6	6.5		18	6.5	2.3	35
Zinc	80	61	73	69	45	42	45	19	267	244	91
CHLORINATED HYDROCARBONS (MT/yr)											
Total DDT	0.04	0.03	0.002	0.001	0.001	0.004	0.005	19	0.40	0.45	114
Total PCB	0	0	nd	nd	nd	nd	nd	19	0.82	1.58	192

a. For Total PCB, the average concentration for January to September was 4.72; for October to December, 29.1.

b. For Chlorinated hydrocarbons Project values: Analyses of two 1–week composite samples of each effluent.

c. Project value for DDT based on 52 weekly composites.

d. MBAS is Methylene blue active substances.

e. Less than values calculated at 1/2 minimum detection level.

f. Mass emissions for 1992 are extrapolated to 12 months based on January to October data.

Sources: Mitchell and McDermott 1975; Schafer 1976, 1977, 1978, 1980, 1982, 1984; SCCWRP 1986c; Stull 1988, pers. comm.; Horvath 1992, pers. comm.

Appendix D-5. Average concentrations of constituents in the TWRF effluent, 1974-1992.

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Flow (mgd)	0.4	0.84	1.3	1.22	4.5	4.0	3.3	1.8	2.0	3.3	4.1	4.4
liters/day x 10(6)	2	3	5	5	17	15	12	7	8	12	16	17
GENERAL CONSTITUENTS (mg/l)												
Total Suspended Solids	3.0	3.0	3.0	5.5	3.9	4.7	4.6	2.2	2.4	3.4	3.3	2.6
Settleable solids	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Oil and Grease	1.7	0.4	0.7	1.2	<1.2	1.2	2.1	1.6	<1	<1	<1	<1
BOD (5–day)	3.0	3.0	3.7	5.2	3.4	4.9	5.3	3.2	2.3	2.5	3.2	2.5
Total Nitrogen	16.00	16.80	17.10	16.21	16.40	17.75	18.53	18.16	17.18	15.25	15.02	16.37
Phosphorus (PO4–P)	10.0	9.7	9.4	9.1	7.0	7.6	7.1	7.5	8.2	6.3	6.6	6.3
Detergent (MBAS)	0.60	0.10	0.04	0.07	0.11	0.10	0.13	0.09	0.08	0.05	0.05	0.05
Cyanide (CN)		<0.001	<0.004	0.008	<0.002	0.008	0.0014	0.024	0.020	<0.003	<0.050	<0.050
Phenols	<0.950	<0.010	<0.030	0.010	0.010	0.011	<0.002	0.006	<0.004	<0.001	<0.100	NA
TRACE METALS (mg/l)												
Silver		0.001	0.010	0.017	<0.002	<0.002	0.003	0.001	<0.010	0.006	0.019	0.050
Arsenic		0.002	0.003	0.020	0.003	<0.001	<0.001	0.010	<0.010	<0.040	<0.001	0.010
Cadmium	0.007	0.007	0.004	0.003	0.002	<0.010	0.005	0.001	<0.010	0.020	0.004	0.004
Chromium		0.005	0.004	0.006	0.001	<0.005	0.011	0.002	<0.010	0.036	0.006	0.018
Copper	0.160	0.050	0.019	0.008	0.017	<0.002	0.036	0.012	0.020	0.016	0.020	0.016
Mercury		0.0002	0.0004	0.001	<0.001	<0.001	0.0002	<0.002	<0.002	<0.001	<0.002	<0.002
Nickel	0.060	0.036	0.030	0.019	0.033	0.170	0.020	0.003	<0.050	0.049	0.025	0.030
Lead	0.033	0.051	0.018	0.028	0.007	<0.020	0.040	0.018	<0.100	0.043	0.024	0.020
Zinc	0.190	0.110	0.080	0.044	0.046	0.018	0.056	0.065	0.500	0.042	0.030	0.130

Appendix D5 (Cont).

Year	1986	1987	1988	1989	1990	1991	1992 [a]	Survey Totals n	Mean	Std. Dev.	C.V.
Flow (mgd)	4.0	2.8	2.9	2.6	2.3	2.7	2	19	2.7	1.2	46
liters/day x 10(6)	15	11	11	10	9	10	8	19	10	4.6	46
GENERAL CONSTITUENTS (mg/l)											
Total Suspended Solids	2.7	2.3	2.5	2.5	2.6	2.1	1.9	19	3.1	1.0	32
Settleable solids	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	19	-	-	-
Oil and Grease	<1	<1	<1	<1	<1	<1	<1	19	0.5	0.7	153
BOD (5-day)	2.6	2.3	2.6	2.4	2.7	3.1	2.6	19	3.2	1.0	30
Total Nitrogen	15.60	17.82	18.88	19.55	18.76	21.41	17.88	19	17.4	1.6	9
Phosphorus (PO4-P)	5.6	5.7	5.5	6.0	5.8	6.1	5.4	19	7.1	1.5	21
Detergent (MBAS)	0.06	0.06	0.07	0.05	0.05	0.07	<0.09	19	0.1	0.1	130
Cyanide (CN)	<0.050	0.006	0.007	<0.050	0.012	<0.04	<0.01	18	0.005	0.007	153
Phenols	0.300	<0.005	<0.005	<0.100	0.031	<0.01	<0.01	19	0.019	0.068	353
TRACE METALS (mg/l)											
Silver	0.005	<0.004	0.003	0.002	<0.005	<0.010	<0.009	18	0.007	0.012	189
Arsenic	<0.050	<0.001	0.004	<0.010	<0.005	<0.030	<0.011	18	0.003	0.005	185
Cadmium	0.002	<0.006	<0.003	<0.003	<0.005	<0.005	<0.004	19	0.003	0.005	153
Chromium	0.006	<0.003	<0.003	0.003	<0.010	<0.010	<0.008	18	0.005	0.009	165
Copper	0.021	<0.010	<0.002	0.010	0.010	<0.032	<0.05	19	0.022	0.036	164
Mercury	<0.002	<0.001	<0.0002	<0.001	<0.002	<0.0002	<0.200	18	0.0001	0.0002	281
Nickel	0.020	<0.014	<0.010	0.010	<0.040	<0.045	<0.05	19	0.027	0.039	147
Lead	0.030	<0.011	<0.030	<0.030	0.002	<0.010	<0.009	19	0.017	0.017	104
Zinc	0.037	<0.029	0.029	0.039	0.032	0.036	<0.05	19	0.078	0.112	143

a. Values for 1992 are based on data from January to October extrapolated to 12 months.

Sources: Los Virgenes Municipal Water District; Whitbeck, S. 1992, TWRF, LVMWD, pers. comm.

Appendix D-6. Annual mass emissions of constituents in the TWRF effluent, 1974-1992.

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Flow (mgd)	0.4	0.84	1.3	1.22	4.5	4.0	3.3	1.8	2.0	3.3	4.1	4.4
liters/day x 10(6)	2	3	5	5	17	15	12	7	8	12	16	17
GENERAL CONSTITUENTS (MT/yr) [b]												
Total Suspended Solids	1.7	3.5	5.4	9.3	24.2	26.0	21.0	5.5	6.6	15.5	18.7	15.8
Settleable solids	0.03	0.06	0.09	0.08	0.31	0.28	0.23	0.12	0.14	0.23	0.28	0.30
Oil and Grease	0.94	0.46	1.26	2.02	3.73	6.63	9.57	3.98	1.38	2.28	2.83	3.04
BOD (5–day)	1.7	3.5	6.6	8.8	21.1	27.1	24.2	8.0	6.4	11.4	18.1	15.2
Total Nitrogen	8.8	19.5	30.7	27.3	102.0	98.1	84.5	45.2	47.5	69.5	85.1	99.5
Phosphorus (PO4–P)	5.5	11.3	16.9	15.3	43.5	42.0	32.4	18.7	22.7	28.7	37.4	38.3
Detergent (MBAS)	0.33	0.12	0.07	0.12	0.68	0.55	0.59	0.22	0.22	0.23	0.28	0.30
Cyanide (CN)	0.00	0.001	0.004	0.01	0.01	0.04	0.01	0.06	0.06	0.01	0.14	0.15
Phenols	0.26	0.01	0.03	0.02	0.06	0.06	0.005	0.01	0.01	0.002	0.28	0.00
TRACE METALS (MT/yr)												
Silver	0.00	0.001	0.02	0.03	0.01	0.01	0.01	0.002	0.01	0.03	0.11	0.30
Arsenic	0.00	0.002	0.01	0.03	0.02	0.003	0.002	0.02	0.01	0.09	0.003	0.06
Cadmium	0.004	0.01	0.01	0.01	0.01	0.03	0.02	0.002	0.01	0.09	0.02	0.02
Chromium	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.005	0.01	0.16	0.03	0.11
Copper	0.09	0.06	0.03	0.01	0.11	0.01	0.16	0.03	0.06	0.07	0.11	0.10
Mercury	0.00	0.0002	0.001	0.002	0.003	0.003	0.0005	0.002	0.003	0.002	0.006	0.006
Nickel	0.03	0.04	0.05	0.03	0.21	0.94	0.09	0.01	0.07	0.22	0.14	0.18
Lead	0.02	0.06	0.03	0.05	0.04	0.06	0.18	0.04	0.14	0.20	0.14	0.12
Zinc	0.10	0.13	0.14	0.07	0.29	0.10	0.26	0.16	1.38	0.19	0.17	0.79

Appendix D6 (Cont).

Year	1986	1987	1988	1989	1990	1991	1992 [a]	Survey Totals n	Mean	Std. Dev.	C.V.
Flow (mgd)	4.0	2.8	2.9	2.6	2.3	2.7	2	19	2.7	1.2	46
liters/day x 10(6)	15	11	11	10	9	10	8	19	10	4.6	46
GENERAL CONSTITUENTS (MT/yr) [b]											
Total Suspended Solids	14.9	8.9	10.0	9.0	8.3	7.8	5.2	19	11.4	7.1	62
Settleable solids	0.28	0.19	0.20	0.18	0.16	0.19	0.17	19	0.18	0.08	45
Oil and Grease	2.76	1.93	2.00	1.80	1.59	1.87	1.66	19	2.72	2.15	79
BOD (5-day)	14.4	8.9	10.4	8.6	8.6	11.6	8.6	19	11.7	6.8	58
Total Nitrogen	86.2	68.9	75.6	70.2	59.6	79.9	59.3	19	64.1	27.7	43
Phosphorus (PO4-P)	30.9	22.0	22.0	21.6	18.4	22.8	17.9	19	24.6	10.4	42
Detergent (MBAS)	0.33	0.23	0.28	0.18	0.16	0.26	0.15	19	0.28	0.17	59
Cyanide (CN)	0.14	0.02	0.03	0.09	0.04	0.07	0.02	19	0.05	0.05	106
Phenols	1.66	0.01	0.01	0.18	0.10	0.02	0.02	19	0.14	0.38	262
TRACE METALS (MT/yr) [b]											
Silver	0.03	0.01	0.01	0.01	0.01	0.02	0.01	19	0.03	0.07	212
Arsenic	0.14	0.00	0.02	0.02	0.01	0.06	0.02	19	0.03	0.04	134
Cadmium	0.01	0.01	0.01	0.01	0.01	0.01	0.01	19	0.02	0.02	125
Chromium	0.03	0.01	0.01	0.01	0.02	0.02	0.01	19	0.03	0.04	150
Copper	0.12	0.02	0.00	0.04	0.03	0.06	0.08	19	0.06	0.04	70
Mercury	0.006	0.002	0.0004	0.002	0.003	0.0004	0.33	19	0.020	0.076	385
Nickel	0.11	0.03	0.02	0.04	0.06	0.08	0.08	19	0.13	0.21	160
Lead	0.17	0.02	0.06	0.05	0.01	0.02	0.01	19	0.07	0.06	82
Zinc	0.20	0.06	0.12	0.14	0.10	0.13	0.08	19	0.24	0.32	131

a. Mass Emissions for 1992 are extrapolated to 12 months.

b. Less than detection level values calculated at 1/2 detection level for plotting.

Sources: Los Virgenes Municipal Water District; Whitbeck, S. 1992 TWRF, pers. comm.

APPENDIX E

Type and Size of Spills of 500 Gallons or more in Santa Monica Bay Area. 1973-1987, 1991.

Appendix E. Type and size of spills of 500 gallons or more in Santa Monica Bay, 1973-1987 and 1991.*

Year	Amount (gal) Spilled	Amount (gal) ecovered		Type of Spill	Source Type**		Primary Cause	Contributing Cause
1976	200000	0		Not elsewhere specified	NV	Land Facility	Unintentional Discharge	ATT
1984	42000	0		Caustic soda solution	NV	Land Facility	Structure Failure	Corrosion
1984	33600	0		Oil, fuel	V	Freight Ship	Structure Failure	Collision
1979	28000	0		Oil: Clarified	V	Fishing Boat	Equipment Failure	EWR
1974	21000	21000		Oil, Crude	NV	OPN	Equipment Failure	Unknown
1974	15000	0		Not elsewhere specified	NV	Land Facility	ID	Unknown
1976	12000	0		Gasoline, Aviation (4.86g Pb/gal)	NV	Land Facility	Equipment Failure	Unknown
1991	9240	0		Diesel oil and Napthalene	NV	Pipeline	Structure Failure	Anchor Impact
1978	8000	0		Oil, Crude	NV	Land Facility	Unknown	Unknown
1980	6300	6090		Oil: Crude	V	Tanker Ship	Unintentional Discharge	Unknown
1975	5000	0		Gasoline, Aviation (4.86g Pb/gal)	NV	LVN	Unknown	Unknown
1977	5000	0		Jet fuel	NV	Air Craft	Equipment Failure	Unknown
1978	4500	0		Oil, Crude	NV	Land Facility	Equipment Failure	Unknown
1983	4200	0		Oil, Crude	NV	OPN	Equipment Failure	Unknown
1983	4200	0		Oil: Crude	NV	Land Facility	Structure Failure	WTH
1976	4000	0		Hydrochloric acid	NV	LVN	CS	NEC
1977	4000	0		Oil, fuel	NV	Rail Road Equip.	Structure Failure	CNC
1977	4000	0		Oil, fuel	NV	Rail Road Equip.	CS	Collision
1983	3780	0		Sulfuric acid	NV	Land Facility	Structure Failure	Unknown
1975	3500	3500		Oil, misc: Mineral seal	NV	LVN	Unintentional Discharge	Unknown
1979	3360	0		Oil, fuel	NV	Land Facility	Equipment Failure	SEC
1983	3150	0		Oil: Crude	NV	OPN	Equipment Failure	CUT
1983	3000	0		Not elsewhere specified	NV	Land Facility	Equipment Failure	MNT
1973	2400	0		Jet fuel (Kerosene, heavy)	NV	NEC	Structure Failure	Collision
1982	2100	0		Oil, misc: Absorption	NV	Unknown	Unknown	Unknown
1984	2100	0		Oil, misc: transformer	NV	OPN	Structure Failure	Unknown
1976	2000	0		Distillates: Flashed feed stocks	NV	OPN	Equipment Failure	Unknown
1976	2000	0		Jet fuel	NV	OPN	Equipment Failure	Corrosion
1980	2000	0		Oil: Crude	NV	Tanker Truck	CS	NEC
1980	2000	0		Oil: Crude	NV	Land Facility	Equipment Failure	DEF
1980	2000	0		Oil: Crude	NV	LVN	CS	NEC
1981	2000	0		Not elsewhere specified	NV	OMF	Equipment Failure	PFG
1981	2000	0		Gasoline, Aviation (4.86g Pb/gal)	NV	Tanker Truck	CS	Collision
1981	2000	0		Not elsewhere specified	NV	Land Facility	Equipment Failure	Unknown
1984	1680	0		Oil, fuel	NV	OPN	Structure Failure	Corrosion
1982	1470	0		Not elsewhere specified	NV	NEC	NS	NEC
1977	1260	0		Oil, Crude	NV	OPN	Structure Failure	DEF
1978	1260	0		Oil, fuel	V	Freight Ship	Equipment Failure	Unknown
1976	1200	0		Gasoline, Auto (4.23g Pb/gal)	NV	LVN	CS	NEC
1979	1050	0		Oil, Crude	NV	Unknown	Unknown	Unknown
1974	1000	0		Hydrochloric acid	NV	Land Facility	Equipment Failure	DEF
1974	1000	1000		Oil, Crude	V	Tanker	Unintentional Discharge	NEC
1976	1000	1000		Oil, Crude	NV	LVN	CS	NEC
1977	1000	1680	***	Oil, Crude	V	Tanker Ship	Equipment Failure	Valve
1979	1000	0		Oil, fuel	V	TNKB	Unintentional Discharge	Unknown
1979	1000	0		Oil, Crude	NV	Unknown	Unknown	Unknown
1981	1000	0		Oil, misc: Spray	NV	Land Facility	Unintentional Discharge	Unknown
1984	1000	0		Jet fuel (Kerosene, heavy)	NV	Land Facility	Equipment Failure	Unknown
1976	850	0		Oil, Crude	NV	Land Facility	ID	SAB
1981	850	800		Oil: Crude	V	Tanker	Unintentional Discharge	Unknown
1979	840	0		Not elsewhere specified	NV	Land Facility	Unintentional Discharge	ATT
1976	700	700		Oil, fuel	V	USCG	Unintentional Discharge	ATT
1979	630	0		Benzene	V	Tanker Ship	Unintentional Discharge	TOP
1981	630	630		Oil, fuel	V	Freight Ship	Unintentional Discharge	ATT
1985	630	0		Oil, fuel	V	POTH	Unintentional Discharge	TRN
1984	600	0		Gasoline, Aviation (4.86g Pb/gal)	NV	LVN	CS	PFG
1974	500	490		Oil, Crude	NV	OPN	Equipment Failure	DEF
1974	500	500		Oil, fuel	NV	LVN	Equipment Failure	SEC
1978	500	0		Chlorine	NV	OMF	Unknown	Unknown
1979	500	0		Oil, Crude	NV	Unknown	Unknown	Unknown
1979	500	0		Not elsewhere specified	NV	ONP	Unknown	Unknown
1981	500	0		Oil, fuel	NV	Unknown	Unknown	Unknown

Source: U.S. Coast Guard, Dept. of Transportation, Washington D.C., unpublished data.

* Data not available for 1987 to 1990, only partial data for 1991.

** NV = Non Vessel; V = Vessel

*** As recorded in USCG data.

Information was not available for definitions of some codes used for vessel type and causes.

Note: In 1976, 10,000 lbs of Cyclohexenyltrichlorosilane were spilled from a land facility with none recovered.

APPENDIX F

National Pollutant Discharge Elimination System Permits.

STATE OF CALIFORNIA
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LOS ANGELES REGION

ORDER No. 90-079

NPDES NO. CA0061654 (CI 6948)

WASTE DISCHARGE REQUIREMENTS
STORMWATER/URBAN RUNOFF DISCHARGE
for
LOS ANGELES COUNTY
and
CO-PERMITTEES

The California Regional Water Quality Control Board, Los Angeles, (Regional Board) finds :

1. The County of Los Angeles, in cooperation with the following cities : Agoura Hills, Beverly Hills, Culver City, El Segundo, Hermosa Beach, Inglewood, Los Angeles, Manhattan Beach, Rancho Palos Verdes, Redondo Beach, Rolling Hills Estates, Rolling Hills, Santa Monica, Torrance, West Hollywood, and Westlake Village, has submitted a report of waste discharge (NPDES permit application) dated March 15, 1990 for issuance of waste discharge requirements for the County of Los Angeles and other cities tributary to Los Angeles County (excluding Antelope Valley) under the National Pollutant Discharge Elimination System (NPDES Permit No. CA0061654).

2. The discharges consist of surface runoff generated from various land uses in all the hydrologic drainage basins which discharge into water courses flowing into water bodies in Los Angeles County. The quality of these discharges varies considerably and is affected by land use, basin hydrology and geology, season, and the frequency and duration of storm events. The constituents of concern and significance in these discharges are: total and fecal coliform and enterococci bacteria, total suspended solids, biochemical oxygen demand, oil and grease, heavy metals, nutrients, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, pesticides and herbicides, and petroleum hydrocarbons.

3. The objective of this permit is to develop a timely, comprehensive, and cost-effective stormwater pollution control program to minimize pollutants in urban runoff/stormwater discharges to water bodies in Los Angeles County.

4. Due to the complexity and networking of drainage facilities within and tributary to Los Angeles County, the county and adjacent areas discharging storm water into Los Angeles County are divided and prioritized into five drainage basins for the implementation of the permit. The owners/operators of all facilities impacting stormwater quality will be ultimately a party to these waste discharge requirements. The County of Los Angeles together with the cities identified above, the initial parties filing for the system-wide permit, are 'Permittees', with the County of Los Angeles as the 'Principal Permittee' and the rest as 'Co-Permittees'. All other cities and recognized entities such as Caltrans, college/university campuses, hospitals, parks, agricultural areas, real estate developments and waste disposal facilities identified in this Order, are designated 'Co-Participants'. A 'Co-Participant' will be a 'Co-Permittee' upon becoming an active party to the permit.

   Attachments 1 and 2 show, respectively, the list of cities and a partial list of entities designated as Co-Participants for this permit. The list of entities will be revised as necessary.

5. The County of Los Angeles, as the 'Principal Permittee', will obtain the cooperation of 'Co-Participants' to become 'Co-Permittees'. The Regional Board has the discretion and authority to require non-cooperating cities and/or entities to become 'Co-Permittees' or obtain individual stormwater discharge permits, pursuant to 40 CFR 122.26 (a).

6. Los Angeles County as the 'Principal Permittee' is the permit coordinator responsible for general administration of this Order, and coordinating cooperation by 'Co-Permittees', including but not limited to the implementation of local self-monitoring programs and Best Management Practices, and the preparation and submittal of reports required by this Order.

7. Los Angeles County obtains its authority to :

   - control pollutants in stormwater discharge
   - prohibit illegal discharges and control spills
   - require compliance and carry out inspections

of drainage facilities in the County of Los Angeles from the Los Angeles County Flood Control Act and various county ordinances which address industrial wastes and waste discharges within the unincorporated areas of Los Angeles County and contract cities. 'Co-Permittees' with the status of incorporated cities have various forms of legal authority in place, such as charters, State Code provisions for General Law cities, city ordinances and applicable portions of Municipal Codes and the State Water Code, to regulate stormwater/urban runoff discharges.

8. The division and prioritization of Los Angeles County and adjacent areas into five drainage basins for program implementation are based on hydrological characteristics of the watersheds, perceived importance and beneficial uses of water bodies, and the existence of an adequate infrastructure for program implementation. The five drainage basins are :

I : Santa Monica Bay Drainage Basin

II : Upstream Los Angeles River Drainage Basin, to and including Sycamore Canyon Channel (San Fernando Valley);

III : Upper San Gabriel River (San Gabriel Valley) Drainage Basin.

IV : Lower Los Angeles River Drainage Basin

V : Lower San Gabriel River Drainage Basin; and Santa Clarita Valley Basin.

Attachment 3 shows a map of Los Angeles County with the boundary delineations of the five drainage basins.

Attachment 4 shows Co-Participant cities in Los Angeles County (and their respective populations).

[Note: Detailed maps of the Los Angeles County storm drain system with boundary delineations of drainage basins are available for review at the Regional Board Office.]

9. A number of studies on stormwater/urban runoff pollution in the permit areas has been conducted by agencies such as the City of Los Angeles, the Southern California Coastal Water Research Project and the Southern California Association of Governments. These studies indicate stormwater/urban runoff contributes significantly to the deterioration of the quality of water bodies in Los Angeles County.

The University of California at Los Angeles, under the sponsorship of the Santa Monica Bay Restoration Project, is currently compiling and summarizing data and information on stormwater/urban runoff discharges for the Santa Monica Bay watershed.

10. The Los Angeles County Department of Public Works has an active surface water quality monitoring program in the permit area, comprising twenty-eight monitoring stations located at principal storm drains and water conservation facilities. The Surface Water Quality Monitoring Program comprises the collection and analysis of dry weather water samples for general minerals, pesticides, total petroleum hydrocarbons, heavy metals and bacteria (total and fecal coliform, KF streptococci and enterococci). Volatile organic constituents are tested semi-annually at selected stations. Stormwater runoff is monitored three to four times annually at twenty-one stations for minerals, pesticides, heavy metals (total and dissolved), bacteria, total and organic suspended solids, oil and grease, biochemical oxygen demand, total organic carbon and volatile organics.

11. The Los Angeles County Department of Public Works and some cities have on-going activities that reduce stormwater/urban runoff pollutant loads. These activities include periodic catch-basin cleaning and street sweeping, public information on proper disposal of household hazardous waste, and emergency responses to reports of illegal dumping, illicit disposal, illegal connections, and industrial waste spills. The Los Angeles County Department of Public Works also participates and coordinates action with local, State, and Federal agencies responding to spills and illegal dumping reports that threaten surface waters.

12. The Regional Board currently regulates industrial process and point source non-process wastewater and stormwater discharges to storm drain systems through NPDES permits. Point source discharges including stormwater will continue to be regulated by the Regional Board. An information system will be developed and maintained to update pollutant loadings to designated

drainage facilities and water bodies from permitted point source discharges.

13. The State Water Resources Control Board (State Board) adopted a Water Quality Control Policy for the Enclosed Bays and Estuaries of California on May 16, 1974. The policy provides that the discharge of industrial process waters to enclosed bays and estuaries shall be prohibited. Storm water and urban runoff are not considered industrial process waters for the purpose of that policy.

14. The State Board adopted a revised Water Quality Control Plan for Ocean waters of California (Ocean Plan) on March 22, 1990, which amended the Plan adopted on September 22, 1988. The Plan contains water quality objectives for the coastal waters of California.

15. The Regional Board adopted a revised Water Quality Control Plan for the Los Angeles River Basin (Basin Plan) on November 27, 1978. The Basin Plan incorporates the Ocean Plan, and contains water quality objectives for the basin, including the beneficial uses of water bodies.

16. The beneficial uses of water bodies in Los Angeles County and their tributary streams include contact water recreation, non-contact water recreation, wildlife habitat, preservation of rare and endangered species, marine habitat, estuarine habitat, fish migration, fish spawning, industrial service and process supply, agricultural water supply, shellfish harvesting, navigation, commercial and sport fishing, and groundwater recharge.

17. Section 405 of the Water Quality Act of 1987 added Section 402(p) to the Clean Water Act of 1972 to require the Environmental Protection Agency (EPA) to establish regulations for stormwater/urban runoff discharge under the National Pollutant Discharge Elimination System (NPDES).

18. The Federal Clean Water Act allows EPA to delegate its NPDES permitting authority to States with an approved environmental regulatory program. The State of California is one of the delegated States. The Porter-Cologne Act (State Water Code) authorizes the State Board, through its Regional Boards, to regulate and control the discharge of pollutants into waters of the state and tributaries thereto.

19. Although Water Code Section 13263 (a) requires that waste discharge requirements issued by Regional Boards shall include provisions to implement water quality based objectives, numerical water quality standards

are not provided in this Order. Information is not available to establish appropriate numerical limits, and determine locations where permittees shall be made accountable. The requirements in this Order will provide the necessary information while concurrently achieving reductions in pollutant loads to water bodies from stormwater/urban runoff discharges. Numerical water quality objectives will be developed by Board staff for consideration in the permit renewal process and utilized for the evaluation of Best Management Practices.

20. Due to the significance of the Los Angeles County Stormwater/Urban Runoff Program, the Regional Board, in recognition of the need for public involvement and participation in the development and implementation of an effective program will conduct at a minimum an annual workshop, prior to approving plans submitted by Permittees, to solicit comments and to inform the public of the progress of the program. Comments presented will be referred to Los Angeles County for response.

21. Stormwater/urban runoff discharges to drainage facilities that cross County boundaries and Regional Board jurisdictions, and which are regulated under NPDES permits, are the regulatory responsibility of those agencies issuing the permits.

22. The issuance of waste discharge requirements for this discharge is exempt from the provisions of the California Environmental Quality Act (CEQA); Chapter 3 (commencing with Section 21100) of Division 13 of the Public Resources Code in accordance with Water Code Section 13389.

The Board has notified the Permittees and interested agencies and persons of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

The Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

This Order shall serve as a National Pollutant Discharge Elimination System permit pursuant to Section 402 of the Federal Clean Water Act, or amendments thereto, and shall take effect at the end of ten days from the date of its adoption provided the Regional Administrator, EPA, has no objections.

IT IS HEREBY ORDERED that the Permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act as amended and regulations and guidelines adopted thereunder, shall comply with the following:

1.0 COMPLIANCE

1.1 The Permittees and Co-Permittees shall comply with the requirements contained in this Order according to the following schedule:

	DRAINAGE BASIN	STARTING DATE FOR COMPLIANCE WITH REQUIREMENTS
I.	Santa Monica Bay	July 1, 1990
II.	Upper Los Angeles River (San Fernando Valley)	July 1, 1992
III.	Upper San Gabriel River (San Gabriel Valley)	July 1, 1992
IV.	Lower Los Angeles River	July 1, 1993
V.	Lower San Gabriel River and Santa Clarita Valley	July 1, 1993

2.0 REQUIREMENTS - YEAR 1

2.1 For each Drainage Basin, prepare and submit to the Regional Board within 12 months of the starting date for compliance, according to the schedule under 1.1:

2.1.1 Water quality data and flow data from 1980 to the present to facilitate identification of sources of pollutants present in discharges from the prioritized drainage basin. "Drainage areas" in the drainage basin are to be reported and the "drainage areas" associated with each drainage basin clearly identified.

For purposes of stormwater/urban runoff, a "drainage area" is defined as a subdivision of a drainage basin which is unique in land use patterns, and pollutant characteristics and loadings.

2.1.2 The 90th percentile value for the water quality parameters, (i) Total Suspended Solids (TSS), and (ii) Oil and Grease, from the data set of all wet weather samples collected from 1980 to the present. These data will be used to establish guidance for early action control of stormwater pollution.

The 90th percentile for a given water quality parameter is defined as the concentration value exceeded in ten percent of the samples of the reference data set.

2.1.3 Additional information of a qualitative nature that would contribute to isolating and identifying sources of problems. Such information should include but not be limited to visual observations of factors exacerbating stormwater contamination, principal land use classifications and Standard Industrial Code (SIC) categories of facilities in "drainage areas", and a description of soils, dumps, landfills, waste disposal sites and Resource Conservation and Recovery Act (RCRA) facilities associated with each area.

2.1.4 Monthly precipitation data from rain gauge stations, relevant to the drainage basin, for the years 1980 to the present, and an estimate of the area of impervious surfaces (including paved areas and building roofs) within each "drainage area".

2.1.5 Documentation of existing procedures to detect and address illegal discharges and illicit disposal practices.

2.1.6 Documentation of existing practices and improvement plans to control pollutants in stormwater/urban runoff from construction sites.

2.1.7 Documentation of existing stormwater/urban runoff management practices and existing Best Management Practices (BMPs) for the control of pollutants in discharges from residential, commercial and industrial areas.

For purposes of this permit, a Best Management Practice is defined as a stormwater quality management practice that has been demonstrated to reduce stormwater/urban runoff constituents of concern in studies in the United States and elsewhere, or a stormwater/urban runoff quality management practice that can significantly control stormwater/urban runoff pollution.

2.1.8 Plan with schedule of implementation, for approval by the Executive Officer, of early action BMPs.

For purposes of this permit, an early action BMP is defined as an existing stormwater/urban runoff quality management practice that is optimized to the maximum extent practicable (MEP) in efficiency for the control of stormwater runoff pollution, such as improving the frequency of storm drain catchment basin cleaning or the stricter enforcement of existing regulations, or a BMP that is not specific to stormwater/urban runoff constituents or "drainage area" in its constituent removal capacity and can be applied on a system-wide basis, such as public outreach and educational programs.

For purposes of this permit, maximum extent practicable means to the maximum extent possible, taking into account equitable considerations of synergistic, additive and competing factors, including but not limited to gravity of the problem, fiscal feasibility, public health risks, societal concern, and social benefits.

The Principal-Permittee, in the submittal of plans and schedules to the Executive Officer, shall demonstrate that public input has been obtained.

For purposes of this permit, public input is demonstrated by, (i) disseminating the notice of availability of plans for review and comment, to the public at large, environmental groups, Federal, State and local officials and other interested parties, and (ii) addressing concerns expressed by the public.

The Board may modify the plans in response to public input received at the Board during its comment/review period. Permittees are required to implement the original or modified plan on approval by the Executive Officer.

2.1.9 A workplan for the development of a stormwater/urban runoff monitoring program, for approval by the Executive Officer, to include but not be limited to the following information :

- listing of constituents and parameters to be monitored and the rationale for their choice.
- listing of monitoring locations and the rationale for their choice.
- listing of sampling methodology of choice and frequency of sampling for both wet weather and dry weather flow.
- supplementary information that influences the design of the monitoring plan.

The Principal-Permittee, in the submittal of the workplan to the Executive Officer, shall demonstrate that public input has been obtained.

2.1.10 Documentation that each Permittee, individually and/or jointly, through the establishment of a joint powers authority or a stormwater utility, possesses adequate legal authority to operate and manage stormwater/urban runoff quality management programs, and/or plans to obtain the necessary legal authority to regulate illegal discharges and illicit disposal practices into storm drains, and to prosecute violators.

3.0 REQUIREMENTS - YEAR 2

3.1 For each Drainage Basin, prepare and submit to the Regional Board, for approval by the Executive Officer, within 24 months of the starting date of compliance, according to the schedule under 1.1:

3.1.1 A monitoring program based on the approved workplan. This program shall be designed to:

- o detect accurately the constituents and parameters of concern, in discharges indicated in the workplan, and to identify their possible sources.
- o identify illegal dischargers and/or locations of illicit disposal practices.

Monitoring reports for this program shall be submitted according to the format and frequency to be approved by the Executive Officer.

3.1.2 Plan with schedule of implementation for additional BMPs, judged appropriate for each city or drainage basin, to control pollutants from residential, commercial and industrial sites to the maximum extent practicable.

Both structural and non-structural BMP measures are to be evaluated at the MEP standard. Examples of non-structural measures include catch basin cleaning, street sweeping and public education, while controls such as detention/retention basins, first flush diversions, grassy swales and porous pavements are examples of structural measures.

3.1.3 Plan with schedule of implementation of procedures to detect and eliminate illegal discharges and illicit disposal practices.

3.1.4 Plan with schedule of implementation of measures to control pollutants in surface runoff from construction sites.

The Principal Permittee, in the submittal of plans and schedules (items 3.1.2, 3.1.3, and 3.1.4) to the Executive Officer shall demonstrate that public input has been obtained. The Board may modify the plans in response to public input received at the Board during its comment/review period. Permittees are required to implement the original or modified plans on approval by the Executive Officer.

3.2 Evidence of satisfactory progress of implementation of plan and schedule for early action BMPs.

3.3 Evidence of all requisite legal authority to regulate illegal discharges and illicit disposal practices to drainage facilities, and to prosecute violators.

4.0 REQUIREMENTS - YEAR 3

4.1 For each Drainage Basin, submit to the Regional Board, within 36 months of the starting date of compliance, according to the schedule under 1.1, the following:

4.1.1 Evidence of satisfactory progress of implementation of plan and schedule for early action BMPs and additional BMPs.

4.1.2 Evidence of implementation and progress of procedures to detect and eliminate illegal discharges and eliminate illicit disposal practices.

4.1.3 Evidence of implementation and progress of measures to control pollutants in surface runoff from construction sites.

5.0 EXPIRATION AND RENEWAL

5.1 This Order expires on June 18, 1995.

5.2 The Permittees shall file a report of waste discharge (ROWD), not later than 180 days before the expiration date, as application for reissuance of waste discharge requirements. This report of waste discharge shall include but not be limited to the following:

5.2.1 Summary of the results of the monitoring program.

5.2.2 Summary of BMPs implemented and evaluations of their effectiveness.

5.2.3 Summary of procedures implemented to detect illegal discharges and illicit disposal practices and an evaluation of their effectiveness.

5.2.4 Summary of measures implemented to control pollutants in surface runoff from construction sites and an evaluation of their effectiveness.

5.2.5 Evaluation of the need for additional BMPs, source control, and/or structural control measures.

5.2.6 Proposed plan of stormwater/urban runoff quality management activities that will be undertaken during the term of the next permit.

I, Robert P. Ghirelli, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Los Angeles Region, on June 18, 1990.

ROBERT P. GHIRELLI, D.Env.
Executive Officer

ATTACHMENT I

LIST OF CO-PARTICIPANT CITIES

Agoura Hills
Arcadia
Avalon
Baldwin Park
Bellflower
Beverly Hills
Burbank
Cerritos
Commerce
Covina
Culver City
Downey
El Monte
Gardena
Glendora
Hawthorne
Hidden Hills
Industry
Irwindale
La Habra Heights
La Mirada
La Verne
Lawndale
Long Beach
Lynwood
Maywood
Montebello
Norwalk
Palos Verdes Estates
Pasadena
Pomona
Redondo Beach
Rolling Hills Estates
San Dimas
San Gabriel
Santa Clarita
Sant Monica
Signal Hill
South Gate
Temple City
Torrance
Walnut
West Hollywood
Whittier
Alhambra
Artesia
Azusa
Bell
Bell Gardens
Bradbury
Carson
Claremont
Compton
Cudahy
Diamond Bar
Duarte
El Segundo
Glendale
Hawaiian Gardens
Hermosa Beach
Huntington Park
Inglewood
La Canada Flintridge
Lakewood
La Puente
Lancaster
Lomita
Los Angeles
Manhattan Beach
Monrovia
Monterey Park
Palmdale
Paramount
Pico Rivera
Rancho Palos Verdes
Rolling Hills
Rosemead
San Fernando
San Marino
Santa Fe Springs
Sierra Madre
South El Monte
South Pasadena
Thousand Oaks
Vernon
West Covina
Westlake Village

ATTACHMENT 2

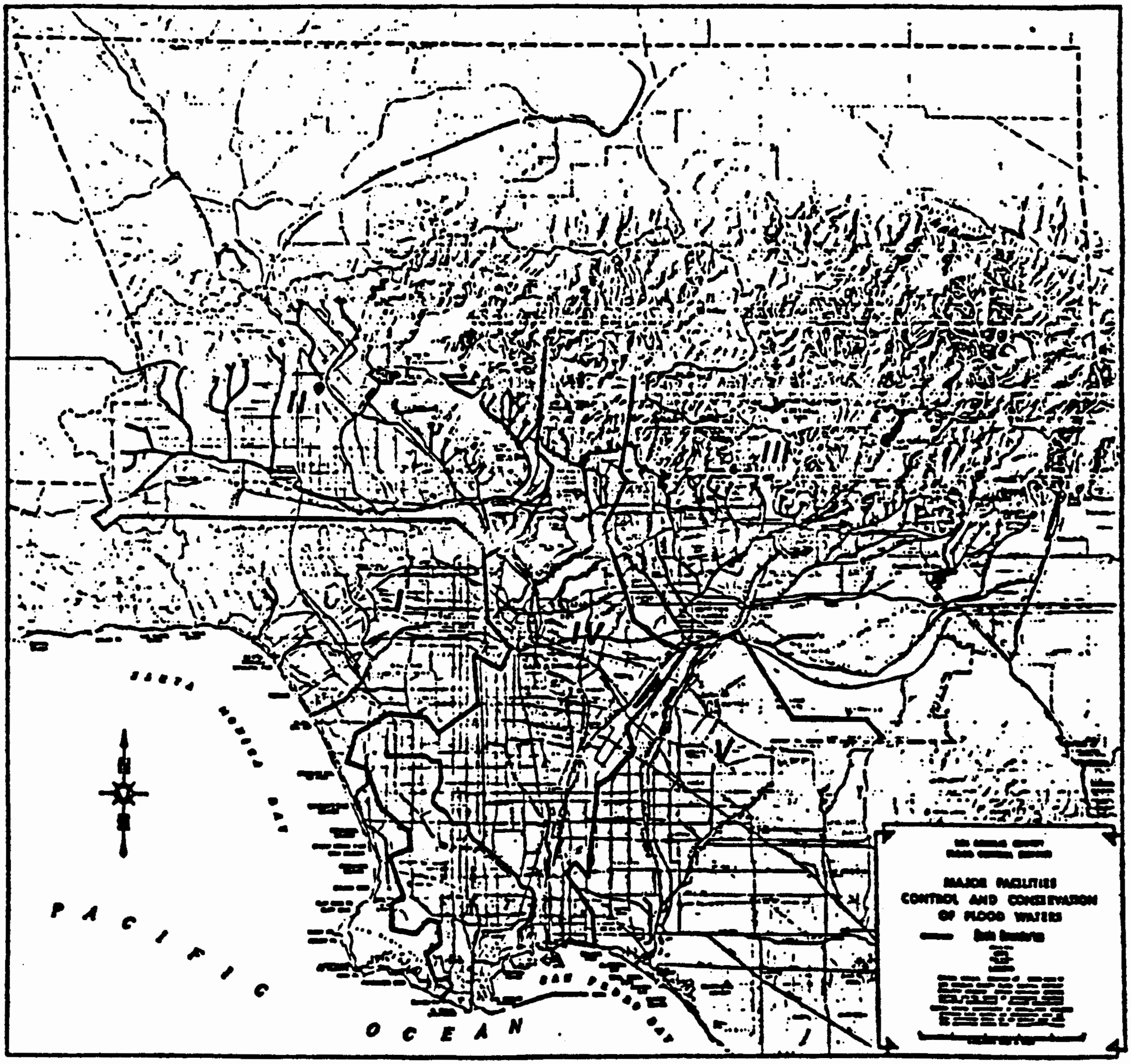
LIST OF ENTITIES (PARTIAL LIST)

Caltrans
Army Corps of Engineers
Railroad Rights of Way
Federal Hospitals
The State University System
University of California Campuses
National Forest Service
Federal Military Facilities

[This list will be updated during the permit process to indicate actual identity of agencies and entities.]

ATTACHMENT 3

DELINEATIONS OF DRAINAGE BASIN BOUNDARIES FOR LOS ANGELES COUNTY



ATTACHMENT 4

CITIES (AND POPULATIONS) TRIBUTARY TO DRAINAGE BASINS

Santa Monica Bay

Agoura Hills	19,000	Rancho Palos Verdes	46,000
Beverly Hills	34,000	Redondo Beach	64,700
Culver City	40,950	Rolling Hills	2,090
El Segundo	15,750	Rolling Hills Estates	7,875
Hermosa Beach	19,750	Santa Monica	96,500
Inglewood	102,300	Thousand Oaks	104,400
Los Angeles	3,400,500	Torrance	142,200
Manhattan Beach	35,300	West Hollywood	38,400
Westlake Village	8,025	Palos Verdes Estates	15,000

Upper Los Angeles River

Burbank	93,800	Glendale	166,100
Hidden Hills	1,950	Los Angeles	3,310,057
San Fernando	20,700		

Upper San Gabriel River

Alhambra	74,900	Arcadia	49,100
Azusa	38,250	Baldwin Park	63,300
Bradbury	930	Claremont	36,550
Covina	43,250	Diamond Bar	74,120
Duarte	21,350	El Monte	95,400
Glendora	47,400	Industry	370
Irwindale	1,230	La Canada Flintridge	20,800
La Habra Heights	5,450	La Puente	33,550
La Verne	30,500	Monrovia	34,000
Montebello	58,200	Monterey Park	64,600
Pasadena	132,200	Pomona	119,000
Rosemead	47,700	San Dimas	32,500
San Gabriel	34,900	San Marino	13,800
Sierra Madre	11,250	South El Monte	18,700
South Pasadena	24,500	Temple City	31,900
Walnut	26,400	West Covina	94,200

(CONTINUED)

Lower Los Angeles River

Alhambra	74,900	Bell	28,250
Bell Gardens	38,300	Carson	88,800
Commerce	11,700	Compton	93,000
Cudahy	20,700	Downey	86,800
El Segundo	15,750	Gardena	50,900
Glendale	166,100	Hawthorne	67,400
Huntington Park	51,200	Inglewood	102,300
La Canada Flintridge	20,800	Lakewood	76,500
Lawndale	27,300	Lomita	20,300
Los Angeles	3,400,500	Lynwood	53,700
Maywood	24,650	Montebello	58,200
Monterey Park	64,600	Palos Verdes Estates	15,000
Paramount	44,450	Pasadena	132,200
Pico Rivera	57,300	Rancho Palos Verdes	46,000
Redondo Beach	64,700	Rolling Hills	2,090
Rolling Hills Estates	7,875	Signal Hill	8,150
South Gate	79,200	South Pasadena	24,500
Torrance	142,200	Vernon	80

Lower San Gabriel River

Artesia	14,950	Bellflower	60,900
Cerritos	58,400	Downey	86,800
Hawaiian Gardens	12,350	La Habra Heights	5,450
Lakewood	76,500	La Mirada	42,600
Long Beach	419,800	Norwalk	90,800
Paramount	44,450	Pico Rivera	57,300
Santa Clarita	115,700	Santa Fe Springs	16,400
Signal Hill	8,150	Whittier	74,100

Population estimates are taken from Report 89 E-1 published by the State of California Department of Finance.

The cities of Avalon (Pop: 2,490), Lancaster (Pop: 82,200), and Palmdale (Pop: 45,850) which are within Los Angeles County are not part of this permit.

APPENDIX G

Dischargers Into Santa Monica Bay.

Appendix G. Dischargers in Santa Monica Bay (RWQCB,LAR unpubl. data).

Agency Name	Facility Name	Flow (mgd)
So Cal Edison	Redondo Generation Station	1143.00
Los Angeles, City of DWP	Haynes Generating Station	1014.71
So Cal Edison	El Segundo Generating Station	606.00
Los Angeles, City of DWP	Scattergood Generating Station	495.76
Los Angeles, City of DWP	Hyperion Treatment Plant	420.00
Los Angeles County Sant. Dist.	JWPCP, Carson	420.00
Los Angeles, City of DWP	Harbor Generating Station	390.00
Union Pacific Resources Co	Wilmington and Terminal Island	165.80
Unocal Corp	Los Angeles Refinery	40.00
Unocal Corp	Carson Refinery	39.12
Pacific Texas Pipeline	Marine Terminal & Storage Fac.	33.40
Los Angeles, City of DWP	Terminal Island Treatment Plant	30.00
Star Kist Foods	Plant No 1	26.90
Chevron U.S.A. Inc	El Segundo Refinery	19.80
Las Virgenes MWD	Tapia Park Plant, NPDES	16.10
Mobil Oil Corp	Torrance Refinery	16.00
Stocker Resources, Inc	Inglewood Oil Fd., Baldwin Hills	7.55
Hermosa Beach Investment Co	Hermosa Beach Strand Hotel	7.20
Arco	Watson Refinery	4.32
United Food Processors	Terminal Island Plant	4.07
Franciscan Promenade	Franciscan Ceramics	3.60
US Navy	Long Beach Naval Shipyard	3.17
Texaco Refining & Marketing Inc	Los Angeles Plant (Wilmington)	2.88
Pan Pacific Fisheries	Plant No 1 & 2, Terminal Island	2.74
GATX Tank Storage Terminals Co	Carson Terminal – NPDES	2.50
Rhone–Poulenc Basic Chemical Co	Dominguez Indust. Chem. Plant	2.30
United States Borax & Chem Corp	Wilmington Plant	2.23
Santa Monica, City of	Arcadia Drinking Wtr. Trt. Plant	1.85
Metropolitan Stevedore Co	Pier G, Berth 212, LB Harbor	1.71
Channel Gateway Ltd Partnership	Channel Gateway	1.50
Chiat/Day, Inc	Chiat/Day, Inc	1.40
Ultramar Inc	Marine Term, Berth 164	1.30
Four Corners Pipeline Co	Long Beach Marine Term 2	1.08
Arco C.Q.C. Kilm, Inc	Arco C.Q.C. Kilm, Inc	1.04
Monterey Park, City of	GW–Fern Well	0.93
Caltrans	Century and San Diego Freeway	0.86
Las Virgenes MWD	GW–Tapia Groundwater Discharge	0.80
Unocal Corp	Tank Leak-Unocal SS #1120	0.72
Los Angeles, City of DWP	Alamitos Barrier Proj, Unit 2 & 3	0.65
Texaco Refining & Marketing Inc	Carson Sulfur Recovery Plant	0.65
Cushman Investment & Dev. Corp	Landmark Square	0.60
Los Angeles, City of DWP	Marine Tank Farm, Harbor Steam	0.60
Howard Hughes Properties	Tank Leak–Culver City Facility	0.58
BP North America Petroleum Inc	San Pedro Marine Terminal	0.50
International Light Metals Corp	Torrance Facility	0.50
Los Angeles County DWP	Malibu Mesa WW Recl, NPDES	0.50
Scharff Werner G.	GW–Werner Scharff	0.50
Chevron U.S.A. Inc	San Pedro Marine Terminal	0.43
Western Fuel Oil Co	San Pedro Facility	0.41
Texaco Refining & Marketing Inc	Tank Leak–Texaco Service Station	0.36
General Telephone Co of CA	Tank Leak–Malibu Facility	0.34
Los Angeles, City of DWP	Olympic Tank Farm, Skim Pond	0.30
Mobil Oil Corp	Tank Leak–Mobil SS #11–FRN	0.29
Cochran (342 South) Avenue	342 S. Cochran	0.29
CWD Cloverdale Associates	328 Cloverdale Apartments	0.29
Lerner Building & Mgt. Co	Village on Canon	0.29
Defense Logistics Agency	Defense Fuel Sup. Terminal Is.	0.28
Harbor Cogeneration Company	Harbor Cogeneration Company	0.27
GATX Tank Storage Terminals Co	Los Angeles Harbor Terminal	0.25
Hayworth Associates	Hayworth Associates	0.25
Project West Corporation	616 South Burnside	0.25
DMG, Ltd	Office Building	0.25
Wilshire Landmark II	Wilshire Landmark II	0.23
Mercury Casualty Company	Home Office Building	0.22
Praxair, Inc	Linde Division, Wilmington	0.22

Appendix G (Cont).

Agency Name	Facility Name	Flow (mgd)
W & M Partners Development Corp	Watt City Center	0.22
Southwest Marine, Inc	San Pedro Yard	0.21
Shell Oil Co	Mormon Island Marine Terminal	0.20
Rohm and Haas Southern Calif.	Borden Chemical	0.19
Mobil Oil Corp	Southwestern Terminal–Area I	0.15
Riverbanks Bulk Water	Deionized Water, Wilmington	0.15
Southern California R.T.D.	Tank Leak–Division 7	0.15
CWD Detroit Associates	618 S. Detroit Apartments	0.14
Malibu Grand Prix	Tank Leak–Malibu Grand Prix	0.14
North Oakhurst Partnership	GW–North Oakhurst Partnership	0.14
Unisys Corporation	Tank Leak–Memorex Corp	0.14
Frank Pickett	Tank Leak–Pickett Service Stat.	0.13
Mobil Oil Corp	HT–Vernon Facility	0.13
Unocal Corp	Tank Leak–Unocal SS #5021	0.12
California Sulphur Co	Sulfur Pelletizing, Wilmington	0.11
Los Angeles County DWP	Big Rock Mesa Drainage Facility	0.11
Cal Fed Enterprises	Thayer Ltd	0.10
Dorchester Partners	Dorchester Partners	0.10
Las Virgenes MWD	GW–Irrigation Well–Westlake	0.10
Los Angeles, City of DWP	Harbor Steam Plant, Skim Pond	0.10
Park Mile Associates	Lowy Plaza	0.10
Wilshire West Inc	Wilshire West Inc.	0.10
Wilshire Westwood Associates	Wilshire Westwood Associates	0.10
Alvarado Grand Plaza	Alvarado Grand Plaza	0.09
University of Southern California	Institute For Marine & Coastal	0.09
Il Mook Kang	Maplewood Apartments	0.08
Center for Early Education	School	0.08
Arco T.S. & Four Corners Pipe	Long Beach Marine Term 3	0.07
Clark–Swall, Ltd	Clark–Swall, Ltd	0.07
Clinton Partnership	Clinton Partnership	0.07
Howard Hughes Properties	Tank Leak–Lot 2	0.07
Trillium Woodland Hills	Office Building	0.07
Burke Company, The	Edoco Technical Products	0.07
Los Angeles, City of DWP	Alamitos Barrier Proj, Unit 1	0.07
Los Angeles, City of DWP	West Coast Barrier Proj, 8	0.06
Beverly Springs Medical Center	Beverly Hot Springs	0.06
Los Angeles, City of DWP	Harbor Steam Plant, N Skim Tank	0.06
Los Angeles, City of DWP	West Coast Barrier Proj, 6	0.06
Los Angeles, City of DWP	Dominguez Gap Barrier Proj, 3	0.06
Unocal Corp	Los Angeles Terminal West	0.06
Culver City Unified Sch. Dist.	Culver City Natatorium	0.05
Los Angeles, City of DWP	West Coast Barrier Proj, 7	0.05
Los Angeles, City of DWP	Dominguez Gap Barrier Proj, 1 & 2	0.05
Redman Equipment & Mfg Co	Torrance Heat Exchanger Mfg & Rp	0.05
Todd Shipyards Corporation	Ship Build & Repair, LA Harbor	0.05
Atochem North America, Inc	Detergent Man–Carson	0.05
Delta Towers Joint Venture	Century Plaza Towers, Offices	0.05
Four Corners Pipeline Co	Marine Terminal, Berth 121, LB	0.05
Gardena, City of	Primm Memorial Swimming Pool	0.05
GATX Terminals Corporation	Bulk Chem. Store, Berth 70, SP	0.05
GATX Terminals Corporation	Berth 172, L.A. Marine Terminal	0.05
Inglewood, City of	Centinela Swim Pool, 700 Warren	0.05
Inglewood, City of	Fuel, Wash & Steam Clean Fac.	0.05
Kim Bong – Hwan	GW–Korean Youth Center	0.05
Los Angeles, City of DWP	West Coast Barrier Proj, 3 & 4	0.05
Petro Diamond Terminal Company	Marine Terminal, Berth 83, LB	0.05
Pine Realty, Inc	Gateway West Bldg, LA	0.05
Reef U.S.A. Fund II Corp	Century Square Shopping Center	0.05
Reynolds Metal Company	Torrance Extrusion Plant	0.05
Third and Fairfax Plaza Assoc	Office Building	0.05
Wickland Properties	Wilmington Marine Terminal	0.05
Wilmington Liq. Bulk Terminals	Petroleum & Chemical Terminal	0.05
Northrop Corp	Aircraft Mfg, Hawthorne	0.05
Los Angeles, City of DWP	West Coast Barrier Proj, 2	0.04
Richard Ellis / Yarmouth Group	Tank Leak–May Co. Site	0.04

Appendix G (Cont).

Agency Name	Facility Name	Flow (mgd)
Los Angeles, City of DWP	West Coast Barrier Proj. 5	0.04
Los Angeles, City of DWP	West Coast Barrier Proj. 1	0.04
Voi-Shan Aerospace Products	Tank Leak	0.04
Airesearch Manufacturing Co	Torrance Facility	0.04
Amakasu Investment Co	Wilshire Renaissance Apts.	0.04
H R Capital-North Doheny	West Hollywood Facility	0.04
Honeywell Inc	Tank Leak-Honeywell Inc	0.04
Mcgregor Co., The	4141 Wilshire Blvd. Associates	0.04
Tiger Co	GW-Tiger Co.	0.04
Two Rodeo Associates	Two Rodeo Associates	0.04
Westlake Kingstown Ltd	Westlake Kingstown Ltd	0.04
Arco Petroleum Products Co	Tank Leak-Arco Station #5028	0.03
Nakano Koar Inc	Tank Leak-Nakano Koar Partner	0.03
Unocal Corp	Tank Leak-Unocal SS #1715	0.03
Unocal Corp	Tank Leak-Unocal SS #0932	0.03
Unocal Corp	Tank Leak-Unocal SS #1715	0.03
Westwood Gateway II Ltd	Tank Leak-Breninvest Property	0.03
Coastfed Properties	The Casden Co	0.03
Los Angeles Times	Times Mirror Parking Structure	0.03
Arco Petroleum Products Co	Tank Leak-Arco Station #5090	0.03
Arco Petroleum Products Co	Tank Leak-Arco Station #6171	0.03
Douglas Aircraft Co	Torrance Facility	0.03
Morton Salt Co	Morton Salt Co	0.02
Astani Marco H.	GW-40 Units Apartments	0.02
Tracinda Corporation	Corp. Headquarters	0.02
Unocal Corp	Tank Leak-Unocal SS #3859	0.02
Unocal Corp	Tank Leak-Unocal SS #5317	0.02
Unocal Corp	Tank Leak-Unocal SS #0981	0.02
Arco Petroleum Products Co	Tank Leak-Former Arco #1361 NPDES	0.02
Jack Slomoric	Office Building-1026 Robertson	0.02
Jack Slomoric	Office Building-1030 Robertson	0.02
American Home Mortgage Corp	Tank Leak-Former Gasoline S.S.	0.02
Los Angeles County Medical Assoc	1930 W. 6th St. Cl 6933	0.02
Masseline Manor	Masseline Manor Apartment	0.02
Mobil Oil Corp	Tank Leak-Mobil SS #11-FC6	0.02
Suresh Manibhai	701 W. P.C.H. Cl 6941	0.02
Thrifty Oil Co	Tank Leak-Thrifty Oil #023	0.02
Unocal Corp	Tank Leak-Unocal SS #2325	0.02
Maguire Thomas Partnets, Inc	The Gas Company Tower	0.01
Shell Oil Co	Tank Leak-Shell Oil Property	0.01
Arco Petroleum Products Co	Tank Leak-Arco Station #1946	0.01
Exxon Co, USA	Tank Leak-Exxon SS #3733	0.01
Altadena Texaco Market	Tank Leak-Altadena Texaco Mkt.	0.01
Los Angeles County DWP	GW-Dominguez Gap Barrier 7A	0.01
Milton Meyer & Co	Milton Meyer & Co	0.01
Arco T.S. & Four Corners Pipe	Long Beach Marine Term 1	0.009
Cal-Four Capital Thayer Assoc	Office Building	0.009
Bee Chemical Co./Morton Intl	Tank Leak-Bee Chemical Co	0.007
Los Feliz Associates	Villas Apartments	0.007
Pacific Bell	Tank Leak-Inglewood Veh. Maint.	0.007
Peter Giorganni	Peter Giorganni	0.007
Elixir Industries	Tank Leak-Elixir Industries	0.006
Beverly Connection, Ltd	Shopping Mall	0.005
Centerwest Wilshire-Glendon	Tank Leak-Center West	0.005
Glenfed Development Corp	Sunset Apartment	0.005
Green's Ready-Mixed Concrete	Ready-Mixed Concrete Plant	0.005
Hara Co	New Wilshire	0.005
HBWC Ltd	HBWC Ltd	0.005
House Ear Institute	House Ear Institute	0.005
Hyatt Hotel Corp	Hyatt House at LA Intl. Airport	0.005
Lake View Mansion Partnership	Apartment	0.005
Los Angeles Free Clinic Inc	Los Angeles Free Clinic	0.005
Ogden Avenue Associates, Ltd	Ogden Avenue Associates, Ltd	0.005
Panglossian Development Corp	Panglossian Development Corp	0.005
Sheldon M Gordon Co	Ma Maison Hotel	0.005

Appendix G (Cont).

Agency Name	Facility Name	Flow (mgd)
State Farm Mutual Auto Ins Co	Insurance Office, Westlake Vill.	0.005
Refiners Marketing Company	Terminal Is. Tank Farm, Lube Oil	0.004
Federal Employees Dist. Co	LA Discount Dept. Store	0.004
Kinneloa Irrigation Dist.	GW-K3 Water Well	0.003
Central Associates	Central Bank Office Building	0.003
Mobil Oil Corp	Tank Leak-Mobil SS #11-EBK	0.003
Texaco Refining & Marketing Inc	Tank Leak-Texaco Station Aband.	0.003
Los Angeles Unified School District	Tank Leak-Lincoln Medi Magnet	0.002
San Pedro Marine, Inc.	Berth 74, San Pedro	0.002
Aggie Cal.	Basin H Boat Repair Facility	0.001
Al Larson Boat Shop	Al Larson Boat Shop	0.001
GBW Properties Inc	Real Estate Developer	0.001
General Telephone Co. of Calif	Tank Leak-Santa Monica Cleanup	0.001
Jan Development Co	Reno Apartments	0.001
Los Angeles County DWP	Municipal Storm Sewer System	0.001
Mobil Oil Corp	Tank Leak-Mobil SS #11-KWL	0.001
Northrop University	Data Processing School	0.001
San Pedro Boatworks	Berth 44 Outer Harbor	0.001
Windward Yacht & Repair Inc	Yacht Repair, Marina Del Rey	0.001
Abraham Moradzudeh & Sam Shaou	Abraham Moradzudeh & Sam Shaou	0.001
Beverly Mercedes Place, Ltd	Beverly Mercedes Place	0.001
Northrop Corp	Aircraft Mfg. El Segundo	0.001
Real Property West Inc	Pacific Financial Center	0.001
Cerritos Yacht Anchorage, Inc	Berth 205C	0.0002
Koll Co., The	GW-550 Hope St. Building	0.0001

Source: Modified from RWQCB, LAR 1992 unpubl. data

APPENDIX H

Recorded Sewage Overflows into Ballona Creek, 1965-1992.

Appendix H. Recorded sewage overflows into Ballona Creek, 1965-1992.

Date	Flow Duration (Hr)	Total Flow (mg)	Peak Flow Rate (mgd)	Date	Flow Duration (Hr)	Total Flow (mg)	Peak Flow Rate (mgd)
11/22/65	1.7	[a]	[a]	03/04/83	12.5	0.62	1.7
12/29/65	5.0	[a]	[a]	03/05/83	8.5	0.26	0.7
11/07/66	2.5	[a]	[a]	03/06/83	3.5	0.12	0.7
11/21/67	1.5	[a]	[a]	03/07/83	3.0	0.10	0.7
11/22/67	3.2	[a]	[b]	03/08/83	2.5	0.08	0.7
01/25/69	14.6	21.8	59.3	03/12/83	2.0	0.06	0.7
02/23/69	3.5	0.8	7.4	03/18/83	1.5	0.06	0.7
11/29/70	7.2	9.6	59.3	03/19/83	2.0	0.08	0.7
12/24/71	2.0	0.2	5.3	09/15/84	2.5	0.09	1.7
01/07/74	15.4	[a]	[a]	10/20/84	0.8	[c]	[c]
08/17/77	5.1	2.4	16.4	11/17/84	0.8	[c]	[c]
12/28/77	3.8	0.8	8.5	11/22/84	1.0	0.28	5.5
12/30/77	3.0	0.7	8.5	11/24/84	2.0	0.24	4.3
01/17/78	8.5	10.7	56.0	11/28/84	1.0	0.23	4.3
02/10/78	9.5	7.6	59.3	12/19/84	6.7	0.05	1.2
03/01/78	14.0	90.4	49.8	12/22/84	1.0	0.04	1.0
03/02/78	13.5	11.0	34.4	12/31/84	0.8	[c]	[c]
03/04/78	19.2	43.2	89.8	01/05/85	1.7	0.11	1.9
03/05/78	13.0	17.1	40.3	01/12/85	2.3	0.50	7.2
03/06/78	11.2	1.2	5.3	01/19/85	1.0	0.50	1.2
01/05/79	5.5	3.2	18.5	02/02/85	1.8	0.02	0.5
01/15/79	6.5	3.5	21.2	02/16/85	1.0	0.06	1.2
01/16/79	1.5	0.3	6.4	02/18/85	2.5	0.02	0.2
03/27/79	9.5	12.1	53.0	02/23/85	1.8	0.04	0.5
03/28/79	3.5	1.0	14.3	03/02/85	2.1	0.22	4.8
02/14/80	1.5	0.1	2.1	03/09/85	1.5	0.02	0.2
02/15/80	17.8	18.9	56.0	07/12/85	-	0.01	[c]
02/16/80	15.8	37.6	110.0	07/20/85	1.0	0.03	1.0
02/17/80	13.5	12.9	49.8	07/22/85	0.1	[c]	[c]
02/18/80	18.5	16.9	37.1	07/26/85	1.7	0.04	0.5
02/22/80	9.8	2.0	12.2	08/02/85	2.5	[c]	[c]
02/23/80	7.2	1.3	6.4	09/06/85	0.5	[c]	[c]
03/02/80	9.8	9.3	44.0	09/21/85	1.6	0.10	2.4
03/03/80	11.0	2.4	10.1	01/30/86	4.4	0.80	4.8
03/14/82	1.3	0.1	2.1	01/31/86	4.6	0.82	3.5
03/17/82	5.2	2.3	21.2	02/14-15/86	8.2	10.23 [d]	39.6
11/30/82	5.0	1.52	12.7	02/19/86	6.5	1.56	7.8
02/02/83	6.4	0.34	1.7	03/08/86	5.2	2.31	18.5
02/05/83	2.0	[a]	[a]	03/15/86	2.9	0.55	7.0
02/27/83	5.8	0.42	2.4	03/16/86	9.8	24.28	171.0
02/28/83	3.0	0.06	0.7	09/25/86	0.4	0.000 [d]	20.0
03/01/83	20.8	6.77	15.4	10/22-23/86	2.4	2.76 [d]	41.0
03/02/83	20.3	7.17	13.4	10/31/87	7.0	4.11 [d]	31.0
03/03/83	17.0	1.67	4.3				

Source: CLA, DPW, unpubl. data.

Note: No record available for 1968, 1972, 1973, 1975, and 1976.
No overflow recorded in 1981.

a = Insufficient data to calculate.
b = No record due to power failure.
c = Flow immeasurably small.
d = Stored 1,000,000 gallons in holding tanks.

APPENDIX I

Los Angeles County Beach Closures 1986-1992.

Appendix I. Los Angeles County beach closures, 1986-1992 (LAC,DHS unpubl. data).

LOS ANGELES COUNTY BEACH CLOSURES
1986 - 1992

Date Closed	No. of Days	Location	Cause
03/20/86	2	Redondo Pier to ¼ mile southward.	Sewage discharge under Redondo Pier.
09/26/87	2	Temescal Storm Drain to Sunset Storm Drain.	Sewage discharge due to sewage pump failure.
10/07/87	1	100 yds. north and south of Santa Monica Canyon Storm Drain.	Sewage discharge due to blocked sewer line. 100 gallons.
10/22/87	6	½ mile north of Sunset Storm Drain to ½ mile south of the Bel Air Bay Club.	Sewage discharge due to pump failure.
10/22/87	6	Ventura County border to Long Beach City border.	Sewage discharge at North Outfall Treatment Facility, due to heavy rains. 2.7M gallons.
10/22/87	42	Marina Del Rey Beach.	Excessive bird population leading to elevated bacterial levels.
10/30/87	13	Temescal Storm Drain to Sunset Storm Drain.	Unknown.
10/31/87	12	Ventura County border to Long Beach City border.	Sewage discharge at North Outfall Treatment Facility, due to heavy rains. 4.11M gallons.
11/25/87	5	Temescal Storm Drain to Sunset Storm Drain.	Unknown.
12/01/87	3	Temescal Storm Drain to Sunset Storm Drain.	Sewage discharge due to unknown sewer system failure. Approximately 2K gallons.
12/30/87	3	Pulga Canyon Storm Drain to Santa Monica Canyon Storm Drain.	Unknown.
06/03/88	1	¼ mile either side of Pulga Storm Drain.	Sewage discharge due to sewage pump failure.
07/06/88	1	¼ mile either side of Sunset Storm Drain.	Sewage discharge due to line blockage.
09/15/88	2	Santa Monica Pier south to Pico/Kenter Storm Drain.	Suspected sewage discharge from Santa Monica Pier Storm Drain.
10/07/88	1	Pico/Kenter Storm Drain to ¾ miles southward.	Possible diesel fuel flow from Pico/Kenter Storm Drain.
11/10/88	3	Venice Pier to Grand Ave. Storm Drain.	Sewage discharge into Ballona Creek due to sewer line blockage.
12/12/88	3	Sunset Storm Drain to Temescal Storm Drain.	Sewage discharge due to sewage pump failure.

Appendix I (Cont.)

LOS ANGELES COUNTY BEACH CLOSURES
1986 - 1992

Date Closed	No. of Days	Location	Cause
01/23/89	3	200 yds. north and south of Santa Monica Pier.	Small sewage discharge under Santa Monica Pier.
03/06/89	3	King Harbor south ¼ mile to Ainsworth Court.	Sewage discharge due to restaurant sewer line blockage.
05/02/89	2	Venice Pier to Imperial Ave. Storm Drain.	Sewage discharge into Ballona Creek due to sewage pump failure, 100K gallons.
09/26/89	3	¼ mile either side of Ashland Storm Drain.	Sewage discharge of unknown origin into Ashland storm drain. Est. less than 500 gallons.
11/20/89	1	½ mile either side of Pulga Storm Drain.	Sewage discharge due to pump failure caused by tripped circuit breaker. Est. 1.5K gallons.
12/13/89	2	Sunset Storm Drain to Temescal Storm Drain.	Sewage discharge due to pump failure caused by faulty air check valve at pump station 639. Approximately 6.5K gallons.
02/17/90	4	Entire Los Angeles County coastline from Topanga Canyon Storm Drain to Palos Verdes Point.	Discharge of primary treated sewage from North Outfall Treatment Facility, due to heavy rains. Approximately 7.6M gallons.
9/19/90	9	Santa Monica Pier south to Ashland storm drain. Reopened Ashland to Hart St. on 9/21/90.	Possibly caused by construction on the Pico/Kenter storm drain. Release of accumulated debris. Not sewage related.
12/10/90	4	King Harbor south to Pearl Street extended (appx. ¼ mi. north and south of Redondo Pier)	Small sewage leak from 12" main.
02/28/91	14	Topanga Canyon Blvd. south to Palos Verdes Point. Closure reduced to Marina Del Rey entrance channel south to the El Segundo city line and Marina Del Rey on 3/5/91.	Discharge of 2.31M gallons partially treated sewage at the North Outfall Treatment Facility due to heavy rains.
03/01/91	13	Topanga Canyon to the Ventura County border. Closure reduced to Topanga Canyon to Malibu Creek on 3/6/91.	Washout of private sewage treatment systems due to heavy rains.
03/24/91	1	Surfrider Beach, Malibu.	Diesel fuel spill.
03/29/91	2	Grand Ave. north to Imperial Highway.	Diesel fuel spill.

Appendix I (Cont.)

LOS ANGELES COUNTY BEACH CLOSURES
1986 - 1992

Date Closed	No. of Days	Location	Cause
11/21/91	4	Imperial Highway storm drain, one mile north and south.	Sewer line break at Hyperion Treatment plant resulting in flow of sewage into Imperial Hwy. storm drain and 2K gallons of sewage into ocean. Partially reopened 11/22/91.
02/10/92	11	Entire L.A. County coastline, from Ventura County of Long Beach City.	Discharge of 66.12M gal. partially treated sewage at the North Outfall Treatment Facility due to heavy rains. Partially reopened 2/19/92 from MDR entrance channel to Cabrillo Beach.
05/02/92	3	Dockweiler Beach, ½ mile north to 1 mile south of Marina Del Rey entrance channel and Marina Del Rey Beach.	High Bacteria counts detected in Ballona Creek, most likely caused by a small sewage discharge which occurred when a contractor accidently drilled into a sewer line. This coincided with civil disturbances in Los Angeles and as a precautionary measure beaches were closed.
05/16/92	1	Redondo Beach Pier, south to Ruby St. (appx. ¼ mile).	Leaking sewer line under the Redondo Beach Pier. Quantity unknown.
07/29/92	1	Redondo Beach Pier, south to Ruby St. (appx. ¼ mile).	Leaking sewer line under the Redondo Beach Pier. Quantity 50 - 75 gallons.
08/15/92	3	Rose Ave. south to Imperial Highway (appx. 4 miles).	High bacteria counts originating from sewage in upper Ballona Creek, source unknown. Coastline reopened 8/18/92 and Marina Del Rey Beach reopened 8/19/92.
08/17/92	3	Redondo Beach Pier, south to Knobhill Ave. (appx. ¾ mile)	Leaking sewer line under the Redondo Bch. Pier due to vandalism. Amount and duration unknown.
09/04/92	1	Avenue 23, Los Angeles, south to Imperial Highway. (appx. 2½ miles).	High bacteria counts detected in Ballona Creek, source unknown, with the potential to affect adjacent beaches.
09/16/92	1	Pico Blvd. south to Windward Ave. (appx. 2 miles).	Collapsed sewer line discharging into Ashland Storm Drain.

LITERATURE CITED

Abbott, I. A., and G. J. Hollenberg. 1976. Marine algae of California. Stanford Univ. Press, Stanford, CA. 827 p.

AHF. See University of Southern California, Allan Hancock Foundation.

Akin, E. W., W. A. Benton, and W. F. Hill. 1971. Enteric viruses in fresh and saline waters: a review of their occurrence and survival. *In* V. Snoeyink and V. Griffin (eds.) Virus and water quality: occurrence and control. Univ. Ill. Urbana.

Allen, B. H. 1990. Classification of oak woodlands. Fremontia, July: 22-25.

Allen, M. J. 1982. Functional structure of soft-bottom fish communities of the southern California shelf. Ph. D. Dissertation, Univ. Calif., San Diego, La Jolla, CA. 577 p. (available from Univ. Microfilms Internatl., Ann Arbor, MI, no. 8300991).

Allen, M. J., H. Pecorelli, and J. Word. 1976. Marine organisms associated with outfall pipes in Santa Monica Bay, California. J. Water Pollut. Control Fed. 48:1881-1893.

Allen, M. J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA Tech. Rep. NMFS 66. 151 p.

Allen, M. J., and R. Voglin. 1976. Regional and local variation of bottom fish and invertebrate populations. Pages 217-221 *in* Coastal water research project annual report for the year ended 30 June 1976. So. Calif. Coast. Water Res. Proj., El Segundo, CA. 263·p.

Alzieu, C. 1986. TBT detrimental effects on oyster culture in France - Evolution since antifouling paint regulation. 1986 Proc. Oceans '86. Mar. Technol. Soc., IEEE, Washington, D.C. Vol 4:1130-1134.

Anderson, D. W., and J. J. Hickey. 1970. Oological data on egg and breeding characteristics of brown pelicans. Wilson Bull. 82:14-28.

Anderson, D. W., J. R. Jehl, Jr., R. W. Risebrough, L. A. Woods, Jr., L. R. DeWeese, and W. G. Edgecomb. 1975. Brown pelicans: Improved reproduction off the southern California coast. Science 190(4216):806-808.

Anderson, D. W., and J. O. Keith. 1980. The human influence on seabirds nesting success: Conservation implications. Biol. Cons. 18:65-80.

Anderson, J. W., S. M. Bay, and B. E. Anderson. 1988. Characteristics and effects of contaminated sediments from southern California. Prepared for California State Water Resources Control Board, Sacramento, CA. So. Calif. Coastal Water Res. Proj., Long Beach, CA. Contract No. 6-214-250-0.

Anderson, J. W., and R. W. Gossett. 1986. Final report on polynuclear aromatic hydrocarbon contamination in sediments from coastal waters of southern California. CSWRCB, Sacramento, CA 95801. 50 p. plus appendices.

Anikouchine, W., and R. Sternberg 1973. The World Ocean: An Introduction to Oceanography, Prentice-Hall, Inc.

Armstrong, G. 1991. Shore protection construction along the California coast, Coastal Zone '91, Vol. I, Proceeding of the Seventh Symposium on Coastal and Ocean Management, O. Magoon, H. Converse, V. Tippie, L. Tobin, and D. Clark, ed., American Society of Civil Engineers.

Atlas, R. M. 1984. Microbiology: Fundamentals and applications. MacMillan Publ. Co. New York, NY. 879 p.

Atwood, J., and D. Minsky 1983. Least tern foraging ecology at three major California breeding colonies, Western Birds, Vol. 14, No. 2.

Azam, R. 1986. Chapter 7. Nutrient cycling and foodweb dynamics in Southern California Bight: The microbial foodweb. Pages 274-288 *in* R. W. Eppley (ed.), Lecture notes on coastal and estuarine studies. Vol. 15, Plankton dynamics of the Southern California Bight. Springer-Verlag, NY. 373 p.

Bakus, J. 1975. Ballona Lagoon: Marine biology and water quality. Prepared for Isthmus Land Owners Association by Tetra Tech, Pasadena, CA. 27 p.

Barletta, R. J., and R. A. Webber. 1986. A tale of three giant sewage systems. Jour. Water Pollut. Cont. Fed. 58(9):871-879.

Bascom, W. 1977. The disposal of waste in the ocean. Pages 276-285 *in* H. W. Menard (ed.), Ocean Science. W. H. Freeman and Co., San Francisco, CA.

Bascom, W. 1978. Life in the bottom: San Diego and Santa Monica Bays, Palos Verdes and Point Loma Peninsulas. Pages 57-80 *in* W. Bascom (ed.), Coastal water research project annual report, 1978. So. Calif. Coastal Water Res. Proj., El Segundo, CA 90245.

Bascom, W., and Staff of SCCWRP. 1980. The effects of sludge disposal in Santa Monica Bay. Pages 197-234 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1979-1980. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 363 p.

Becker, D. S., T. C. Ginn, M. L. Landolt, and D. B. Powell. 1987. Hepatic lesions in English sole (*Parophrys vetulus*) from Commencement Bay, Washington (USA). Mar. Environ. Res. 23:153-173.

Beers, J. R. 1986. Chapter 4. Organisms and the food web. Pages 84-175 *in* R. W. Eppley (ed.), Lecture notes on coastal and estuarine studies. Vol. 15, Plankton dynamics of the Southern California Bight. Springer-Verlag, NY. 373 p.

Bent, A. C. 1926. Life histories of North American marsh birds. U.S. Nat. Mus., Bull. 135. 392 p.

Bernstein, B. B., R. W. Smith, and B. E. Thompson. 1984. Sampling design and replication for benthic monitoring. Pages 21-36 *in* W. Bascom (ed.), Coastal water research project biennial report, 1983-1984. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 332 p.

BLM. See Bureau of Land Management.

BLM. See United States Department of Interior, Bureau of Land Management.

Boardman, C., 1988. Organochlorine pesticides in California least terns (*Sterna antillarum browni*). M.S. Thesis, California State Univ., Long Beach.

Boardman, C., and C. Collins, 1992. Lead in the feathers of the California least tern (*Sterna antillarum browni*), Bulletin of the Southern California Academy of Science, in press.

Bongersma-Sanders, M. 1957. Mass mortality in the sea. Pages 941-1010 *in* Hedgpeth, J. W. (ed.), Treatise on marine ecology and paleoecology, Vol. 1, Ecology, Geol. Soc. Am., Mem. 67.

Bonnell, M. L., B. J. LeBoeuf, M. O. Pierson, D. H. Dettman, G. D. Farrens, and C. B. Heath. 1981. Final report: Summary of marine mammals and seabirds surveys of the Southern California Bight area, 1975-1978. Vol. III, Investigator's reports. Center for Coastal Marine Studies, University of California, Santa Cruz, CA. Prepared for Bureau of Land Management, Cont. AA550-CT7-36.

Britt, J. O., and E. B. Howard. 1983. Tissue residues of selected environmental contaminants in marine mammals. Pages 80-94 *in* E. B. Howard (ed.), Pathobiology of marine mammal diseases, Vol. 2. CRC Press, Inc., Boca Raton, FL.

Brooks, F., 1992. Drought as a predisposing factor in plant disease, Southern California Botanists 18th Annual Symposium on The Drought: Effects on Native Plants, 24 October.

Brown, D. A., R. W. Gossett, G. P. Hershelman, C. F. Ward, and J. N. Cross. 1984. Metal and organic contaminants in sediments and animals. Pages 179-193 *in* W. Bascom (ed.), Coastal water research project biennial report, 1983-1984. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 332 p.

Brown, D. A., R. W. Gossett, G. P. Hershelman, C. F. Ward, A. M. Westcott, and J. N. Cross. 1986. Municipal wastewater contamination in the Southern California Bight: Part I - Metal and organic contaminants in sediments and organisms. Mar. Environ. Res. 18:291-310.

Brown, V., and G. Lawrence. 1965. The Californian Wildlife Region. 2nd revised edition. Naturegraph Publishers, Healdsburg, CA. 128 p.

Browning, R. J. 1980. Fisheries of the North Pacific. Revised edition. Alaska Northw. Publ. Co., Anchorage, AK. 423 p.

Bureau of Land Management. 1981. Final environmental impact statement: Proposed 1982 Outer Continental Shelf oil and gas lease sale offshore southern California. OCS Sale No. 68, Vol. 1 of 2.

Cabelli, V. J. 1980. Epidemiology of enteric viral infections. Pages 291-304 *in* International Symposium on Viruses and Wastewater Treatment. M. Goddard and M. Butler (eds). Pergamon Press, London.

Cabelli, V. J. 1983a. Water-borne viral infections. Pages 107-130 *in* M. Butler, A. R. Medlen, and R. Morris (eds.) Viruses and disinfection of water and wastewater. Univ. of Surry Press, Guilford, England.

Cabelli, V. J. 1983b. Public health and water quality significance of viral diseases transmitted by drinking water and recreational water. Water Sci. Technol. 15:1-15.

Cabelli, V. J., A. P. Dufour, L. J. McCabe, M. A. Levin, and P. W. Haberman. 1979. Relationship of microbial indicators to health effects at marine bathing beaches. AJPH. 69 (7): 690-696.

Cabelli, V. J., A. P. Dufour, L. J. McCabe, and M. A. Levin. 1982. Swimming associated gastroenteritis and water quality. Am. J. Epidemiol. 115:606-616.

Cabelli, V. J., A. P. Dufour, L. J. McCabe, and M. A. Levin. 1983. A marine recreational water quality criterion consistent with indicator concepts and risk analysis. J. Water Pollut. Control Fed. 55:1306-1314.

Calabrese, E. J., and A. J. Sorenson. 1977. The health effects of PCBs with particular emphasis on human high risk groups. Rev. Environ. Health 2:285-304.

California Coastal Zone Conservation Commission. 1975. Preliminary coastal plan, hearing draft, March 1975, San Francisco, CA.

California Department of Fish and Game. 1982. Determination of the status of the Ballona wetlands, Los Angeles County, California, December 1, 1982. CDFG, Long Beach, CA., 27 p.

California Department of Fish and Game. 1986. Review of some California fisheries for 1985. Calif. Coop. Ocean. Fish. Invest. Rep. 27:7-15.

California Department of Fish and Game. 1987. Review of some California fisheries for 1986. Calif. Coop. Ocean. Fish. Invest. Rep. 28:11-20.

California Department of Fish and Game 1992. State and Federal endangered and threatened animals of California. Calif. Dep. Fish Game, Sacramento, CA. 6 p.

California Department of Parks and Recreation. 1978. Malibu Lagoon State Beach resource management plan, general development plan, environmental impact report. The Resources Agency, Sacramento, CA. 31 p. plus appendices.

California Employment Development Department. 1992. Largest industries in the Los Angeles five-county area, based on U. S. census report. Calif. Employ. Dev. Dep., Sacramento, CA.

California Least Tern Recovery Team. 1980. California least tern recovery plan. Prepared by U.S. Fish Wildl. Serv., Region 1, Portland, OR, in cooperation with the Recovery Team. 58 p.

California Native Plant Society 1988. Inventory of Rare and Endangered Vascular Plants of California, Special Publ. No. 1, 4th ed., September.

California State Water Pollution Control Board. 1959. Oceanographic survey of the continental shelf area of southern California. Calif. State Water Pollution Control Bd. Publ. No. 20. 560 p.

California State Water Quality Control Board. 1964. An investigation of the effects of discharged waste on kelp. Calif. State Water Quality Control Bd., Publ No. 26, Sacramento, CA. 124 p.

California State Water Quality Control Board. 1965. An oceanographic and biological survey of the southern California mainland shelf. Publ. No. 27, Calif. State Water Quality Control Bd.,Sacramento, CA. 446 p. plus appendices.

California State Water Resources Control Board. 1979. California marine waters: Areas of special biological significance reconnaissance survey report. Mugu Lagoon to Latigo Point, Ventura and Los Angeles Counties. Rpt. 79-5. California State Water Resources Control Bd., Sacramento, CA.

California State Water Resources Control Board. 1982. California state mussel watch 1980-1981: trace metals and synthetic organic compounds in mussels from California's coast, bays, and estuaries. California State Water Resources Control Bd.,Sacramento, CA. 157 pp. plus appendices.

California State Water Resources Control Board. 1983. Polychlorinated biphenyls (PCBs). Spec. Proj. Rep. No. 83-1sp. California State Water Resources Control Bd.,Sacramento, CA. 174 p.

California State Water Resources Control Board 1988. California State Mussel Watch, Ten Year Data Summary, 1977-1987, Water Quality Monitoring Report No. 87-3, May 1988.

California State Water Resources Control Board. 1990. Water quality control plan, ocean waters of California, California ocean plan. State Water Resources Control Board. 22 p.

Campana, S. E. 1983. Mortality of starry founders (*Platichthys stellatus*) with skin tumors. Can. J. Fish. Aquat. Sci. 40:200-207.

Carefoot, T. 1977. Pacific seashores. J. J. Douglas Ltd., North Vancouver, B.C. 208 p.

Carlisle, J. G., Jr. 1969. Results of a six-year trawl study in an area of heavy waste discharge: Santa Monica Bay, California. Calif. Dept. Fish and Game 55(1):26-46.

Carlisle, J. G., Jr., C. H. Turner, and E. E. Ebert. 1964. Artificial habitat in the marine environment. Calif. Dep. Fish Game, Fish Bull. 124. 93 p.

Carter, J. W., W. N. Jessee, M. S. Foster, and A. L. Carpenter 1985. Management of artificial reefs designed to support natural communities. Bulletin of Marine Science. 37(1): 114-128.

Casali, O., G. Castelli, D. Fontana and F. Marabini, 1991. The safeguard of the coastal environment: a possibility of a preventive action against the erosive phenomena, Coastal Zone '91, Vol. I, Proceeding of the Seventh Symposium on Coastal and Ocean Management, O. Magoon, H. Converse, V. Tippie, L. Tobin, and D. Clark, ed., American Society of Civil Engineers.

CCZCC. See California Coastal Zone Conservation Commission.

CDC. See Centers for Disease Control.

CDFG. See California Department of Fish and Game.

CDPR. See California Department of Parks and Recreation.

Centers for Disease Control. 1987. Outbreak of viral gastroenteritis -- Pennsylvania and Delaware. MMWR 36:710-711.

Chartrand, A. 1988. Montrose Chemical Corporation: strategies for managing a widespread point source contaminant. Pages 50-56 *in* The Bay Institute of San Francisco, Managing inflows to California's bays and estuaries, The Bay Institute of San Francisco, Sausalito, CA.

Chartrand, A. B., S. Moy, A. N. Safford, T. Yoshimura, and L. A. Schinazi. 1985. Ocean dumping under Los Angeles Regional Water Quality Control Board permit: A review of past practices, potential adverse impacts, and recommendations for future action. Calif. Water Quality Control Bd., Los Angeles region, March 1985. 47 p. plus appendices.

Chevron U.S.A. 1987. Annual NPDES 1985 summary report. Regional Water Quality Control Board, Los Angeles Region, Tech. Rep., Los Angeles, CA. 24 p.

Chew, K. K., and A. P. Ma. 1987. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) -- common littleneck clam, U. S. Fish and Wildlife Service Biological Report 82(11.78), U. S. Army Corps of Engineers, TR EL-82-4, 22 p.

City of Los Angeles. 1987. HERS Project update. CLA, Los Angeles, CA. September. 7 p.

City of Los Angeles, Bureau of Engineering. 1977. Draft environmental impact report and environmental impact statement for the City of Los Angeles Wastewater Facilities Plan. City of Los Angeles, Dep. Publ. Works, Los Angeles, CA.

City of Los Angeles, Department of Airports. 1992. Los Angeles International Airport passenger forecast. City Los Angeles, Dep. Airports, Los Angeles, CA.

City of Los Angeles, Department of Public Works. 1982. Final environmental impact statement and environmental impact report for the City of Los Angeles wastewater facilities plan. CLA,DPW, Los Angeles, CA.

City of Los Angeles, Department of Public Works. 1987. Hyperion Treatment Plant and Santa Monica Bay 1986 Annual Summary Report. NPDES Permit No. CA0109991. (File No. 1492). April 1987. 21 p. plus appendices.

City of Los Angeles, Department of Public Works. 1988. Hyperion treatment plant and Santa Monica Bay, annual summary report 1987, September-December. City of Los Angeles, Board. Publ. Works, Bur. Sanit., Los Angeles, CA. 351 p.

City of Los Angeles, Department of Public Works. 1989. Hyperion treatment plant and Santa Monica Bay, annual summary report 1988. City of Los Angeles, Dep. Publ. Works, Bur. Sanit., Env. Monit. Div., Los Angeles, CA. 192 p.

City of Los Angeles, Department of Public Works. 1990. Hyperion treatment plant and Santa Monica Bay, annual summary report 1989. City of Los Angeles, Dep. Publ. Works, Bur. Sanit., Env. Monit. Div., Los Angeles, CA. 190 p.

City of Los Angeles, Department of Public Works. 1991. Marine monitoring in Santa Monica Bay, annual assessment report for the period July, 1989 through June, 1990. City of Los Angeles, Dep. Publ. Works, Bur. Sanit., Env. Monit. Div., Los Angeles, CA. 221 p.

City of Los Angeles, Department of Public Works. 1992. Hyperion treatment plant and Santa Monica Bay, annual summary report 1991. City of Los Angeles, Dep. Publ. Works, Bur. Sanit., Env. Monit. Div., Los Angeles, CA. 166 p.

City of Los Angeles, Department of Public Works and U.S. Environmental Protection Agency. 1977. Draft environmental impact report and environmental impact statement for the City of Los Angeles wastewater facilities plan, September 1977. CLA,DPW, Los Angeles, CA. Grant CA-06-1034.

City of Santa Monica. 1991. Land Use Survey and Data Base, Summary Report. City Santa Monica, Santa Monica, CA (May).

CLA. See City of Los Angeles.

CLA,BE. See City of Los Angeles, Bureau of Engineering.

CLA,DA. See City of Los Angeles, Department of Airports.

CLA,DPW. See City of Los Angeles, Department of Public Works.

CLA,DPW and USEPA. See City of Los Angeles, Department of Public Works and U.S. Environmental Protection Agency.

Clark, J. 1979. Ballona wetlands study. Urban Planning Program. Univ. Calif., Los Angeles. Los Angeles, CA.

Clark, C., 1992. How dry is a drought?, Southern California Botanists 18th Annual Symposium on The Drought: Effects on Native Plants, 24 October.

CLTRT. See California Least Tern Recovery Team.

CNPS (see California Native Plant Society)

Collins, C. T. 1992. Metals in eggs of California least tern in southern California. So. Calif. Acad. Sci. Bull. 91(2):49-54.

Connally, D. W., R. E. Schlotterbeck, and D. A. Rundstrom. 1982. Marine ichthyoplankton entrainment studies, Vol. II, Analysis and interpretation, August 1979-September 1980. Prepared by MBC Applied Environmental Sciences, Costa Mesa, CA, for So. Calif. Edison Co., Rosemead, CA. 62 p.

Cooper, C. F., and J. R. Jehl, Jr. 1980. Potential effects of space shuttle sonic booms on the biota and geology of the California Channel Islands: Synthesis of research and recommendations. Center for Marine Studies, San Diego State Univ., San Diego, CA. Tech. Rep. 80-2. 43 p.

Cooper, R. C., and C. A. Keller. 1969. Epizootiology of papillomas in English sole, *Parophrys vetulus*. Nat. Cancer Inst. Monogr. 31:173-185.

Cordle, F., P. Corneliussen, C. Jelinek, B. Hackley, R. Lehman, J. McLaughlin, R. Rhoden, and R. Shapiro. 1978. Human exposure to polychlorinated biphenyls and polybrominated biphenyls. Environ. Health Perspectives 24:157-172.

Couch, E. B. 1915. Study of the ecology of the marine algae at Point Fermin, California. M.S. thesis, Univ. So. Calif., Los Angeles, CA. 67 p.

Covey, C. 1984. The earth's orbit and the ice ages. Sci. Amer. 250(2):58-66.

Cowan, D. F., W. A. Walker, and R. L. Brownell, Jr. 1986. Pathology of small cetaceans stranded along southern California beaches. Pages 325-367 *in* M. M. Bryden and R. Harrison (eds.), Research on dolphins. Claredon Press, Oxford.

Cross, J. N. 1982a. Evaluation of otter trawl data. Pages 91-98 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1981-1982. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 294 p.

Cross, J. N. 1982b. Intertidal fishes of southern California. Pages 111-117 *in* W. Bascom (ed.), Coastal water research project, biennial report, 1981-1982, So. Calif. Coastal Water Res. Proj., Long Beach, CA.

Cross, J. N. 1985. Fin erosion among fishes collected near a southern California municipal wastewater outfall (1972-82). Fish. Bull. U.S. 83:195-206.

Cross, J. N. 1986. Epidermal tumors in *Microstomus pacificus* (Pleuronectidae) collected near a municipal wastewater outfall in the coastal waters off Los Angeles (1971-1983). Calif. Fish Game 72:68-77.

Cross, J. N. 1988. Fin erosion and epidermal tumors in demersal fish from southern California. Pages 57-64 *in* D. A. Wolfe and T. P. O'Connor (eds.), Ocean processes in marine pollution. Vol. 5, Urban wastes in coastal marine environments. Krieger Publishing Co., Malabar, FL.

Cross, J. N., J. T. Hardy, J. E. Hose, G. P. Hershelman, L. D. Antrim, R. W. Gossett, and E. A. Crecelius. 1988. Contaminant concentrations and toxicity of sea-surface microlayer near Los Angeles, CA. Marine Environmental Research.

Cross, J. N. and J. E. Hose. 1988. Evidence for impaired reproduction in white croaker (*Genyonemus lineatus*) from contaminated areas off Southern California. Mar. Environ. Res. 24, 185-188.

Cross, J. N., J. Roney, and G. S. Kleppel. 1985. Fish food habits along a pollution gradient. Calif. Dept. of Fish & Game. 71(1):28-39.

CSWPCB. See California State Water Pollution Control Board.

CSWQCB. See California State Water Quality Control Board.

CSWRCB. See California State Water Resources Control Board.

Cushman Realty Corporation. 1992. Foreign ownership summary of downtown Los Angeles office buildings. Cushman Realty Corp., Los Angeles, CA.

Dahlheim, M. E., H. D. Fisher, and J. D. Schempp. 1984. Sound production by the gray whale and ambient noise levels in Laguna San Ignacio, Baja California Sur, Mexico. Pages 511-541 *in* M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.), The gray whale. Academic Press, Inc., Orlando, FL.

Danielsen, K. C., and W. L. Halvorson. 1990. Valley oak restoration: a community approach. Fremontia, July:52.

Davis, S., K. Kolb and J. Jarbeau, 1992. Drought tolerance and xylem embolism in chaparral and coastal sage of California, Southern California Botanists 18th Annual Symposium on The Drought: Effects on Native Plants, 24 October.

Dawson, E. Y. 1959. A preliminary report on the benthic marine flora of southern California. Pages 169-264 *in* Oceanographic survey of the continental shelf area of southern California. State Water Pollut. Cont. Bd., Sacramento, CA. Publ. 20.

Dawson, E. Y. 1965. Intertidal algae. Pages 230-231, Appendix 351-438 *in* An oceanographic and biological survey of the southern California mainland shelf. California State Water Quality Control Board, Sacramento, CA. Publ. 27.

Dawson, E. Y. 1966. Seashore plants of southern California. Calif. Nat. Hist. Guides 19. Univ. Calif. Press, Los Angeles, CA. 101 p.

Dayton, P. K., and M. J. Tegner. 1984. Catastrophic storms, El Niño, and patch stability in a southern California kelp community. Science 224:283-285.

deGoeij, J. J. M., V. P. Guinn, D. R. Young, and A. J. Mearns. 1974. Neutron activation analysis of Dover sole liver and marine sediments. Pages 189-200 *in* Comparative Studies of Food and Environmental Contamination. International Atomic Energy Agency, Vienna.

Dock, C. F., and R. W. Schreiber. 1981. The birds of Ballona. Pages Bi-1 to Bi-88 *in* R. W. Schreiber (ed.), Biota of the Ballona region, Los Angeles County. Suppl. I, Marina Del Rey/Ballona local coastal plan. Los Angeles Co. Nat. Hist. Mus. Found., Los Angeles, CA.

Dohl, T. P., K. S. Norris, R. C. Guess, J. D. Bryant, and M. W. Honig. 1981. Final report: Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975-1978. Vol. III, Investigator's reports. Prepared for Bureau of Land Management, Cont. AA550-CT7-36. Center for Coastal Marine Studies, University of California, Santa Cruz, CA.

Dorsey, J. 1988. Wastewater discharge in Santa Monica Bay: I. Introduction and effects on macrofaunal assemblages. Pages 27-31 *in* Managing inflows to California's bays and estuaries, Symposium 13-15 November 1986, Monterey, CA. The Bay Institute, Sausalito, CA.

Drake, D. E., and D. S. Gorsline. 1973. Distribution and transport of suspended particulate matter in Hueneme, Redondo, Newport, and La Jolla Submarine Canyons, California. Geol. Soc. Am., Bull. 84:3949-3968.

Dufour, A. P. 1976. *E. coli*: the fecal coliform. Pages 48-58 *in* A. W. Hoadley and B. J. Dutka (eds.) Bacterial indicators. Health hazards associated with water. ASTM, Philadelphia, PA.

Dufour, A. P., and V. Cabelli. 1983. The risk of infectious disease associated with the marine environment. Pages 217-232 *in* Bascom, W. (ed.), The effects of waste disposal on kelp communities. So. Calif. Coast. Water Res. Project, Long Beach, CA, and Inst. Mar. Res., Univ. Calif., San Diego, La Jolla, CA.

Economic Development Corporation. 1992. Economic and industry forecast for the Los Angeles five-county area. Econ. Dev. Corp., Los Angeles, CA.

Edmond, T., G. Schaiberger et al. 1978. Detection of enteroviruses near deep marine sewage outfalls. Mar. Poll. Bull. 9: 246.254.

Eganhouse, R.P., D.L. Blumfield, and I.R. Kaplan. 1983. Long-chain alkylbenzenes as molecular tracers of domestic waste in the marine environment. Environ. Sci. Technol. 17:523-530.

Eganhouse, R. P., J. N. Johnson, D. R. Young, and D. J. McDermott. 1976. Mercury in southern California waters: Inputs, distribution, and fate. Tech. Man. 227. SCCWRP, Long Beach, CA. 57 pp.

Eganhouse, R.P., and I.R. Kaplan. 1985. Alpha-tocopheryl acetate as an indicator of municipal waste contamination in the environment. Environ. Sci. & Technol. 19:282-285.

Eisler, R. 1978. Mercury contamination standards for marine environments. Pages 241-272 *in* J. H. Thorp and J. W. Gibbons (eds.), Energy and environmental stress in aquatic systems, Tech. Information Ctr., U. S. Dept. Energy, Washington, DC.

Eliason, J. R. and H. P. Foote. 1972. Preliminary report - Coastal power plant survey using thermal infrared and tracer dye technique on Southern California Edison Plants: Mandalay, Ormond Beach, El Segundo-Scattergood, Redondo Beach, Long Beach, Alamitos-Haynes, Huntington Beach, San Onofre. Prepared for Southern California Edison Company, Rosemead, CA. Pac. Northw. Labs., Battelle Memorial Inst., Richland, WA.

Emery, K. O. 1960. The sea off southern California: A modern habitat of petroleum. John Wiley & Sons, Inc., New York, NY. 366 p.

Emmel, T., and J. Emmel. 1973. The Butterflies of Southern California, Natural History Museum of Los Angeles County, Science Series 26, November 30, 1973.

Engineering Science, Inc. 1987. Study work plan for Santa Monica Bay stormwater pollutant reduction study. Prepared for City of Los Angeles, Wastewater Prog. Mgmt. Div., Los Angeles, CA. Engineering Science, Inc., Pasadena, CA. 70 p.

Environmental Quality Analysts, Inc., and Marine Biological Consultants, Inc. 1973. Thermal effect study, final summary report, Redondo Beach Generating Station. Prepared for Southern California Edison Company, Rosemead, CA., July 1973. 116 p. with appendices.

Eppley, R. W. 1986. Chapter 8. People and the plankton. Pages 289-303 *in* R. W. Eppley (ed.), Lecture notes on coastal and estuarine studies. Vol. 15, Plankton dynamics of the Southern California Bight. Springer-Verlag, New York, NY. 373 p.

Eppley, R. W., and O. Holm-Hansen. 1986. Chapter 5. Primary production in the Southern California Bight. Pages 176-215 *in* R. W. Eppley (ed.), Lecture notes on coastal and estuarine studies. Vol. 15, Plankton dynamics of the Southern California Bight. Springer-Verlag, New York, NY. 373 p.

Eppley, R. W., E. H. Renger, W. G. Harrison, and J. J. Cullen. 1979. Ammonium distribution in southern California coastal waters and its role in the growth of phytoplankton. Limnol. Oceanogr. 24(3):495-509.

EQA/MBC. See Environmental Quality Analysts, Inc., and Marine Biological Consultants, Inc.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A Field Guide to Pacific Coast Fishes of North America, from the Gulf of Alaska to Baja California. Houghton Mifflin Co., Boston. 336 p.

Evans, W. E., J. R. Jehl, Jr., and C.F. Cooper (eds.). 1979. Potential impact of space shuttle sonic booms on the biota of the California Channel Islands: Literature review and problem analysis. U.S. Air Force, Space Missile Sys. Org., Cont. F04701-78-C-0060.

Faber, P. M., E. Keller, A. Sands, and B. M. Massey. 1989. The ecology of riparian habitats of the southern California coastal region: A community profile. U.S. Department of the Interior, Fish and Wildlife Service, Research and Development, National Wetlands Research Center, Washington, D.C. 20240. 152 p.

Fattal, B., E. Peleg-Olevsky, Y. Yoshe-Purer, and H. I. Shuval. 1986. The association between morbidity among bathers and microbial quality of sea water. Water Sci. Tech. 18:59-69.

Fattal, B., R. J. Vasl, E. Katznelson, and H. I. Shuval. 1983. Survival of bacterial indicator organisms and enteric viruses in the Mediterranean coastal waters off Tel Aviv. Water Res. 17:397-402.

Fay, R. C. 1972. An evaluation of the health of the benthic marine biota of Ventura, Los Angeles and Orange Counties. Prepared for Southern California Association of Governments, Los Angeles, CA. With E. D. Michael, J. A. Vallee, and G. B. Anderson. Cover page is titled Coastline planning program, inshore waters inventory. 132 pp.

Fay, R. C., J. A. Vallee, and P. Brophy. 1978. An analysis of fish catches obtained with an otter trawl in Santa Monica Bay, 1969-1973. Calif. Fish Game 64:104-116.

Fitch, J. E., and R. J. Lavenberg. 1971. Marine food and game fishes of California. Univ. Calif. Press, Berkeley, CA. 179 p.

Fitch, J. E. and R. J. Lavenberg. 1975. Tidepool and nearshore fishes of California. Univ. Calif. Press, Berkeley, CA. 156 p.

Fitzgerald, W. F., G. A. Gill, and A. D. Hewitt. 1983. Air-sea exchange of mercury. Pages 297-316 *in* C. S. Wong, E. Boyle, K. W. Bruland, J. D. Burton, and E. D. Goldburg (eds.), Trace metals in seawater. NATO Conference Series IV: Marine Sciences. Plenum Press, New York, NY.

Ford, R., and G. Collier. 1976. An ecological evaluation of Ballona Lagoon. Prepared for Isthmus Land Owners Association by Center for Marine Studies, San Diego State University. 76 p. plus appendices.

Fowler, S. W. 1982. Biological transfer and transport processes. Pages 1-65 *in* G. Kullenberg (ed.), Pollutant transfer and transport in the sea, Vol. II. CRC Press, Boca Raton, FL.

Friesen, R. D., W. K. Thomas, and D. R. Patten. 1981. The mammals of Ballona. Pages M-1 to M-54 *in* R. W. Schreiber (ed.), Biota of the Ballona region, Los Angeles County. Suppl. I, Marina Del Rey/Ballona local coastal plan. Los Angeles Co. Nat. Hist. Mus. Found., Los Angeles, CA.

Galloway, J. N. 1979. Alteration of trace metal geochemical cycles due to the marine discharge of wastewater. Geochim. Cosmochim. Acta 43:207-218.

Garabrant, D. H., J. Held, B. Langholz, J. M. Peters, and T. M. Mack. 1992. DDT and related compounds and risk of pancreatic cancer. J. Natl. Cancer Inst. 84:764-771.

Garber, W. F., and F. F. Wada. 1988. Water quality in Santa Monica Bay, as indicated by measurements of total coliforms. *In*: D. A. Wolfe and T. P. O'Connor (eds.), Oceanic processes in marine pollution. Vol. 5, Urban wastes in coastal marine environments. Douglas Krieger Publ. Co., Malabar, FL.

Garrett, K. and J. Dunn. 1981. Birds of Southern California: Status and Distribution, Los Angeles Audubon Society.

Gerba, C., S. Goyal, et al. 1979. Failure of indicator bacteria to reflect the occurrence of enteroviruses in marine waters. Am. J. Pub. Health. 69: 1116-1123.

Gerba, C., J. Rose, et al. 1985. Waterborne gastroenteritis and viral hepatitis. CRC Crit. Rev. Env Control. 15: 213-226.

Gerba, C. P. and G. E. Schaiberger. 1975. Effects of particulates on virus survival in seawater. J. Wat. Poll. Contr. Fed. 47:93-103.

Gold, M., M. Bartlett, J. Dorsey, and C. McGee. 1990. An assessment of inputs of fecal indicator organisms and human enteric viruses from two Santa Monica Bay storm drains, Technical Report. Santa Monica Bay Restor. Proj., Monterey Park, CA. 40 p.

Gold, M., M. Bartlett, J. Dorsey, and C. McGee. 1991. Storm drains as a source of surf zone bacterial indicators and human enteric viruses to Santa Monica Bay. Prepared for Santa Monica Bay Restor. Proj., Monterey Park, CA. Heal the Bay, Santa Monica, CA. 31 p.

Gold, M., M. Bartlett, C. McGee, and G. Deets. 1992. Pathogens and indicators in storm drains within the Santa Monica Bay watershed, draft report. Santa Monica Bay Restor. Proj., Monterey Park, CA. 42 p.

Goodman, J. S. 1935. The marine algae in the vicinity of Flat Rock Point near Redondo, California. M.S. thesis, Univ. So. Calif., Los Angeles, CA. 75 p.

Gorsline, D. S., R. L. Kolpack, H. A. Karl, D. E. Drake, P. Fleischer, S. E. Thornton, J. R. Schwalbach, and C. E. Savrda. 1984. Studies of fine-grained sediment transport processes and products in the California Continental Borderland. Pages 395-415 *in* D. A. V. Stow and D. J. W. Piper (eds.), Fine-grained sediments: deep-water processes and facies, Blackwell Sci. Publ., Palo Alto, CA.

Gossett, R. W. 1988. Measurement of oxygenated metabolites of DDTs and PCBs: a caution. Mar. Environ. Res. 26:155-159.

Gossett, R., H. W. Puffer, R. H. Arthur, J. F. Alfafara, and D. R. Young. 1982. Levels of trace organic compounds in sportfish from southern California. Pages 29-38 *in* W. Bascom (ed.), Coastal Water Research Project biennial report for the years 1981-1982. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 294 p.

Gossett, R. W, H. W. Puffer, R. H. Arthur, Jr., and D. R. Young. 1983. DDT, PCB, and benzo(a)pyrene levels in white croaker (*Genyonemus lineatus*) from southern California. Mar. Pollut. Bull. 14(2):60-65.

Graham, N. E., and W. B. White. 1988. The El Niño Cycle: A natural oscillator of the Pacific Ocean - atmosphere system. Science 240:1293-1302.

Grant, U. S. and F. P Shepard. 1939. Shallow-water sediment-shifting processes along the Southern California coast. Proc. 6th Pac. Sci. Congr., p. 801-805.

Green, L. W. 1980. Historical survey of the Santa Monica Mountains of California. U.S. Dep. Interior, Washington, D.C.

Greenberg, A. E., L. S. Clesceri, and A. D. Eaton. 1992. Standard methods for the examination of water and wastewater; 18th edition. Amer. Publ. Health, Assoc., Amer. Wat. Works Assoc., and Wat. Environ. Feder. Washington, DC.

Greenberg, A. E., R. R. Trussell, and L. S. Clesceri. 1985. Standard methods for the examination of water and wastewater. 16th edition. Am. Public Health Assoc., Washington, DC. 1268 p.

Greene, C. S., and R. W. Smith. 1975. Numerical analysis of data on a benthic community. Pages 69-78 *in* Costal water research project annual report for the year ended June 1976. So. Calif. Coast. Water Res. Proj., El Segundo, CA 163 p.

Greene, G. E. 1992. Ozone disinfection and treatment of urban storm drain dry-weather flows: A pilot treatment plant demonstration project on the Kenter Canyon storm drain system in Santa Monica, draft report. Prepared for Santa Monica Bay Restor. Proj., Monterey Park, CA. City of Santa Monica, Off. City Engineer. 48 p.

Grigg, R. W. 1978. Long-term changes in rocky bottom communities off Palos Verdes. Pages 157-184 *in* W. Bascom (ed.), Coastal water research project annual report for the year 1978. So. Calif. Coast. Water Res. Proj., El Segundo, CA. 253 p.

Grigg, R. W., and R. S. Kiwala. 1970. Some ecological effects of discharged wastes on marine life. Calif. Fish Game 56(3):145-155.

Grinnell, J. 1935. A revised life-zone map of California. Univ. Calif. Publ. Zool. 40(7):327-330.

Grinnell, J., H. C. Bryant, and T. I. Storer. 1918. The game birds of California. Univ. Calif. Press, Berkeley.

Grinnell, J., and A. H. Miller. 1944. The distribution of the birds of California. Pac. Coast Avifauna No. 27.

Gustafson, R. J. 1981. The vegetation of Ballona. Pages Bo-1 to Bo-32 *in* R. W. Schreiber (ed.), Biota of the Ballona region, Los Angeles County. Suppl. I, Marina Del Rey/Ballona local coastal plan. Los Angeles Co. Nat. Hist. Mus. Found., Los Angeles, CA.

Haaker, P. L. 1975. The biology of the California halibut, *Paralichthys californicus* in Anaheim Bay, California. Pages 137-152 *in* E. D. Lane and C. W. Hill (eds.), Marine resources of Anaheim Bay. Calif. Dept. Fish and Game, Fish Bull. 165.

Haaker, P., K. Henderson, and D. Parker, 1986. California Abalone, State of California, Resources Agency, Department of Fish and Game, Marine Resources Leaflet No. 11.

Haner, B. E., and D. S. Gorsline. 1978. Processes and morphology of continental slope between Santa Monica and Dume Submarine Canyons, Southern California. Mar. Geol. 28:77-87.

Hardy, J. T. 1982. The sea surface microlayer: Biology, chemistry, and anthropogenic enrichment. Prog. Oceanog. 11:307-328.

Harris, L. H. 1980. Changes in intertidal algae at Palos Verdes. Pages 35-75 *in* W. Bascom (ed.). Coastal water research project biennial report for the years 1979-1980. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 363 p.

Harris, L. H. 1983. Changes in intertidal algae at Palos Verdes. Pages 274-281 *in* The effects of waste disposal on kelp communities. So. Calif. Coast. Water Res. Proj. and Inst. Mar. Res., Univ. Calif. Symposium 24-25 January 1983, Scripps Instit. Oceanogr., La Jolla, CA.

Hartman, B. and D. E. Hammond. 1981. Use of carbon and sulfur isotopes as correlation parameters for the source identification of beach tar in the Southern California Borderland. Geochim. Cosmochim. Acta 45(5):309-319.

Hartmann, O. 1959. The benthic fauna of southern California in shallow depths and possible effects of wastes on the marine biota. Pages 79-124 *in* Oceanography survey of the continental shelf area of southern California. Allan Hancock Foundation, Univ. So. Calif., Los Angeles, CA.

Head, W., 1989. The California Chaparral, and Elfin Forest, Naturegraph Publishers, Inc.

Hedgpeth, J. W. (ed.). 1957. Treatise on marine ecology and paleoecology. Vol. I, Ecology. Memoir, 67(1), Geol. Soc. Amer., 1296 pp.

Hedgpeth, J. W., and S. Hinton. 1961. Common seashore life of southern California. Naturegraph Co., Healdsburg, CA. 65 p.

Heesen, T. C., and D. J. McDermott. 1974. DDT and PCB in benthic crabs. Pages 109-111 *in* Coastal water research project annual report for the year ended 30 June 1974. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Helvey, M., and R. W. Smith. 1985. Influence of habitat structure on the fish assemblage associated with two cooling water in-take structures in southern California. Bull. Mar. Sci. 37(1):189-199.

Hendricks, T. J. 1976. Current velocities required to move sediments. Pages 71-76 *in* Coastal water research project Annual Report 1976. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Hendricks, T. J. 1979. A study to evaluate the dispersion characteristics of waste discharges to the open coastal waters of California. Univ. Calif., Inst. Mar. Res. (IMR Ref. 79-9), 78 p.

Hendricks, T. J. 1980. Currents in the Los Angeles area. Pages 243-256 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1979-1980. S. Calif. Coastal Water Res. Proj., Long Beach, CA. 363 p.

Hendricks, T. J. 1987. A study of sediment composition, transport, and deposition off Palos Verdes. Final Report to County Sanitation Districts of Los Angeles County. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 46 pp.

Herbison, K. T. 1981. 316(b) fish impingement inventory. Res. and Develop. Ser., So. Calif. Edison Co., Rosemead, CA. 178 p.

Herring, J. R., and A. L. Abati. 1978. Effluent particle dispersion. Pages 113-126 *in* W. Bascom (ed.), Coastal water research project annual report for the year 1978. So. Calif. Coast. Water Res. Proj., El Segundo, CA. 253 p.

Hershelman, G. P., H. A. Schafer, T.-K. Jan, and D. R. Young. 1981. Metals in marine sediments near a large California municipal outfall. Mar. Pollut. Bull. 12(4):131-134.

Hoffman, M. S. 1992. The world almanac and book of facts, 1993. World Almanac, New York, NY. 960 p.

Holmes, W. N., and J. Cronshaw. 1977. Biological effects of petroleum on marine birds. Pages 359-398 *in* D. C. Malins (ed.), Effects of petroleum on arctic and subarctic marine environments and organisms, Vol. 2. Academic Press, NY.

Horn, M. H., and L. G. Allen. 1981. Comparison of the structure and function of estuarine and harbor fish communities in southern California. Estuaries 4:243.

Hose, J. E., J. N. Cross, S. G. Smith, and D. Diehl. 1987. Elevated circulating erythrocyte micronuclei in fishes from contaminated sites off southern California. Mar. Environ. Res. 22(3):167-176.

Hubbs, C. L. 1949. Changes in the fish fauna of western North America correlated with changes in ocean temperature. J. Mar. Res. 7(3):459-487.

Hubbs, C. L. 1974. Review of: Marine zoogeography by John C. Briggs (McGraw-Hill Book Co.) Copeia 4:1002-1005.

Humphrey, H. E. B. 1987. The human population: An ultimate receptor for aquatic contaminants. Hydrobiol. 149:75-80.

Humphrey, H. E. B. 1988. Chemical contaminants in the Great Lakes: The human health aspect. Pages 153-165 *in* M. J. Evans (ed.), Toxic contaminants and ecosystem health; A Great Lakes focus. John Wiley and Sons, New York, NY.

Ikeda, D., S. Morey, and M. Skinner. 1991. Protecting the floral treasure of the Santa Monica Mountains. Fremontia 19(3):3-5.

Imperial, M., D. Robadue, Jr., and T. Hennessey, 1991. Approaches to environmental management planning: the CZMA and the National Estuary Program, Coastal Wetlands, Symposium on Coastal and Ocean Management, S. Bolton and O. Magoon, ed., American Society of Civil Engineers, 1991.

Ingersoll, L. A. 1908. Century history of Santa Monica Bay cities. Los Angeles, CA.

IRC. See Intersea Research Corporation.

Intersea Research Corporation. 1973. Thermal effects study summary report - Scattergood Steam Plant. Summary report for Los Angeles Department of Water and Power, Los Angeles, CA. Intersea Res. Corp., La Jolla, CA. Part 1. 102 p.

Intersea Research Corporation. 1979. 1978 receiving water monitoring report, NPDES. Monitoring and reporting program for the Scattergood and El Segundo Generating Stations. Prepared for Los Angeles Department of Water and Power and Southern California Edison Co., Rosemead, CA. Intersea Res. Corp., La Jolla, CA. 132 p.

Intersea Research Corporation. 1981. 1980 receiving water monitoring report, NPDES. Monitoring and reporting program for the Scattergood and El Segundo Generating Stations. Prepared for Los Angeles Department of Water and Power and Southern California Edison Co., Rosemead, CA. Intersea Res. Corp., La Jolla, CA. 120 p.

Jacobson, J. L., G. G. Fein, S. W. Jacobson, P. M. Schwartz, and J. K. Dowler. 1984. The transfer of polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs) across the human placenta and into maternal milk. Am. J. Public Health 74(4):378-379.

Jacobson, S. W., G. G. Fein, J. L. Jacobson, P. M. Schwartz, and J. K. Dowler. 1985. The effect of intrauterine PCB exposure on visual recognition memory. Child Develop. 56:853-860.

Jackson, G. A. 1986. Chapter 2. Physical oceanography of the Southern California Bight. Pages 13-52 *in* R. W. Eppley (ed.), Lecture notes on coastal and estuarine studies. Vol. 15, Plankton dynamics of the Southern California Bight. Springer-Verlag, New York, NY. 373 p.

Jaeger, E. C., and A. C. Smith. 1966. Introduction to the natural history of southern California. Univ. Calif. Press, Berkeley, CA. 104 p.

James M. Montgomery Engineers, Inc. 1988. Filtration-Disinfection study. Part II: Virus monitoring final report. Prepared for the Las Virgenes Metropolitan Water district.

Jan, T-K., M. D. Moore, and D. R. Young. 1977. Metals in seafood near outfalls. Pages 153-158 *in* Coastal water research project annual report for the year ended 30 June 1977. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 253 p.

Jehl, J. R., Jr., and C. F. Cooper, eds. 1980. Potential effects of space shuttle booms on the biota and geology of the California Channel Islands: Research reports. Center for Marine Studies, San Diego State Univ., San Diego, CA. Tech. Rep. 80-1. 246 p.

Jenkins, K. D., D. A. Brown, G. P. Hershelman, and C. Meyer. 1982. Contaminants in white croakers *Genyonemus lineatus* (Ayres, 1855) from the southern California Bight. I. Trace metal detoxification/toxification. *In*: W. B. Vernberg, A. Calabrese, F. P. Thurberg, and F. J. Vernberg (eds)., Physiological mechanisms of marine pollutant toxicity. Academic Press, New York, NY.

Johnson, S. C., and J. Roney. 1988. Wastewater discharge in Santa Monica Bay: II. Assemblages of macroinvertebrate and demersal fish. Pages 32-36 *in* Managing inflows to California's bays and estuaries, Symposium 13-15 November 1986, Monterey, CA. The Bay Institute, Sausalito, CA.

Johnson, T. D., A. M. Barnett, E. E. DeMartini, and L. P. Purcell. 1992. Habitat value of a southern California artificial reef. Pages 69-74 *in* P. M. Grifman and S. E. Yoder (eds.), Perspectives on the marine environment. Univ. So. Calif., Sea Grant Prog., Los Angeles, CA.

Johnston, B. E. 1962. California's Gabrielino Indians. Southw. Mus., Los Angeles, CA. 198 p.

Jones, G. F. 1969. The benthic macrofauna of the mainland shelf of southern California. Allan Hancock Monographs. in Mar. Biol. No. 4. Univ. So. Calif., Los Angeles, CA. 220 p.

Jordan, D. S. 1887. The fisheries of the Pacific Coast. Pages 589-630 *in* G. B. Goode, (ed.), Fisheries and fishing industries of the United States, Section II, U.S. 47th Congr. 1st Sess., Senate Misc. Doc. 124, Ser. 19098-2003, Washington, DC.

Josslyn, M., S. Chamberlain, P. Goodwin, and K. Cuffe. 1992. Wetland inventory and restoration potential, Santa Monica Bay Restoration Project (draft). Prepared for Santa Monica Bay Restor. Proj., Monterey Park, CA. San Francisco State Univ., Romberg Tiburon Cen., Tiburon, CA. 91 p.

Journal of Commerce. 1990. U. S. census report: West Coast waterborne import/exports. J. Commerce.

Katz, A., and I. R. Kaplan. 1981. Heavy metals behavior in coastal sediments off southern California: A critical review and synthesis. Mar. Chem. 10:261-299.

Kauwling, T. J., and D. J. Reish. 1975. A quantitative study of the benthic polychaeteous annelids of Anaheim Bay and Huntington Harbour, California. Pages 57-68 *in* E. D. Lane and C. W. Hill (eds.), The marine resources of Anaheim Bay. Calif. Dep. Fish Game, Fish Bull. 165. 195 p.

Kelley, D. 1988. Fuel tanks at L. A. Airport are polluting water table. Los Angeles Times, Los Angeles, CA. Mar 25. Pt. II. p. 8.

Kerr, R. A. 1992. A successful forecast of an El Niño winter. Science 255:402.

Keswick, B. H., T. K. Satterwhite, P. G. Johnson, H. L. DuPont, S. L. Secor, J. A. Bitsura, G. W. Gary, and J. C. Hoff. 1985. Inactivation of Norwalk virus in drinking water by chlorine. App. Environ. Microbiol. 50(2):261-264.

Kettenring, K. N. 1981. The trace metal stratigraphy and recent sediment history of antrogencus particulates on the San Pedro Shelf, California. Ph.D. Dissertation. UCLA, Los Angeles, CA. 156 p.

Kim, J. 1975. Indicative, pathogenic, and marine bacteria in the sea. Pages 15-22 *in* Coastal water research project annual report for the year ended 30 June 1975. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 211 p.

Kimura, J. C. 1974. Chapter 2: Climate. Pages 2-1 to 2-70 *in* M. D. Dailey, B. Hill, and N. Lansing (eds.), A summary of knowledge of the southern California coastal zone and offshore areas. Vol. I: Physical environment. Prepared for Bureau of Land Management, Contract No. 08550-CT4-1, by Southern California Ocean Studies Consortium, Dominguez Hills, CA.

Kleppel, G., E. Manzanilla, B. Teter, and S. Petrich. 1982. Santa Monica Bay plankton distribution. Pages 71-84 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1981-1982. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 294 p.

Kobayashi, H., and B. E. Rittmann. 1982. Microbial removal of hazardous organic compounds. Env. Sci. Tech. 16:170-183.

Kolpack, R.L. 1979. Distribution of suspended particulate matter near sewage outfalls in Santa Monica Bay, California. Pages 205-239 *in* H. D. Palmer and M. G. Gross (eds.), Ocean dumping and marine pollution. Dowden, Hutchinson, and Ross, Stroudsburg, PA. 268·p.

Korpics, J. J. 1988. Regulation of storm water point source discharges. Jour. Water Pollut. Control. Fed. 60(1):50-56.

Kraft, C. 1978. Draft working paper - Malibu Lagoon and Wetlands. Los Angeles/Orange County regional coastal wetland workshop, 17-18 August 1978, Calif. State Univ., Long Beach, CA.

Krahn, M. M., L. D. Rhodes, M. S. Myers, L. K. Moore, W. D. MacLeod, and D. C. Malins. 1986. Associations between metabolites of aromatic compounds in bile and the occurrence of hepatic lesions in English sole (*Parophyrs vetulus*) from Puget Sound, Washington. Arch. Environ. Contam. Toxicol. 15:61-67.

Kroeber, A. L. 1925. Handbook of the Indians of California. Bur. Am. Ethnology, Bull. 78 (1976 Ed.), Dover Publ., New York, NY. 995 p.

Kurzel, R. B., and C. L. Cetrulo. 1981. The effect of environmental pollutants on reproduction including birth defects. Environm. Sci. Tech. 15(6):626-640.

Kuhn, G. G., and F. P. Shepard. 1981. Should southern California build defenses against violent storms resulting in lowland flooding as discovered in records of past century. Shore and Beach 49(4):3-10.

LAC. See Los Angeles County.

LAC,A-C. See Los Angeles County, Auditor-Controller.

LAC,DBH. See Los Angeles County, Department of Beaches and Harbors.

LAC,DPW. See Los Angeles County, Department of Public Works.

LAC,DRP. See Los Angeles County, Department of Regional Planning.

LAC,OCAO. See Los Angeles County, Office of Chief Administration Officer.

LAC,SD. See Los Angeles County Sanitation Districts.

Ladd, J. M., S. P. Hayes, M. Martin, M. D. Stephenson, S. L. Coale, J. Linfield, and M. Brown. 1984. California state mussel watch: 1981-1983. Trace metals and synthetic organic compounds in mussels from California's coast, bays, and estuaries. Biennial Report. Calif. State Water Resources Control Bd., Water Quality Monitoring Report No. 83-6TS. Sacramento, CA. 81 p.

Lane, E. D., and C. W. Hill, eds. 1975. The marine resources of Anaheim Bay. Dep. Fish Game, Fish Bull. 165. 195 p.

LA Times. See Los Angeles Times.

LCMR,IRC. See Lockheed Center for Marine Research and Intersea Research Corporation.

Lecky, J. H. 1985. Preliminary report: An analysis of impacts to the gray whale population from entanglement in gillnets. Nat. Oceanic Atmos. Admin., Nat. Mar. Fish. Ser., Southw. Reg., Los Angeles, CA. 26 p.

Lees, D. C. 1992. What can southern California learn from the EXXON VALDEZ oil spill experience? Pages 105-130 *in* P. M. Grifman and S. E. Yoder (eds.), Perspectives on the marine environment. Univ. So. Calif., Sea Grant Prog., Los Angeles, CA.

Leinberger, C. 1988. Atlantic, Vol. 26.

Lewis, R. D., and K. K. McKee. 1989. A guide to the artificial reefs of southern California. Calif. Dep. Fish Game, Long Beach, CA. 73 p.

LFCRRT. See Light Footed Clapper Rail Recovery Team.

Light Footed Clapper Rail Recovery Team. 1983. Light Footed Clapper Rail Recovery Plan. Endangered Species Program, U.S. Fish Wildl. Ser., Region 1, Portland, OR. 33 p. plus attachments.

Limbaugh, C. 1955. Fish life in the kelp beds and the effects of kelp harvesting. Inst. Mar. Resources, Univ. Calif., San Diego, La Jolla, CA. IMR Ref. 55-9. 156 p.

Littler, M. M., and S. N. Murray. 1975. Impact of sewage on the distribution, abundance and community structure of rocky intertidal macro-organisms. Mar. Biol. 30:277-291.

Lockheed Center for Marine Research and Intersea Research Corporation. 1979. 1978 receiving water monitoring report, NPDES monitoring and reporting program for the Scattergood and El Segundo Generating Stations. Prepared for Los Angeles Department of Water and Power, Los Angeles, CA, and Southern California Edison Company, Rosemead, CA. April 1979. Lockheed Center for Mar. Res. and Intersea Res. Corp., La Jolla, CA. 132 p. plus appendices.

Long, E. R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Tech. Mem. NOC OMA 52; 175p and Appendices.

Los Angeles County. 1987. Economic Profile. Los Angeles, CA.

Los Angeles County, Auditor-Controller. 1988. Tax payer's guide, County of Los Angeles, 1987-1988. LAC,A-C, Los Angeles, CA. 171 p.

Los Angeles County, Department of Beaches and Harbors. 1987. Attendance report. Los Angeles County, Los Angeles, CA.

Los Angeles County Department of Beaches and Harbors. 1992. 1991 attendance report. Los Angeles Co. Dep. Beaches Harbors, Los Angeles, CA.

Los Angeles County, Department of Public Works. 1985. Plan for flood control and water conservation, maps 2, 3, 7, 16, and 17. LAC,DPW, Los Angeles, CA.

Los Angeles County, Department of Regional Planning. 1988. Marina del Rey/Ballona land use distribution, October 1988. LAC,DRP, Los Angeles, CA.

Los Angeles County, Office of the Chief Administrative Officer. 1981. Report on the investigations concerning reported cases of cancer in lifeguards and Pico-Kenter Storm Drain. LAC,OCAO, Los Angeles, CA. 40 p.

Los Angeles County Sanitation Districts. 1988. Joint water pollution control plan 1988 revised application for modification of secondary treatment requirements for discharges into marine waters. LAC,SD, Whittier, CA.

Los Angeles County Sanitation Districts. 1992. Joint Water Pollution Control Plant, unpublished data. LAC,SD, Whittier, CA.

Los Angeles Times. 1991. Ballona wetlands land exchange, 14 September.

Los Angeles Times. 1992. L. A. accepts Occidental Corp.'s gift of 2 acres of coastal land. Los Angeles Times, 11 Nov., Sec. B., p. 3, 8.

Los Angeles Times. 1993. Chevron to stop dumping waste near shoreline, 4 February.

Love, M. S., J. S. Stephens, Jr., P. A. Morris, M. M. Singer, M. Sandhu, and T. C. Sciarrotta. 1986. Inshore soft substrata fishes in the Southern California Bight: An overview. Calif. Coop. Oceanic Fish. Invest. Rep. 27: 84-106.

Luoma, S. N. 1983. Bioavailability of trace elements to aquatic organisms. Sci. Total Environ. 28:1-22.

MacGregor, J. S. 1976. DDT and its metabolites in the sediments off southern California, USA. Fish Bull., U.S. 74(1):27-35.

Mahoney, J. B., F. H. Midlige, and D. G. Deuel. 1973. Fin rot disease of marine and euryhaline fishes in the New York Bight. Trans. Amer. Fish. Soc. 102:596-608.

Malins, D. C., M. M. Krahn, D. W. Brown, L. D. Rhodes, M. S. Myers, B. B. McCain, and S.-L. Chan. 1985a. Toxic chemicals in marine sediment and biota from Mukilteo, Washington: Relationships with hepatic neoplasms and other hepatic lesions in English sole (*Parophrys vetulus*). J. Natl. Cancer Inst. 74:487-494.

Malins, D. C., M. M. Krahn, M. S. Myers, L. D. Rhodes, D. W. Brown, C. A. Krone, B. B. McCain, and S.-L. Chan. 1985b. Toxic chemicals in sediments and biota from a creosote-polluted harbor: Relationships with hepatic neoplasms and other hepatic lesions in English sole (*Parophrys vetulus*). Carcinogenesis 6:1463-1469.

Malins, D. C., B. B. McCain, D. W. Brown, S. L. Chan, M. S. Myers, J. T. Landahl, P. G. Prohaska, A. J. Friedman, L. D. Rhodes, D. G. Burrows, W. D. Gronlund, and H. O. Hodgins. 1984. Chemical pollutants in sediments and diseases of bottom-dwelling fish in Puget Sound, WA. Environ. Sci. Technol. 18:705-713.

Malins, D. C., B. B. McCain, D. W. Brown, M. S. Myers, and S.-L. Chan. 1986. Marine pollution study: Los Angeles vicinity. Final Report to CSWRCB, Sacramento, CA. NOAA, NMFS, Seattle, WA. 64 pp.

Malins, D. C., B. B. McCain, D. W. Brown, M. S. Myers, M. M. Krahn, and S.-L. Chan. 1987. Toxic chemicals, including aromatic and chlorinated hydrocarbons and their derivatives, and liver lesions in white croaker (*Genyonemus lineatus*) from the vicinity of Los Angeles. Environ. Sci. Technol. 21:765-770.

Malme, C. I., P. R. Miles, C. W. Clark, P. Tyack, and J. E. Bird. 1983. Investigations of the potential effect of underwater noise from petroleum industry activities on migrating gray whale behavior. Final report for period of 7 June 1982 - 31 July 1983, for Dep. Interior, MMS, Alaska OCS Office, Anchorage, Alaska. BBN Laboratories, Inc., Cambridge, MA. Report No. 5366, pp. 1-1-G-9.

Manci, K., 1989. Riparian ecosystem creation and restoration: a literature summary, U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 89(20), September 1989

Marconsult, Inc. 1971. Santa Monica Bay natural oil seep investigation. Prepared for El Segundo Refinery, Standard Oil Company of California, El Segundo, CA. Marconsult, Inc., Santa Monica, CA. 93 p.

Marine Biological Consultants, Inc. and Southern California Coastal Water Research Project. 1980. Upper Newport Bay stream augmentation October 1979-August 1980 final report. Prepared for Irvine Ranch Water District, Irvine, CA. Marine Biological Consultants, Inc., Costa Mesa, CA., and SCCWRP, Long Beach, CA. 150 pp. with appendices.

Marquez, E. 1975. Port of Los Angeles: A phenomenon of the railroad era. Golden West Books.

Massey, B. W. 1972. Breeding biology of California least tern. M.S. thesis, Calif. State Univ., Long Beach, CA. 101 p.

Massey, B. W. 1973. Recoveries of California least terns. Western Bird Bander 48(3):46-47.

Massey, B. W. 1979. Belding's savannah sparrow. U. S. Army Corps of Engineers, Los Angeles District, Los Angeles, CA. Contract No. DACW09-C-0008. So. Calif. Ocean Studies Consortium, Calif. State Univ., Dominguez Hills, CA.

Massey, B. W., and J. M. Fancher. 1989. Renesting by California least terns, J. Field Ornithol., 60(3) 350-357.

Massey, B. W., and R. Zembal. 1979. A comparative study of the light-footed clapper rail, *Rallus longirostris levipes* in Anaheim Bay and Upper Newport Bay, Orange County, California. U.S. Fish Wildl. Serv. Endangered Species Off., Sacramento, CA.

Mayer, K. E., and W. F. Laudenslayer, Jr. 1988. A guide to wildlife habitats of California. Calif. Dep. Forestry Fire Prot., Sacramento, CA. 166 p.

Maynard, C. 1962. Flight plan for tomorrow. Douglas Aircraft Co., Inc., Santa Monica, CA.

MBC. See Marine Biological Consultants, Inc. or MBC Applied Environmental Sciences

MBC Applied Environmental Sciences. 1982a. Marine ichthyoplankton entrainment studies, August 1979-September 1980. Vol. I, Summary data report, section 316(b), Federal Water Pollution Control Act for Ormond Beach Generating Station, Redondo Beach Generating Station Units 5 & 6 and 7 & 8, and San Onofre Generating Station Unit 1. Prepared for Southern California Edison Company, 82-RD-11. MBC Applied Environ. Sci., Costa Mesa, CA. 220 p.

MBC Applied Environmental Sciences. 1982b. Evaluation of groin emplacement, offshore dredging, and sand replenishment impacts on the marine biota near the Chevron U.S.A. refinery, El Segundo, California. Prepared for Chevron U.S.A., MBC Applied Environ. Sci., Costa Mesa, CA.

MBC Applied Environmental Sciences. 1982c. Reassessment of groin emplacement and beach replenishment impact on the marine biota near the Chevron U.S.A. Refinery, El Segundo, California, based on site-specific data. Prepared for Chevron U.S.A. MBC Applied Environ. Sci., Costa Mesa, CA. 46 pp. with appendices.

MBC Applied Environmental Sciences. 1985. Santa Monica Bay: Sport fishing revitalization study (In response to Assembly Bill No. 2642, Chapter 1525, Statutes 1984). Prepared for California Department of Fish and Game, Sacramento, CA. MBC Applied Environ. Sci., Costa Mesa, CA. 94 pp. plus appendices.

MBC Applied Environmental Sciences. 1986a. National pollutant discharge elimination system, 1986 receiving water monitoring report, Redondo Generating Station, Los Angeles County, California, December 1986. Prepared for Southern California Edison Company, SCE Research and Development Ser. 86-RD-55. MBC Applied Environ. Sci., Costa Mesa, CA. 49 p.

MBC Applied Environmental Sciences. 1986b. Infauna and epibiota associated with transplants of eelgrass (*Zostera marina*) in southern California, March 1986. Prepared for Maguire Thomas Partners, Huntington Partnership, National Marine Fisheries Service and U. S. Fish and Wildlife Service. MBC Applied Environ. Sci., Costa Mesa, CA. 48 pp.

MBC Applied Environmental Sciences. 1987a. Ecology of important fisheries species offshore California. U. S. Dep. Interior, Minerals Mgt. Serv., Pac. OCS Reg., Los Angeles, CA. OCS Study MMS 86-0083. 251 p.

MBC Applied Environmental Sciences. 1987b. Organization of demersal fish assemblages of the Palos Verdes Shelf during 1985-1986. Prepared for Los Angeles Co. Sanitation Dis., Whittier, CA. 140 p.

MBC Applied Environmental Sciences. 1988. The state of Santa Monica Bay: Part one: Assessment of conditions and pollution impacts. Prepared for S. Calif. Assoc. Govt., Los Angeles, CA. MBC Applied Environmental Sciences, Costa Mesa, CA. 420 p.

MBC Applied Environmental Sciences. 1990. Results of benthos monitoring offshore Chevron's El Segundo refinery: survey date, 30 August 1990. Prepared for Chevron U.S.A., El Segundo, CA. 12 p. plus appendices.

MBC Applied Environmental Sciences. In prep. Santa Monica Bay restoration project seafood consumption study. Prepared for Santa Monica Bay Restor. Proj., Monterey, CA. MBC Applied Environmental Sciences.

MBC Applied Environmental Sciences. 1991a. Assessment of biological damage associated with the spill of oil product offshore the Chevron El Segundo Refinery 16 March 1991. Prepared for ENTRIX, Walnut Creek, CA. 24 p. plus appendices.

MBC Applied Environmental Sciences. 1991b. National pollutant discharge elimination system winter 1991 receiving water monitoring report, Scattergood and El Segundo Generating Stations, Los Angeles County, California. Prepared for City of Los Angeles Dep. Water Power and So. California Edison Co., Rosemead, CA. 15 p. plus appendices.

MBC Applied Environmental Sciences. 1991c. National pollutant discharge elimination system, 1991 receiving water monitoring report, Redondo Generating Stations, Los Angeles County, California. Prepared for Southern California Edison Company, Rosemead, CA. 91-RD-26 58 p. plus appendices.

MBC Applied Environmental Sciences and K. Marsh. 1985. DeAnza Peninsula marina feasibility study. MBC Applied Environ. Sci., Costa Mesa, CA. 103 p.

McCain, B. B., M. S. Myers, W. D. Gronlund, S. R. Wellings, and C. E. Alpers. 1978. The frequency, distribution, and pathology of three diseases of demersal fishes in the Bering Sea. J. Fish. Biol. 12:267-276.

McCall, P. L. 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. J. Mar. Res. 35:221-266.

McDermott, D. J., G. V. Alexander, D. R. Young, and A. J. Mearns. 1976. Metal contamination of flatfish around a large submarine outfall. J. Water Pollut. Cont. Fed. 48(8):1913-1918.

McDermott-Ehrlich, D. J., M. J. Sherwood, T. C. Heesen, D. R. Young, and A. J. Mearns. 1977. Chlorinated hydrocarbons in Dover sole, *Microstomus pacificus*: Local migrations and fin erosion. Fish. Bull., U.S. 75(3):513-517.

McDermott-Ehrlich, D., D. R. Young, and T. C. Heesen. 1978. DDT and PCB in flatfish around southern California municipal outfalls. Chemosphere 7(6):453-461.

McGowan, J. A. 1984. The California El Niño, 1983. Oceanus 27(2):48-62.

McQueen, W. 1979. Community groups in the Santa Monica Mountains. Univ. Calif., Los Angeles, CA.

Mearns, A. J. 1977. Coastal gradients in sportfish catches. Pages 127-132 *in* Coastal water research project annual report, 1977. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Mearns, A. J. 1980. Changing coastal conditions: 1979 compared to the past 25 years. Pages 273-286 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1979-1980. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 363 p.

Mearns, A. J. 1988. The "odd fish" : unusual occurrences of marine life as indicators of changing ocean conditions. *In* D. F. Soule & G. S. Kleppel, eds. Marine organisms as indicators. Springer-Verlag, New York. pp. 13-17.

Mearns, A. J., M. J. Allen, and M. J. Sherwood. 1974. An otter trawl survey of Santa Monica Bay, May-June 1972. So. Calif. Coastal Water Res. Proj., El Segundo, CA. TM 209. 24 p.

Mearns, A. J., M. J. Allen, L. S. Word, J. Q. Word, C. S. Greene, M. J. Sherwood, and B. Myers. 1976. Quantitative responses of demersal fish and benthic invertebrate communities to coastal municipal wastewater discharges. Final report to Natl. Mar. Water Quality Lab., U. S. Environ. Prot. Agcy, Corvallis, OR. So. Calif. Coastal Water Res. Proj., El Segundo, CA. Grant R801152, Vol. 1, 67 p.; Vol. 2, 179 p.

Mearns, A. J., and C. S. Greene, (eds.). 1974. A comparative trawl survey of three areas of heavy waste discharge. So. Calif. Coastal Water Res. Proj., El Segundo, CA. TM 215. 76 p.

Mearns, A. J., and M. J. Sherwood. 1974. Environmental aspects of fin erosion and tumors in southern California Dover sole. Trans. Am. Fish. Soc. 103 (4):799-810.

Mearns, A. J., and M. J. Sherwood. 1976. Fin erosion prevalence and environmental changes. Pages 139-141 *in* Coastal water research project annual report for the year ended 30 June 1976. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 253 p.

Mearns, A. J., and M. J. Sherwood. 1977. Distribution of neoplasms and other diseases in marine fishes relative to the discharge of waste water. Ann. N.Y. Acad. Sci. 298:210-224.

Meistrell, J. C., and D. E. Montagne. 1983. Waste disposal in southern California and its effects on the rocky subtidal habitat. Pages 84-102 *in* W. Bascom (ed.), The effects of waste disposal on kelp communities. NOAA, Natl. Sea Grant College Prog., Washington, D.C.

Melniek, J. L. and C. P. Gerba. 1980. Viruses in water and solids. Pub. Health Rev. J. 9:185-213.

Metz, E. 1978. Revised draft working paper - Ballona Creek wetlands (workshop edition). Los Angeles/Orange County regional coastal wetland workshop, 17-18 August 1978, California State Univ., Long Beach, CA.

Miescier, J. J. and V. J. Cabelli. 1982. Enterococci and other microbial indicators in municipal sewage effluents. J. Water Poll. Control Fed. 54:1599-1606.

Miller, B. S., and S. R. Wellings. 1971. Epizootiology of tumors on flathead sole (*Hippoglossoides elassodon*) in East Sound, Orcas Island, Washington. Trans. Amer. Fish. Soc. 100:247-266.

Miller, C. S., and R. S. Hyslop. 1983. California: The geography of diversity. Mayfield Publ. Co., Palo Alto, CA. 255 p.

Miller, D. S., A. Seymour, Jr., D. Shoemaker, M. H. Windsor, D. B. Peakall, and W. B. Kinter. 1975. Possible enzymatic basis of DDE induced eggshell thinning in the white Pekin duck, *Anas platyrhychos*. Bull. Mt. Desert Isl. Biol. Lab.

Minerals Management Service, OCS National Compendium. 1991. Outer Continental Shelf Oil and Gas Information through October 1990. Report 91-0032. 117 p.

Minerals Management Service, Pacific OCS Region. 1983. Draft environmental impact statement, proposed southern California lease offering, February 1984. MMS,POCSR, Los Angeles, CA. 765 p.

Mitchell, F. K., and D. J. McDermott. 1975. Characteristics of municipal wastewater discharges, 1974. Pages 163-166 *in* Coastal Water Research Project annual report for the year ended 30 June 1975. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 211·p.

Mix, M. C. 1986. Cancerous diseases in aquatic animals and their association with environmental pollutants: A critical literature review. Mar. Environ. Res. 20:1-141.

Moore, M., W. Bascom, and H. Stubbs. 1982. Trawl-caught fish and invertebrates. Pages 85-90 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1981-1982. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 294 p.

Moore, M. D., and A. J. Mearns. 1980. Photographic survey of benthic fish and invertebrates communities in Santa Monica Bay. Pages 143-148 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1979-1980. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 363 p.

Morris, R.L., and J. Kim. 1975. Viruses in the marine environment. Pages 23-26 *in* Coastal water research project annual report 1975. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Morris, P. L., A. J. Mearns, and J. Kim. 1976. Viruses and bacteria in coastal waters and shellfish. Pages 97-103 *in* Coastal water research project annual report for the year ended 30 June 1976. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

MMS,OCSNC: See Minerals Management Service, OCS National Compendium.

MMS,POCSR: See Minerals Management Service, Pacific OCS region.

Mullin, M. M. 1986. Chapter 6. Spatial and temporal scales and patterns. Pages 216-273 *in* R. W. Eppley (ed.), Lecture notes on coastal and estuarine studies. Vol. 15, Plankton dynamics of the Southern California Bight. Springer-Verlag, New York, NY. 373 p.

Munz, P., 1964. Shore Wildflowers of California, Oregon and Washington, University of California Press.

Munz, P., 1973. A California Flora and Supplement, University of California Press.

Murchelano, R. A., and R. E. Wolke. 1985. Epizootic carcinoma in the winter flounder, *Pseudopleuronectes americanus*. Science 228:587-589.

Murray, S. N., and M. M. Littler. 1978. Patterns of algal succession in a perturbated marine intertidal community, Journal of Phycology, Vol. 14, pp. 506-512.

Nagano, C. D., D. L. Hogue, R. R. Snelling, and J. P. Donahue. 1981. The insects and related terrestrial arthropods of Ballona. Pages E-1 to E-88 *in* R. W. Schreiber (ed.), Biota of the Ballona region, Los Angeles County. Suppl. I, Marina Del Rey/Ballona local coastal plan. Los Angeles Co. Nat. Hist. Mus. Found., Los Angeles, CA.

Nardin, T. R., R. H. Osborne, D. J. Bottjer, and R. C. Scheidemann, Jr. 1981. Holocene sea-level curves for Santa Monica Shelf, California Continental Borderland. Science 213:331-333.

NAS. See National Audubon Society.

National Audubon Society. 1986. Ballona wetland habitat management plan. Prepared for City of Los Angeles. NAS, Western Reg. Off., Sacramento, CA. 99 p.

National Marine Fisheries Service, National Fishery Statistics Program. 1984. Marine recreational fishery statistics survey, Pacific Coast, 1981-1982. NOAA, Natl. Mar. Fish. Serv., Natl. Fish. Stats. Prog., Washington, DC. Current Fish. Stats. No. 8323. 203 p.

National Marine Fisheries Service, National Fishery Statistics Program. 1985. Marine recreational fishery statistics survey, Pacific Coast, 1983-1984. NOAA, Natl. Mar. Fish. Serv., Natl. Fish. Stats. Prog., Washington, DC. Current Fish. Stats. No. 8325. 189 p.

National Ocean Service. 1986. Tide tables 1987 high and low water predictions west coast of North and South America including the Hawaiian Islands. NOS, Natl. Oceanic and Atmos. Admin., U. S. Dep. Commerce, Washington, D. C. 234 p.

National Oceanic and Atmospheric Administration 1991a. Contaminant trends in the Southern California Bight: inventory and assessment. NOAA Tech. Memo. NOS ORCA 62. 423 p.

National Oceanic and Atmospheric Administration 1991b. Second summary of data on chemical contaminants in sediments from the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 59. Rockville Maryland. 29p plus appendices.

National Research Council, Committee on Ocean Waste Transportation. 1984. Wastewater characteristics. Chapter 2 *in* Ocean disposal systems for sewage sludge and effluent. Natl. Acad. Press, Washington, DC.

National Research Council 1989. Contaminated marine sediments--assessment and remediation. Natl. Acad. Press. Washington D.C.

Neushul, M. (ed.). 1981. Historical review of kelp beds in the Southern California Bight. Neushul Mariculture, Inc., Goleta, CA 93117. So. Calif. Edison, Co., Rosemead, CA. R&D Report 81-RD-98. 74 p.

Neushul, N. and F. T. Haxo. 1968. The life history of *Macrocystis* in the sea. Pages 13-16 *in* W. J. North and C. L. Hubbs (eds.), Utilization of kelp-bed resources in southern California. Calif. Dep. Fish Game, Fish Bull. 139.

NFSP. See National Marine Fisheries Service, National Fishery Statistics Program.

NMFS. See National Marine Fisheries Service.

NOAA: See National Oceanic and Atmospheric Administration.

North, W. J. 1968. Effects of canopy cutting on kelp growth: comparison of experimentation with theory. Pages 223-254 *in* North, W. J., and C. L. Hubbs (eds.), Utilization of kelp-bed resources in southern California. Calif. Dep. Fish Game, Fish Bull. 139.

North, W. J. 1970. Kelp habitat improvement project annual report, 1 July 1969-30 June 1970. W. M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Los Angeles, CA. 93 p.

North, W. J. 1975. Kelp habitat improvement project annual report, 1 July 1974-30 June 1975. W. M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology. 179 p.

North, W. J. 1976. Underwater California. Univ. Calif. Press, Berkeley, CA. 276 p.

North, W. J. 1983. The sea urchin problem. Pages 147-162 *in* W. Bascom (ed.), The effects of waste disposal on kelp communities. Natl. Sea Grant College Prog., NOAA, Washington, D.C.

North, W. J., and C. L. Hubbs, eds. 1968. Utilization of kelp bed resources in southern California. Calif. Dep. Fish Game, Fish Bull. 139:1-264.

NOS. See National Ocean Service.

NRC, COWT. See National Research Council, Committee on Ocean Waste Transportation.

Odum, E. P. 1959. Fundamentals of ecology. W. B. Saunders Co., Philadelphia. 546 pp.

Office of Water Regulations and Standards. 1987. Update #2 to "Quality criteria for water 1986". OWRS, U. S. Environ. Prot. Agcy, Washington, DC, 28 p.

Ohlendorf, H. M., R. W. Risebrough, K. Vermeer. 1978. Exposure of marine birds to environmental pollutants. U.S. Dep. Inter., Fish Wildl. Serv., Wildl. Res. Rep 9.

O'Leary, J., 1989. California coastal sage scrub: general characteristics and future prospects, Southern California Botanists 15 Annual Symposium on Endangered Plant Communities of southern California, 28 October.

OWRS. See Office of Water Regulations and Standards.

Page, G. W., F. C. Bidstrup, R. J. Ramer, and L. E. Stenzel. 1986. Distribution of wintering snowy plovers in California and adjacent states, Western Birds, Vol. 17, No. 4, pp. 145-170.

Page, G. W., and L. E. Stenzel. 1981. The breeding status of the snowy plover in California, Western Birds, Vol 12, No. 1., pp. 1-40.

Page, G. W., L. E. Stenzel, W. D. Shuford, and C. R. Bruce. 1991. Distribution and abundance of the snowy plover on its western North American breeding grounds, Journal of Field Ornithology, Vol. 62, No. 2, pp. 245-255.

Pannell Kerr Forster. 1992. The 1992 Los Angeles lodging forecast. Pannell Kerr Forster, Certified Public Accountants, Los Angeles, CA.

Pastorok, R. A. 1988. Guidance manual for assessing human health risks from chemically contaminated fish and shellfish. Final report. Prepared for U. S. Environmental Protection Agency, Office of Water, Washington, D.C. PTI Environmental Services, Bellevue, WA.

Pastorok, R. A., P. N. Booth, and L. G. Williams. 1986. Estimating potential health risks of chemically contaminated seafood. Puget Sound Notes, Seattle, WA. May 1986.

Patterson, M. M. 1974. Intertidal macrobiology of selected sandy beaches in southern California. Allan Hancock Foundation, Univ. So. California, Los Angeles, CA. 41 p.

Peakall. D. B. 1970. Pesticides and the reproduction of birds. Sci. Am. 222(4).

Pearson, T. H., and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16:229-311.

Peterson, C. H. 1975. Stability of species and of community for the benthos of two lagoons. Ecology 56:958-965.

Phillips, D. J. H. 1980. Quantitative aquatic biological indicators. Applied Science Publishers, Ltd., London, UK.

Phillips, J. H., E. E. Haderlie, and W. L. Lee. 1975. An analysis of the dynamics of DDT in marine sediments. U. S. Environ. Protection Agcy., Off. Res. and Develop., Natl. Environ. Res. Cen., Corvallis, OR. EPA-660/3-75-013. 98 p.

Pierce, K. V., B. McCain, and M. J. Sherwood. 1977. Histology of liver tissue from Dover sole. Pages 207-212 *in* Coastal water research project annual report - 1977. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Pollock, G. A., I. J. Uhaa, A. M. Fan, J. A. Wisniewski, and I. Witherell. 1991. A study of chemical contamination of marine fish from southern California: II. Comprehensive study. Office of Environ. Health Hazard Assess., Calif. EPA, Sacramento CA 95814. 161 p. plus appendices.

Pollock, L. W. 1971. Ecology of intertidal meiobenthos. Pages 141-148 *in* N. C. Hulings (ed.), Proceedings of the First International Conference on Meiofauna, Smithsonian Contrib. Zool. 76.

Poole, M. M. 1984. Migration corridors of gray whales along the Central California coast, 1980-1982. Pages 389-407 *in* M. L. Jones, S. L. Swartz and S. Leatherwood (eds.), The gray whale, *Eschrichtius robustus*. Academic Press, Inc., Orlando, FL.

Pruter, A. T. 1987. Sources, quantities, and distributions of persistent plastics in the marine environment. Mar. Pollut. Bull. 18(bB):305-310.

Puffer, H. W., S. P. Azen, M. J. Duda, and D. R. Young. 1981. Consumption rates of potentially hazardous marine fish caught in the metropolitan Los Angeles area. Typescript. Final report on Project Number R 807 120010. U.S. Environmental Protection Agency, Environmental Research Laboratory - Corvallis, Corvallis, OR. 34 p.

Puffer, H. W., M. J. Duda, and S. P. Azen. 1982. Potential health hazards from consumption of fish caught in polluted coastal waters of Los Angeles County. N. Am. J. Fish. Mgmt. 2:74-79.

Puffer, H. W., and R. W. Gossett. 1983. PCB, DDT, and benzo(a)pyrene in raw and pan-fried white croaker (*Genyonemus lineatus*). Bull. Environ. Contam. Toxicol. 30:65-73.

Quammen, M. L. 1980. The impact of predation by shorebirds, benthic feeding fish and a crab on shallow living invertebrates in intertidal mudflats of two southern California lagoons. Ph.D. dissertation, Univ. California, Irvine, CA.

Quast, J. C. 1968. Some physical aspects of the inshore environment particularly as it affects kelp-bed fishes. Pages 25-34 *in* North, W. J., and C. L. Hubbs (eds.), Utilization of kelp-bed resources in southern California. Calif. Dep. Fish Game, Fish Bull. 139.

Radovich, J. 1961. Relationships of some marine organisms of the northeast Pacific to water temperatures, particularly during 1957 through 1959. Calif. Fish Game, Fish. Bull. 112. 62 p.

Rand, G. M. and S. R. Petrocelli. 1985. Fundamentals of Aquatic Toxicology. Methods and Applications. Hemisphere Pub. Co. New York, NY. 666 pp.

Ramirez, M. G. 1981. The marine mollusks of Ballona. Pages Mo-1 to Mo-9 *in* R. W. Schreiber (ed.), Biota of the Ballona region, Los Angeles County. Suppl. I, Marina Del Rey/Ballona local coastal plan. Los Angeles Co. Nat. Hist. Mus. Found., Los Angeles, CA.

Rancho Palos Verdes 1986. Draft environmental impact report for the Rancho Palos Verdes redevelopment grading and drainage project. Rancho Palos Verdes, California. 98 pp.

Rao, T. K. and J. L. Melniek. 1986. Environmental virology. Amer. Soc. Microbiol. Publ.

Raven, P. H., and H. J. Thompson. 1966. Flora of the Santa Monica Mountains, California. Univ. Calif., Los Angeles, Los Angeles, CA. 189 p.

Rawn, A. M. 1965. Narrative -- C. S. D. County San. Dis. Los Angeles County, Whittier, CA. 176 p.

Regional Water Quality Control Board, Los Angeles Region. 1977. Waste discharge requirements for the County Sanitation Districts of Los Angeles County (Joint Water Pollution Control Plant), Order No. 77-99, NPDES No. CA0053813. RWQCB,LAR, Los Angeles, CA. 33 p.

Regional Water Quality Control Board, Los Angeles Region. 1984. Waste discharge requirements for Chevron U. S. A. Inc. (El Segundo Refinery), Order no. 84-106, NPDES no. CA0000337. LAR,RWQCB, Los Angeles, CA. 22 p.

Regional Water Quality Control Board, Los Angeles Region. 1985a. Waste discharge requirements for City of Los Angeles (Scattergood Generating Station), Order No. 84-111, NPDES No. CA0000370. LAR,RWQCB, Los Angeles, CA. 19 p.

Regional Water Quality Control Board, Los Angeles Region. 1985b. Waste discharge requirements for Southern California Edison Company (El Segundo Generating Station), Order No. 84-113, NPDES No. CA0001147. LAR,RWQCB, Los Angeles, CA. 22 p.

Regional Water Quality Control Board, Los Angeles Region. 1985c. Waste discharge requirements for Southern California Edison Company (Redondo Generating Station), Order no. 84-117, NPDES no. CA0001201. LAR,RWQCB, Los Angeles, CA. 15 p.

Regional Water Quality Control Board, Los Angeles Region. 1987. Waste discharge requirements for City of Los Angeles (Hyperion Treatment Plant), Order No. 87-95, NPDES No. CA0109991. LAR,RWQCB, Los Angeles, CA. 66 p.

Regional Water Quality Control Board, Los Angeles Region. 1988. Annual reports of Hyperion Treatment Plant, Joint Water Pollution Control Plant, Scattergood Generating Station, El Segundo Generating Station, Redondo Generating Station, El Segundo Refinery to LAR,RWQCB. Unpublished set of reports for the years 1983 to 1987. LAR,RWQCB, Los Angeles, CA.

Regional Water Quality Control Board, Los Angeles Region. 1989. Waste discharge requirements for Los Virgenes Municipal Water District, (Tapia Water Reclamation Facility), Order No. 89-076, NPDES No. CA0056014. LAR,RWQCB, Los Angeles, CA. 12p.

Regional Water Quality Control Board, Los Angeles Region. 1990. Waste discharge requirements for Southern California Edison Co., (El Segundo Generating Station). NPDES No. CA0001147. RWQCB,LAR, Los Angeles, CA 27 p.

Regional Water Quality Control Board, Los Angeles Region. 1991. Waste discharge requirements for County Sanitation Districts of Los Angeles County (Joint Water Pollution Control Plant) NPDES No. CA0053813. LAR,RWQCB, Los Angeles, CA. 55p.

Reilly, S. B. 1984. Assessing gray whale abundance: A review. Pages 203-223 *in* M. L. Jones, S. L. Swartz and S. Leatherwood (eds.), The gray whale, *Eschrichtius robustus*. Academic Press, Inc., Orlando, FL.

Reish, D. J. 1980. Effect of domestic wastes on the benthic marine communities of southern California. Helgolander Meeresunters 33:387-383.

Reiter, M. 1984. The Palos Verdes Peninsula. Kendall/Hunt Publ. Co., Dubuque, IA.

Richardson, W. J., C. R. Greene, J. P. Hickie, and R. A. Davis. 1983. Effects of offshore petroleum operations on cold water marine mammals: A literature review. Prepared for American Petroleum Institute, Washington, D.C. API Rep. 4370. 248 p.

Ridgeway, S. H. and M. D. Daily. 1972. Cerebral and cerebellar involvement of trematode parasites in dolphins and their possible role in stranding. J. Wildl. Diseases 8:3-43.

Ridgeway, S. H. and D. G. Johnston. 1965. Two interesting disease cases in wild cetaceans. Am. J. Vet. Res. 26:771-775.

Risebrough, R. W., P.I. 1987. Distribution of organic contaminants in coastal areas of Los Angeles and the Southern California Bight. Submitted to California Regional Water Qual. Cont. Bod., Los Angeles Region, Los Angeles CA. Inst. Mar. Sci., Univ. Calif., Santa Cruz. 114 p. plus appendices.

Risebrough, R. W., B. W. deLappe, E. F. Letterman, J. L. Lane, M. Firestone-Gillis, A. M. Springer, and W. Walker II. 1979. California mussel watch: 1977-1978, Vol. I and III. Water Quality Monitoring Rep. 79-22. State Water Resources Control Bd., Sacramento, CA.

Risebrough, R. W., B. W. deLappe, and W. W. Walker, II. 1976. Transfer of higher-molecular weight chlorinated hydrocarbons to the marine environment. Pages 261-321 *in* H. L. Windom and R. W. Duce (eds.) Marine Pollution Transfer. D. C. Heath and Company, Lexington, MA.

Risebrough, R. W., F. C. Sibley, and M. N. Kirven. 1971. Reproductive failure of the brown pelican of Anacapa Island in 1969. Am. Birds 25:8-9.

Robinson, W. W. 1959. Santa Monica: A calendar of events in the making of a city. Title Insurance and Trust Co., Los Angeles, CA.

Rogan, W. J., B. C. Gladen, J. D. McKinney, N. Carreras, P. Hardy, J. Thullen, J. Tinglestad, and M. Tully. 1986. Neonatal effects of transplacental exposure to PCBs and DDE. J. Pediatrics 109:335-341.

Rogers, B. G., W. T. Ingraham, E. H. Pearle, and L. W. Walters. 1981. Glossary: water and wastewater control engineering. 3rd edition. Water Pollut. Control Federation, Washington, DC, 441 p.

Rosenthal, K. D., D. A. Brown, J. N. Cross, E. M. Perkins, and R. W. Gossett. 1984. Histological condition of fish livers. Pages 229-245 *in* Coastal water research Project biennial report, 1983-1984. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Rote, J. W. 1985. Sources of toxic pollution in Santa Monica Bay, background paper. Prepared by Assem. Off. Res. for Santa Monica Bay Pollut. Inves., Task Force Hearing, Santa Monica, CA.

Round, F. E., and M. Hickman. 1971. Phytobenthos sampling and estimation of primary production. Pages 169-196 *in* N. A. Holme and A. D. McIntyre (eds.), Methods for the study of marine benthos, Blackwell Sci. Publ., Oxford, UK.

Rozengurt, M., and I. Haydock. 1991. Effects of fresh water development and water pollution policies on the world's river - delta - estuary - coastal zone ecosystems, in Coastal Wetlands, Symposium on Coastal and Ocean Management, S. Bolton and O. Magoon, ed., American Society of Civil Engineers, 1991.

Russell, F. E., and P. Kotin. 1957. *Squamous papilloma* in the white croaker. J. Natl. Cancer Inst. 18:857-861.

RWQCB,LAR. See Regional Water Quality Control Board, Los Angeles Region.

Santa Monica Bay Restoration Project. 1992. Progress update, Santa Monica Bay Restoration Project 1991-1992. Santa Monica Bay Restor. Proj., Monterey Park, CA. 18 p.

Sax, N. I., and R. J. Lewis, Sr. 1987. Hawley's condensed chemical dictionary. Van Nostrand Reinhold Do., New York. 1,288 p.

Sayers, M. 1984. Shore whaling for gray whales along the coast of the Californias. Pages 121-157 *in* M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.), The gray whale, *Eschrichtius robustus*. Acad. Press, San Diego, CA.

SCAG. See Southern California Association of Governments.

SCCWRP. See Southern California Coastal Water Research Project.

SCE. See Southern California Edison Company.

SCE,SGD. See Southern California Edison, Steam Generation Division.

Schafer, H. A. 1976. Characteristics of municipal wastewater discharges, 1975. Pages 57-60 *in* Coastal water research project annual report for the year ended 30 June 1976. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 264 p.

Schafer, H. A. 1977. Characteristics of municipal wastewater discharges, 1976. Pages 19-24 *in* Coastal water research project annual report for the year ended 30 June 1977. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 253 p.

Schafer, H. A. 1978. Characteristics of municipal wastewater discharges, 1977. Pages 97-101 *in* W. Bascom (ed.), Coastal water research project annual report for the year 1978. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 253 p.

Schafer, H. A. 1980. Characteristics of municipal wastewater. Pages 235-240 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1979-1980. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 363 p.

Schafer, H. A. 1982. Characteristics of municipal wastewaters 1980-1981. Pages 11-15 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1981-1982. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 294 p.

Schafer, H. A. 1984. Characteristics of municipal wastewater, 1982-1983. Pages 11-19 *in* W. Bascom (ed.), Coastal water research project biennial report, 1983-1984. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 332 p.

Schafer, H. A., and R. W. Gossett. 1988a. Storm runoff in Los Angeles and Ventura Counties. Prepared for Calif. Reg. Water Qual. Control Board, Los Angeles, Reg., Los Angeles, CA. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 97 p.

Schafer, H. A., and R. W. Gossett. 1988b. Characteristics of storm water runoff from the Los Angeles and Ventura Basins. Prepared for California State Water Resources Control Board, Los Angeles Region, Los Angeles, CA. So. Calif. Coastal Water Res. Proj., Long Beach, CA. Contract No. 6-157-140-0.

Schafer, H. A., R. W. Gossett, C. F. Ward, and A. M. Westcott. 1984. Chlorinated hydrocarbons in marine mammals. Pages 109-116 *in* Coastal Water Research Project biennial report, 1983-1984. So. Calif. Coastal Water Res. Proj., Long Beach, CA.

Scholl, J. 1983. Aesthetic values of marine mammals derived from partyboat fishermen surveys, Pt. IV. Pages 57-65 *in* D. Miller (ed.), Coastal marine mammal study, annual report for the period of July 1 1981-June 30, 1982. Prepared for National Marine Fisheries Service Southwest Fisheries Center, La Jolla, CA. Administrative Report LJ-83-21C.

Schreiber, R. W. 1976. Growth and development of nestling brown pelicans. Bird-banding 47:19-29.

Schreiber, R. W. 1981. The biota of the Ballona region, Los Angeles County. Biota of the Ballona region, Los Angeles County. Suppl. I, Marina Del Rey/Ballona local coastal plan. Los Angeles Co. Nat. Hist. Mus. Found., Los Angeles, CA.

Schulman, A. 1986. Gray whale migration through the San Pedro Channel. San Bernardino, CA: Abstract from the sixth biennial conference of the biology of marine mammals, 2-3 May 1986. p. 81.

Schultze, D. L. (ed.). 1986. Digest of California commercial fish laws, January 1, 1986. Calif. Dep. Fish Game, Sacramento, CA. 40 p.

Schwartz, P. M., S. W. Jacobson, G. Fein, J. L. Jacobson, and H. A. Price. 1983. Lake Michigan fish consumption as a source of polychlorinated biphenyls in human cord serum, maternal serum, and milk. Am. J. Public Health 73:293-296.

SDWG. See Sediment Dynamics Workshop Group.

Sediment Dynamics Workshop Group. 1988. Environmental processes affecting DDT contaminated sediments off Palos Verdes, California. Co. Sanit. Dist. of Los Angeles County, Whittier, CA. and U. S. Environmental Protection Agency, Reg. IX, San Francisco, CA. 102 p.

Sharp, R. 1978. Coastal Southern California, K/H Geology Field Guide Series, Kendall/Hunt Publishing Company.

Shaw, M. 1980. Artificial sediment transport and structures in coastal southern california, Univ. of California, San Diego, Scripps Institution of Oceanography, Reference Series No. 80-41

Shaw, W. N., and T. J. Hassler. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) -- Pismo clam. U. S. Fish and Wildlife Service Biological Report 82(11.95), U. S. Army Corps of Engineers, TR EL-82-4, 12 pp.

Shepard, F. P., and G. A. MacDonald. 1938. Sediments of Santa Monica Bay, California. Bull. Am. Assoc. Petrol. Geol. 22(2):201-216.

Sherwood, M. J. 1978. The fin erosion syndrome. Pages 203-221 *in* W. Bascom (ed.), Coastal water research project annual report for the year 1978. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Sherwood, M. J., A. J. Mearns, D. R. Young, B. B. McCain, R. A. Murchelano, G. Alexander, T. C. Heeson, and T-K. Jan. 1978. A comparison of trace contaminants in diseased fishes from three areas. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 115·p.

Simoneit, B. R. T. and I. R. Kaplan. 1980. Triterpenoids as molecular indicators of paleoseepage in recent sediments of the Southern California Bight. Mar. Environ. Res. 3:113-128.

Sindermann, C. J. 1979. Pollution-associated diseases and abnormalities of fish and shellfish: A review. Fish. Bull., U.S. 76:717-749.

Sindermann, C. J., F. B. Ban, N. O. Christensen, V. Dethlefsen, J. C. Harshbarger, J. R. Mitchell, and M. F. Mulcahy. 1980. The role and value of pathobiology in pollution effects monitoring programs. Rap. P. V. Reun. Cons. Int. Explor. Mer. 179:135-151.

Skea, J. C., S. Jackling, J. Symula, H. A. Simonin, E. J. Harris, and J. R. Colquhoun. 1981. Summary of fish trimming and cooking techniques used to reduce levels of oil soluble contaminants. New York Dep. Environ. Conservation, Albany, NY. 36 p.

SMBRP: See Santa Monica Bay Restoration Project

Smith, K., 1991. Beach Politics - The importance of informed, local support for beach restoration projects, Coastal Zone '91, Vol. I, Proceeding of the Seventh Symposium on Coastal and Ocean Management, O. Magoon, H. Converse, V. Tippie, L. Tobin, and D. Clark, ed., American Society of Civil Engineers.

Smith, W. E., K. Funk, and M. E. Zabik. 1973. Effects of cooking on concentrations of PCB and DDT compounds in Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon from Lake Michigan. J. Fish. Res. Bd. Can. 30:702-706.

Smokler, P. E., D. R. Young, and K. L. Bard. 1979. DDTs in marine fishes following termination of dominant California input: 1970-77. Mar. Pollut. Bull. 10:331-334.

Sommer, H., and F. N. Clark. 1946. Effect of red water on marine life in Santa Monica Bay, California. Calif. Fish Game 32(2):100-101.

Soule, D. F., and M. Oguri, eds. 1977. Marine studies of San Pedro Bay, California, Part 13: The marine ecology of Marina del Rey Harbor, California. Inst. Mar. and Coastal Stud., Univ. So. Calif., Los Angeles, CA. USC-SG-2-77. 424 p.

Soule, D. F., and M. Oguri, eds. 1985. The marine environment of Marina del Rey, California in 1984. Marine studies of San Pedro Bay, California Part 20A. Harbors Environmental Projects, Allan Hancock Found., Univ. So. Calif., Los Angeles, CA.

Soule, D. F., and M. Oguri, eds. 1986. The marine environment of Marina del Rey, California in 1985. Marine studies of San Pedro Bay, California Part 20B. Harbors Environmental Projects, Allan Hancock Found., Univ. So. Calif., Los Angeles, CA.

Soule, D. F., and M. Oguri, eds. 1987. The marine environment of Marina del Rey, California in 1986. Marine studies of San Pedro Bay, California Part 20C. Harbors Environmental Projects, Allan Hancock Found., Univ. So. Calif., Los Angeles, CA.

Soule, D. F., M. Oguri, and B. H. Jones. 1992. The marine environment of Marina del Rey, October 1991 to June 1992. In Marine Studies of San Pedro Bay, California, Part 20H. Harbors Environmental Projects. Univ. So. Calif., Los Angeles.

Soutar, A., and J. D. Isaacs. 1969. History of fish populations inferred from fish scales in anaerobic sediments off California. Calif. Coop. Fish. Invest. Rep. 13:63-70.

Soutar, A.,and J. D. Isaacs. 1974. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediments off California. Fish. Bull., U.S. 72:257-274.

Southern California Association of Governments. 1986. Draft baseline projections. So. Calif. Assoc. Gov., Los Angeles, CA.

Southern California Association of Governments. 1988. The state of Santa Monica Bay: Part two: Assessment of the management framework. S. Calif. Assoc. Govt., Los Angeles, CA. 183 p.

Southern California Association of Governments. 1991. Regional comprehensive plan city survey comparison to 1990 census and summed city projections by county. So. Calif. Asso. Gov., Los Angeles, CA.

Southern California Association of Governments. 1992a. Southern California land use data base. So. Calif. Asso. Gov., Los Angeles, CA.

Southern California Association of Governments. 1992b. Regional population model. So. Calif. Asso. Gov., Los Angeles, CA.

Southern California Coastal Water Research Project. 1973. The ecology of the Southern California Bight: Implications for water quality management. SCCWRP, El Segundo, CA. SCCWRP TR104. 531 p.

Southern California Coastal Water Research Project. 1974. Observations with a baited movie camera. Pages 45-52 *in* Coastal water research project annual report for the year ended 30 June 1974. SCCWRP, El Segundo, CA.

Southern California Coastal Water Research Project. 1986a. Polynuclear aromatic hydrocarbon contamination in sediments from coastal waters off southern California. Pages 13-16 *in* So. Calif. Water. Res. Proj., 1986. SCCWRP, Long Beach, CA.

Southern California Coastal Water Research Project. 1986b. Recovery of Santa Monica Bay from sludge discharge. Page 22 *in* So. Calif. Coastal Water. Res. Proj. 1986. SCCWRP, Long Beach, CA.

Southern California Coastal Water Research Project. 1986c. Characteristics of municipal wastewater in 1984 and 1985. Pages 1-5 *in* So. Calif. Coastal Water Res. Proj. -- 1986, SCCWRP, Long Beach, CA.

Southern California Coastal Water Research Project. 1986d. Contaminant levels in the sea-surface microlayer. Pages 6-8 *in* So. Calif. Coastal Water Res. Proj. -- 1986. SCCWRP, Long Beach, CA.

Southern California Coastal Water Research Project. 1986e. Distribution and abundance of megabenthic invertebrates in southern California coastal waters. Pages 20-21 *in* So. Calif. Coastal Water Res. Proj. -- 1986. SCCWRP, Long Beach, CA.

Southern California Coastal Water Research Project. 1987. Annual report. SCCWRP, Long Beach, CA. 101 p.

Southern California Coastal Water Research Project. 1989. Annual report 1988-89. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 90 p.

Southern California Coastal Water Research Project. 1990. Annual report 1989-90. So. Calif. Coastal Water Res. Proj., Long Beach, CA. 115 p.

Southern California Coastal Water Research Project, MBC Applied Environmental Sciences, and University of California, Santa Cruz. 1992. Santa Monica Bay seafood contamination study, draft final report. Prepared for Santa Monica Bay Restor. Proj., Monterey Park, CA, by So. Calif. Coastal Water Res. Proj., Long Beach, CA. 190 p.

Southern California Coastal Water Research Project. 1992. Recovery of Santa Monica Bay from sludge discharge, Technical Report. Southern California Coastal Water Research Project Authority. Long Beach CA. 111 p.

Southern California Edison Company. 1982. Southern California Edison Company 316(b) demonstration, Technical Appendix, Impact assessment model: Bight-wide plankton investigations. Prepared for Calif. Reg. Water Quality Control Board (Los Angeles, San Diego, and Santa Ana Regions). SCE, Rosemead, CA. 71 p.

Southern California Edison Company, Steam Generation Division. 1988. Economic significance of generating stations to SCE. SCE, Rosemead, CA.

Southern California Edison. 1992. El Segundo and Redondo Generating Station, unpublished data. SCE, Rosemead, CA.

Spies, R. B., B. D. Andresen, and D. W. Rice, Jr. 1987. Benzothiazoles in estuarine sediments as indicators of street runoff. Nature 327:697-699.

Squire, J. L., Jr., and S. E. Smith. 1977. Angler's guide to the United States Pacific Coast. Natl. Mar. Fish. Serv., NOAA, Seattle, WA. 139 p.

Stahl, J. F., and R. W. Horvath. 1987. Sludge management and energy production at Los Angeles County Sanitation Districts. Proceedings: 11th U.S./Japan Conference on Sewage Treatment Technology, 1987.

Stallard, M., V. Hodge, and E. D. Goldberg. 1986. TBT in California coastal waters: Monitoring and assessment. Env. Monitor. and Assess.

Stephens, J. S., Jr., P. A. Morris, and W. Westphal. 1983. Assessing the effects of a coastal steam electric generating station on fishes occupying its receiving waters. Pages 194-208 *in* D. F. Soule and D. Walsh (eds.), Waste disposal in the oceans: minimizing impact, maximizing benefits. Westview Press, Boulder, CO.

Stephens, J. S., Jr., P. A. Morris, K. Zerba, and M. Love. 1984. Factors affecting fish diversity on a temperate reef: The fish assemblage of Palos Verdes Point, 1974-1981. Environ. Biol. Fish. 11(4):259-275.

Stephens, J. S., Jr., D. Pondella, II, P. Morris, and D. F. Soule. 1991. Marina del Rey as a fish habitat: studies of the fish fauna since 1977. Pages 27-48 *in* P. M. Grifman and S. E. Yoder (eds.), Perspectives on the marine environment. Univ. So. Calif., Sea Grant Prog., Los Angeles, CA.

Stephens, J. S., Jr., and K. Zerba. 1981. Factors affecting fish diversity on a temperate reef. Environ. Biol. Fish. 6(1):111-121.

Stephenson, M. D., M. Martin, S. E. Lange, A. R. Flegal, and J. H. Martin. 1979. California mussel watch 1977-1978, Volume II, trace metal concentrations in the California mussel, *Mytilus californianus*. Calif. State Water Resources Control Board, Sacramento, CA. Water Quality Monitoring Report 79-22. 110 p.

Stephenson, M. D., S. L. Coale, M. Martin, and J. H. Martin. 1980. California mussel watch 1979-1980: trace metal concentrations in the California mussel, *Mytilus californianus*, and the bay mussel, *M. edulis*, along the California coast and selected harbors and bays. CSWRCB, Sacramento, CA. Water Quality Monitoring Report 80-8. 95 pp.

Stewart, J. 1987. Angry fight on Malibu sewer reaches crucial point. Los angeles Times, October 16, p. II-1.

Stich, H. F., A. B. Acton, and C. R. Forrester. 1976. Fish tumors and sublethal effects of pollutants. J. Fish. Res. Bd. Can. 33:1993-2001.

Stich, H. F., A. B. Acton, K. Oishi, F. Yamazaki, T. Harada, T. Hibino, and H. G. Moser. 1977. Systematic collaborative studies on neoplasms in marine animals as related to the environment. Ann. N.Y. Acad. Sci. 298:374-388.

Strachan, A. R., and R. T. Koski. 1969. A survey of algae off Palos Verdes Point, California. Calif. Fish Game 55(1):47-52.

Straughan, D. 1977a. Influence of power generating facilities on southern California coastal waters, Phase 3: Study of environmental conditions in King Harbor, 1 April 1976-31 March 1977. Report on field biology of subtidal unstable substrates. Inst. Mar. Coastal Stud., Univ. So. Calif., Los Angeles, CA. Res. and Develop. Ser. 77-RD-52. 126 p.

Straughan, D. 1977b. Sandy beaches and sloughs. Southern California baseline study -final report Vol. III, Rpt 2.3. Prepared for Bureau of Land Management, Washington, D.C. 119 p. with appendices.

Straughan, D. 1977c. Influence of power generating facilities on southern California coastal waters, Phase 3. Report on field biology of intertidal rocky shores. Prepared for Southern California Edison Co., Rosemead, CA. R&D Ser. 77-RD-65.

Straughan, D. 1982. Inventory of the natural resources of sandy beaches in southern California. Allan Hancock Found., Univ. So.Calif., Los Angeles, CA. Tech. Rep. No. 6. 447 p.

Stull, J. K., and R. B. Baird. 1985. Trace metals in marine surface sediments of the Palos Verdes Shelf, 1974 to 1980. J. Water Pollut. Cont. Fed. 57(8):833-840.

Stull, J. K., R. B. Baird, and T. C. Heesen. 1986a. Marine sediment core profiles of trace constituents offshore of a deep wastewater outfall. Jour. Water Pollut. Cont. Fed. 58(10):985-991.

Stull, J. K., K. A. Dryden, and P. A. Gregory. 1987. An historical review of fisheries statistics and environmental and societal influences off the Palos Verdes Peninsula, California. Calif. Coop. Oceanic Fish. Invest. Rep. 28:135-154.

Stull, J. K., and C. I. Haydock. 1988. Wastewater discharges and environmental responses: The Palos Verdes case. Pages 44-49 *in* The Bay Institute of San Francisco, Managing inflows to California's bays and estuaries, The Bay Institute of San Francisco, Sausalito, CA.

Stull, J. K., C. I. Haydock, and D. E. Montagne. 1986c. Effects of *Listriolobus pelodes* (Echiura) on coastal shelf benthic communities and sediments modified by a major California wastewater discharge. Estur. Coast. Mar. Sci. 22:1-17.

Stull, J. K., C. I. Haydock, R. W. Smith, and D. E. Montagne. 1986b. Long-term changes in the benthic community on the coastal shelf of Palos Verdes, southern California. Mar. Biol. 91:539-551.

Swartz, R. C., F. A. Cole, D. W. Schults, and W. A. DeBen. 1986. Ecological changes in the Southern California Bight near a large sewage outfall: Benthic conditions in 1980 and 1983. Mar. Ecol. Prog. Ser. 31:1-13.

Sweeney, R. E., and I. R. Kaplan. 1980. Tracing flocculent industrial and domestic sewage transport on San Pedro Shelf, southern California, by nitrogen and sulphur isotope ratios. Mar. Environ. Res. 3:215-224.

Swift, C. C., and G. D. Frantz. 1981. Estuarine fish communities of Ballona. Pages F-1 to F-31 *in* R. W. Schreiber (ed.), The biota of the Ballona Region, Los Angeles County, Los Angeles Co. Mus. Nat. His. Mus. Found., Los Angeles, CA.

Terry, R. D., S. A. Keesling, and E. Uchupi. 1956. Submarine geology of Santa Monica Bay, California. Report to Hyperion Engineers Inc., Geol. Dep., Univ. So. Calif., Los Angeles, CA. 177 p.

Tetra Tech. 1981. Technical evaluation of the County Sanitation Districts of Los Angeles County; Joint Water Pollution Control Plant Section 301(h) application for modification of secondary treatment requirements for discharge into marine waters. Prepared for U.S. Environmental Protection Agency. March 1981. 623 p.

Tetra Tech. 1984. Technical review of the Los Angeles County Sanitation Districts' application for modification of secondary treatment requirements for discharge into marine waters. Draft Report. Prepared for U.S. Environ. Protection Agcy., Washington, DC. Tetra Tech, Inc., Bellevue, WA. 259 p.

Thom, R. M., and T. B. Widdowson. 1978. A resurvey of E. Yale Dawson's 42 intertidal algal transects on the southern California mainland after 15 years. Bull., So. Calif. Acad. Sci. 77:1-13.

Thompson, B. E., and J. Dorsey. 1989. Recovery of Santa Monica Bay from sludge discharge: progress report. Proceedings, Oceans '89. 2:437-442.

Thompson, B. E., J. D. Laughlin, and D. T. Tsukada. 1987. 1985 reference site survey. So. Calif. Coast. Water Res. Proj. Auth., Long Beach, CA. Tech. Rep. 221. 50 p.

Travis, C. C., S. A. Richter, E. A. C. Crouch, R. Wilson, and E. D. Klema. 1987. Cancer risk management. A review of 132 federal regulatory decisions. Environ. Sci. Technol. 21:415-420.

UCLA, WCC: See University of California, Los Angeles, and Woodward-Clyde Consultants.

Ulrey, A. B. and P. O. Greeley. 1928. A list of marine fishes, (Teleostei) of southern California with their distribution. Bull. So. Calif. Acad. Sci. 27:1-53.

United States Army Corps of Engineers, Los Angeles Harbor Department. 1992. Draft Environmental Impact Statement/Environmental Impact Report Deep Draft Navigation Improvements, Los Angeles and Long Beach Harbors San Pedro Bay, California. June 1992.

United States Atomic Energy Commission, Directorate of Licensing. 1973. Final environmental statement related to the proposed San Onofre Nuclear Generating Station Units 2 and 3. Southern California Edison Company and the San Diego Gas & Electric Company. Docket Nos. 50-361 and 50-362. 143 p. plus appendices.

United States Bureau of Census. 1940. U. S. census report. U. S. Bur. Census, Washington, DC.

United States Bureau of Census. 1950. U. S. census report. U. S. Bur. Census, Washington, DC.

United States Bureau of Census. 1960. U. S. census report. U. S. Bur. Census, Washington, DC.

United States Bureau of Census. 1970. U. S. census report. U. S. Bur. Census, Washington, DC.

United States Bureau of Census. 1980. U. S. census report. U. S. Bur. Census, Washington, DC.

United States Bureau of Census. 1990. U. S. census report. U. S. Bur. Census, Washington, DC.

United States Department of Interior, Bureau of Land Management. 1975. Draft environmental impact statement for the proposed 1975 Outer Continental Shelf oil and gas lease sale offshore southern California OCS Sale No. 35. U. S. Dep. Inter., Bur. Land Mgt., Washington, DC. Vol. 1. 792 p.

United States Environmental Protection Agency. 1983. CERCLA investigation, Montrose Chemical Corporation, 20201 South Normandie Avenue, Torrance, CA. United States EPA Region IX, San Francisco, CA.

United States Environmental Protection Agency. 1985. The Carcinogen Assessment Group's evaluation of the carcinogenicity of dicofol (kelthane), DDT, FFR. and DDD (TDE). United States EPA, Office of Health and Environmental Assessment, Washington, DC. 75 p.

United States Environmental Protection Agency. 1986. Bacteriological ambient water quality criteria for marine and fresh recreational waters. PB86-158-045. Natl. Tech. Inf. Serv., Springfield, VA.

United States Environmental Protection Agency. 1988. Final environmental impact statement (EIS) for the Los Angeles/Long Beach (LA-2) ocean dredged material disposal site designation. USEPA, Reg. IX, San Francisco, Ca. 334 p.

United States Environmental Protection Agency, Office of Marine Estuary Protection. 1987. Estuary Program primer. U. S. Environ. Prot. Agcy., Washington, DC. 100 p.

United States Fish and Wildlife Service, 1984. Endangered and threatened wildlife and plants, Federal Register 49(100):21664-21675.

United States Fish and Wildlife Service, U.S. Department of the Interior and Coastal Ecology Group, U.S. Army Corps of Engineers. 1985. California Grunion, Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest), Biological Report 82(11.28), February 1985

United States Food and Drug Administration. 1984. Polychlorinated biphenyls (PCBs) in fish and shellfish; reduction of tolerances; final decision. United States FDA, Rockville, MD. Federal Register, Vol. 49, No. 100. pp. 21514-21520.

University of California, Los Angeles, and Woodward-Clyde Consultants. 1992. Annual pollutant loadings to Santa Monica Bay from storm water runoff (draft final chapter to Assessment of nonpoint sources of contaminants to Santa Monica Bay). Prepared for Santa Monica Bay Restor. Proj., Monterey Park, CA, by Univ. Calif., Los Angeles, Los Angeles, CA. 109 p.

University of Southern California, Allan Hancock Foundation. 1965. An investigation on the fate of organic and inorganic wastes discharged into the marine environment and their effects on biological productivity. Calif. State Water Qual. Control Board, Sacramento, CA. Publ. 29. 116 p.

USACOE/LAHD: See United States Army Corps of Engineers, Los Angeles Harbor Department.

USAEC: See United States Atomic Energy Commission.

USBC. See United States Bureau of Census.

USC, AHF: See University of Southern California, Allan Hancock Foundation.

USEPA. See United States Environmental Protection Agency.

USEPA,OMEP. See United States Environmental Protection Agency, Office of Marine and Estuarine Protection.

USFDA. See United States Food and Drug Administration.

USFWS. See United States Fish and Wildlife Service.

Valiela, I. 1984. Marine ecological processes. Springer-Verlag, New York, NY. 546 p.

Venkatesan, M. I., and I. R. Kaplan. 1986. Progress report ending December 1986 of the project: program of mineralization and cycling in marine systems - organic geochemistry of particulates and sediments. Dep. Earth and Planetary Sci., Univ. Calif., Los Angeles, CA. 8 p.

Venkatesan, M. I., and I. R. Kaplan. 1987. Progress report ending May 1987 of the project: program of mineralization and cycling in marine systems - organic geochemistry of particulates and sediments. Dep. Earth and Planetary Sci., Univ. Calif., Los Angeles, CA. 18 pp.

Versar, Inc. 1988. A retrospective pollution history of southern California. Vol. I. Prepared for NOAA, NOS, Seattle, WA., and NMFS, La Jolla, CA. 104 p. plus appendices.

Vesco, L. L., and R. M. Gillard. 1980. Recovery of benthic marine populations along the Pacific Coast of the United States following natural and man-made disturbances including pertinent life history information. POCS Office, Bureau of Land Management. Pacific OCS Ref. Pap. 53-4. 50 p.

Walther, M. 1991. Dune maintenance, Coastal Zone '91, Vol. I, Proceeding of the Seventh Symposium on Coastal and Ocean Management, O. Magoon, H. Converse, V. Tippie, L. Tobin, and D. Clark, ed., American Society of Civil Engineers.

Wastewater Systems Engineering Division. 1982. City of Los Angeles Wastewater Facilities Plan. WSED, Dep. Pub. Works, Bur. Engineering, City of Los Angeles, Los Angeles, CA. 294 p.

Waters, T. 1988. Chevron plant in El Segundo lays plans for massive oil-leak cleanup. Los Angeles Times, June 12, II:8,16.

Wellings, S. R., C. E. Alpers, B. B. McCain, and B. S. Miller. 1976. Fin erosion disease of starry flounder (*Platichthys stellatus*) and English sole (*Parophrys vetulus*) in the estuary of the Duwamish River, Seattle, Washington. J. Fish. Res. Bd. Can. 33:2577-2586.

Wells, M., 1990. The use of prescribed fire for habitat management in southern California State Park units, *Crossosoma*, Vol. 16, No. 5.

Westman, W. E. 1979. Oxidant effects on California coastal sage scrub. Science 205:1001-1003.

Wetlands Research Associates, Inc. 1990. Port of Los Angeles local wetland mitigation program. Prepared for Port of Los Angeles, San Pedro, CA. Wetlands Res. Assoc., San Rafael, CA.

Wicksten, M. K. 1984. Distribution of some common decapod crustaceans and a pycnogonid from the continental shelf of northern California. Calif. Dept. Fish Game 70(3):132-139.

Widdowson, T. B. 1971. Changes in the intertidal algal flora of the Los Angeles area since the survey of E. Yale Dawson 1956-59. Bull. So. Calif. Acad. Sci. 70(1):2-16.

Willet, G. 1933. A revised list of the birds of southeastern California. Pacific Coast Avifauna No. 21.

Williams, P. M. 1986. Chapter 3. Chemistry of the dissolved and particulate phases in the water column. Pages 53-83 *in* R. W. Eppley (ed.), Lecture notes on coastal and estuarine studies. Vol. 15, Plankton dynamics of the Southern California Bight. Springer-Verlag, New York, NY. 373 p.

Wilson, K. C., P. L. Haaker, and D. A. Hanan. 1977. Restoration of *Macrocystis pyrifera* (Phaeophycea) at Palos Verdes Peninsula, California. Pages 85-89 *in* Proc. 9th international seaweed symposium, Santa Barbara, CA, 20-27 August 1977.

Wilson, K., and H. Togstad. 1983. Storm caused changes in the Palos Verdes kelp forest. Pages 301-307 *in* W. Bascom (ed.), The effects of waste disposal on kelp communities. Natl. Sea Grant College Prog., NOAA, Washington, D. C.

Wilson, R., and E. A. C. Crouch. 1987. Risk assessment and comparisons: An introduction. Science 236:267-270.

Wine, V. 1979. Southern California independent sport fishing survey annual report No. 3. Calif. Fish Game, Long Beach, CA. 100 p.

Winkler, D. L. and K. L. Duncan, J. E. Hose, and H. W. Puffer. 1983. Effects of benzo(a)pyrene on the early development of California grunion, *Leuresthes tenuis* (Pisces, Atherinidae). Fish. Bull., United States 81(3):473-481.

Wolfe, Douglas A., ed. 1986. Plastics in the sea, selected papers from the sixth International Ocean Disposal Symposium. Mar. Pollut. Bull. 18(6B):303-365.

Wood, J. W., and H.-K Wang. 1983. Microbial resistance to heavy metals. Environ. Sci. and Tech. 17:582-590.

Woodell, G., A. Egense, and C. Butcher, 1990. Beach Nourishment Project Compatible with Multiple concerns, Santa Monica Bay, California, County of Los Angeles, Department of Beaches and Harbors

Woodell, G., and R. Hollar. 1991. Historical changes in the beaches of Los Angeles County. Pages 1342-1355 *in* O. T. Magoon, H. Converse, V. Tippie, L. T. Tobin, and D. Clark (eds.), Coastal zone '91. Am. Soc. Civil Engin., New York, NY. Vol. 2.

Woodhouse, C. D. 1984. Patterns of marine mammal mortality in three coastal counties of California. Tech. Rep. Submitted to Arthur D. Little, Inc., Cambridge, MA.

Word, J. Q., C. D. Boatman, C. C. Ebbesmeyer, R. E. Finger, S. Fischnaller,and Q. J. Stober. 1984. Vertical transport of freon extractable and non-extractable material and bacteria (fecal coliform and enterococci) to the surface of marine waters: Some experimental results using secondary sewage effluent. Vol. XI, Sec. 13. Final report for period 1 April 1982 to 31 December 1984 for the Municipality of Metropolitan Seattle, Seattle, WA. Univ. Wash., School of Fish., Fish. Res. Inst. FRI-UW-8413, Seattle, WA.

Word, J. Q., and A. J. Mearns. 1977. Bottom invertebrate populations below 200 meters. Pages 117-120 *in* Coastal water research project annual report for the year ended 30 June 1977. So. Calif. Coast. Water Res. Proj., El Segundo, CA. 253 p.

Word, J. Q., and A. J. Mearns. 1979. 60-meter control survey off southern California. So. Calif. Coastal Water Res. Proj., El Segundo, CA. TM 229. 58 p.

Word, J. Q., B. L. Myers, and A. J. Mearns. 1977. Animals that are indicators of marine pollution. Pages 199-206 *in* Coastal water research project annual report, 1977. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Word, J. Q., and P. L. Striplin. 1980. Benthic microcrustacea and echinoderms on Palos Verdes shelf. Pages 13-20 *in* W. Bascom (ed.), Coastal water research project biennial report for the years 1979-1980. So. Calif. Coast. Water Res. Proj., Long Beach, CA. 363 p.

WRA. See Wetlands Research Associates

WSED. See Wastewater Systems Engineering Division.

Young, D. R. 1978. Priority pollutants in municipal wastewaters. Pages 103-112 *in* W. Bascom (ed.), Coastal water research project annual report for the year 1978. S. Calif. Coastal Water Res. Proj., El Segundo, CA. 253 p.

Young, D. R., R. W. Gossett, and T. C. Heesen. 1988. Persistence of chlorinated hydrocarbon contamination in a coastal marine ecosystem of southern California. In: D. A. Wolfe and T. P. O'Connor (eds.), Oceanic processes in marine pollution. Vol. 5, Urban wastes in coastal marine environments. Krieger Publishing Co., Malabar, FL.

Young, D. R., and T. C. Heeson. 1976. Inputs of DDT and PCB. Pages 23-30 *in* Coastal water research project, annual report for the year ended 30 June 1976. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Young, D. R., and T. C. Heesen. 1977. Chlorinated benzenes in Palos Verdes flatfish. Pages 149-152 *in* W. Bascom (ed.) Coastal water research project annual report for the year ended 30 June 1977. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 253 p.

Young, D. R., and T-K. Jan. 1975. Trace metals in nearshore seawater. Pages 143-146 *in* Coastal water research project annual report 1975. So. Calif. Coastal Water Res. Proj., El Segundo, CA.

Young, D. R., T-K. Jan, and T. C. Heesen. 1978a. Cycling of trace metal and chlorinated hydrocarbon wastes in the Southern California Bight. Pages 481-496 *in* Estuarine Interactions. M.L. Wiley (ed). Academic Press, New York, NY.

Young, D. R., T.-K. Jan, and M. D. Moore. 1977. Metals in power plant cooling water discharges. Pages 25-31 *in* W. Bascom (ed.) Coastal water research project annual project for the year ended 30 June 1977. So. Calif. Coastal Water Res. Proj., El Segundo, CA. 253 p.

Young, D. R., J. N. Johnson, A. Soutar, and J. D. Isaacs. 1973. Mercury concentrations in dated varied marine sediments collected off southern California. Nature 224:273-275.

Young, D. R., D. J. McDermott, and T. C. Heesen. 1976a. Marine inputs of polychlorinated biphenyls off southern California. Pages 199-208 *in* Proc. of the National Conference on Polychlorinated Biphenyls, 19-21 November 1975, Chicago, IL. EPA Report 560/6-75-004.

Young, D. R., D. J. McDermott, and T. C. Heeson. 1976b. DDT in sediments and organisms around southern California outfalls. J. Water Pollut. Control Fed. 48:1919-1927.

Young, D. R., A. J. Mearns, T-K. Jan, T. C. Heeson, M. D. Moore, R. P. Eganhouse, G. P. Hershelman, and R. W. Gossett. 1980. Trophic structure and pollutant concentrations in marine ecosystems of southern California. Calif. Coop. Ocean. Fish. Inves. Rep. XXI:197-206.

Young, D. R., M. D. Moore, G. V. Alexander, T-K. Jan, D. J. McDermott-Ehrlich, R. P. Eganhouse, and P. Hershelman. 1978b. Trace elements in seafood organisms around southern California municipal wastewater outfalls. Southern California Coastal Water Research Project, El Segundo, CA. Publ. No. 60. 104 pp.

Zedler, J. B. 1982. The ecology of southern California coastal salt marshes: A community profile. Biological Services Program, Fish and Wildlife Service, Washington, D.C.

Zedler, J. 1991. Invasive exotic plants: threats to coastal ecosystems, in Perspectives on the marine environment, Proceedings from a symposium on the marine environment of southern California, P. Grifman and S. Yoder, ed., May 10.

Personal Communications

Ackerman, N. 1988. County Sanitation Districts of Los Angeles County, Whittier, CA, pers. comm., October.

Alcaino, C. B. 1988. Sr. Engr, Steam Generating Div., So. Calif. Edison Co., Rosemead, CA, pers. comm., 21 June.

Baird, P. 1992. California State University, Long Beach, pers. comm., 18 December.

Bender, H. 1988. Independent fuel dock, King Harbor, Redondo Beach, CA, pers. comm., 21 March.

Biagi, D. 1988. Director, City of Los Angeles, Dept. Publ. Works, Bur. Sanitation, Los Angeles, CA, pers. comm.

Bratkovich, A. 1988. Great Lakes Environ. Res. Lab., Ann Arbor, MI, pers. comm., June.

Cabelli, V. 1988. University of Rhode Island, Kingston, RI, pers. comm., 9 April.

Calderone and A. P. Dufour. 1988. Pers. comm. to V. J. Cabelli.

Chang, M. 1992. Chief of Navigation Section, Army Corp of Engineers. Los Angeles, CA, pers. comm., 15 December.

Chow, R. 1992. Regional Water Quality Control Board, Los Angeles Region. Los Angeles, CA, pers. comm., 11 December.

Clemens, R. 1988. Harbor Patrol, Redondo Beach, CA, pers. comm., 4 February.

Colbaugh, J. 1988. Las Virgenes Municipal Water District, Calabasas, CA, pers. comm., June.

Coonan, T. 1992. Chevron USA El Segundo Refinery, pers. comm., December.

Coonan, T. 1993. Chevron USA El Segundo Refinery, pers. comm., March.

Cotter, P. J. 1992. Ocean Dumping Permits and Site Manager, Marine Protection Section, U.S. Environmental Protection Agency. San Francisco, CA, pers. comm., 16 December.

Cressey, R. 1992. HTP, pers. comm., December.

Crosse, J. T. 1988. Plant Manager, North Outfall Treatment Facility, Hyperion Treatment Plant, Bur. Sanitation, Dep. Public Works, City of Los Angeles, Playa del Rey, CA, pers. comm., 19 February and 10 June.

Curtis, M. D. 1988. MBC Applied Environmental Sciences, Costa Mesa, CA, pers. comm., 8 April.

Damron, S. 1988. Los Angeles City Department of Water and Power, Los Angeles, CA, pers. comm., 4 April.

Dorsey, J. 1988. Hyperion Treatment Plant, CLA,DPW, Playa del Rey, CA, pers. comm., 24 February and 1 March.

Dorsey, J. 1993. Hyperion Treatment Plant, CLA,DPW, Playa del Rey, CA, pers. comm., March.

Gamble, J. 1992. Las Virgenes Municipal Water District. Calabasas, CA. pers. comm., 15 November.

Gold, M. 1993. Staff Scientist, Heal the Bay, Santa Monica, CA, pers. comm. 16 March.

Gordon, P. 1988. Univ. So. Calif., Planning Inst., Los Angeles, CA, pers. comm., May.

Grant, J. 1992. CDFG, Long Beach, CA, pers. comm., Dec. 10. from William F. Shake, United States Fish and Wildlife Service, October 7, 1983.

Hanan, D. 1988. California Department of Fish and Game, pers. comm.

Harris, S. 1992. California Department of Fish and Game, pers. comm., 23 December.

Herbison, K. T. 1988. Southern California Edison, pers. comm.

Hertel, M. M. 1988. Southern California Edison Company, Rosemead, CA, pers. comm., 16 May.

Hickey, B. 1988. Univ. Washington, Coll. Ocean and Fish. Sci., Seattle, WA, pers. comm., May.

Hildebrand, G. 1993. Supervising Engineer II, LAC,DPW, pers. comm., March.

Holderman, R. 1992. California State Coastal Conservancy, pers. comm., 11 December.

Horvath, R. W. 1988. Head, Monitoring and Research, County Sanitation Districts of Los Angeles County, Whittier, CA, pers. comm., 4 May.

Horvath, R. W. 1992. Head, Monitoring and Research, County Sanitation Districts of Los Angeles County, Whittier, CA, pers. comm., December.

Horvath, R. W. 1993. Head, Monitoring and Research, County Sanitation Districts of Los Angeles County, Whittier, CA, pers. comm., May.

Isbitsky, H. 1992. Assistant Chief for Safety and Sanitation, LACDBH, pers. comm., 23 December.

Jozwiak, L. 1988. National Marine Fishery Service, pers. comm., 21 June.

Jurek, R. 1992. California Department of Fish and Game, pers. comm., December.

Karapetian, E. 1988. Dep. Water and Power, City of Los Angeles, Los Angeles, CA, pers. comm., 3 June.

Kramer, S. H. 1988. Scripps Inst. Oceanogr., Univ. Calif., San Diego, San Diego, CA, pers. comm., May 7.

Kolpack, R. L. 1988. Independent consultant, West Covina, CA, pers. comm., 21 January.

LACHP. See Los Angeles County Harbor Patrol.

LAVCB. See Los Angeles Visitors and Convention Bureau.

Los Angeles County Harbor Patrol. 1988. Los Angeles, CA, pers. comm., 4 February.

Los Angeles Visitors and Convention Bureau. 1988. Los Angeles, CA, pers. comm., May.

Lewis, T. 1988. American Cetacean Society, San Pedro, CA, pers. comm., June.

Manion, S. 1992. Topanga-Las Virgenes Resource Conservation District, pers. comm., 12 December.

Marina del Rey Harbor Marine Information. 1988. Marina del Rey, CA, pers. comm., 4 February.

McCormick, J. 1988. Calif. Dep. Fish Game, Long Beach, CA, pers. comm., 19 April.

McGee. C. 1993. Laboratory Supervisor for Orange County Sanitation Districts, Fountain Valley, CA., pers. comm., March.

MDRHMI. See Marina del Rey Harbor Marine Information.

Mearns, A. J. 1987. United States Dep. Commerce, Natl. Oceanic and Atmos. Admin., Natl. Ocean Serv., Seattle, WA, pers. comm., August.

Michel, P. 1992. Santa Monica Bay Restoration Project, pers. comm., 11 December.

Michel, P. 1993. Santa Monica Bay Restoration Project, pers. comm., March.

Mitchell, J. K. 1987. LAC,DPW, Water Quality Div., Waste Mgmt. Sec., Los Angeles, CA, pers. comm., 15 September.

Mitchell, J. K. 1988. LAC,DPW, Water Quality Div., Waste Mgmt. Sec., Los Angeles, CA, pers. comm., 20 April.

Otott, G. 1988. THUMS Long Beach Company, Long Beach, CA, pers. comm., 10 March.

Otott, G. 1992. THUMS Long Beach Company, Long Beach, CA. pers. comm., 08 January.

Panagakos, R. 1992. Ensign, Army Corps of Engineers, pers. comm., December.

Pitzer, J. 1988. Los Angeles County Harbor Patrol, Redondo Beach, CA, pers. comm., 18 March.

Puffer, H. 1988. pers. comm.

Rogers, G. 1992. Supervisor, City of Santa Monica Beach Cleaning, pers. comm., December.

Schumaker, W. 1988. Chief, Safety and Sanitation Div., Dep. Breaches and Harbors, Los Angeles Co., Marina del Rey, CA, pers. comm., 28 June.

Schumann, J. W. 1988. Environ. and Govt. Affairs, Syst. Dev. Div., Dep. Water and Power, City of Los Angeles, Los Angeles, CA, pers. comm., 21 June.

Shulman, A. 1988. American Cetacean Society, pers. comm., May.

Smith, R. W. 1988. EcoAnalysis, Inc., Ojai, CA, pers. comm., June.

Sowby, M. 1988. RWQCB,LAR, Los Angeles, CA, pers. comm., 10 February.

Sowby, M. 1993. Chief, Research and Investigation Unit, Scientific Program, Office of Oil Spill Prevention and Response, May.

Spackman, R. K. 1988. Chevron USA, Publ. Affairs Mgr., El Segundo, CA, pers. comm., 15 June and 16 June.

Speelmans, T. 1992, LAXFUEL, Los Angeles, CA, pers. comm., Dec.

Stenzel, L. 1993. Point Reyes Bird Observatory, pers. comm., 5 January.

Stephens, J. S. Jr. 1988. Dep. Biology, Occidental College, Los Angeles, CA, pers. comm., 7 May.

Stull, J. 1988. Environmental scientist, Los Angeles County Sanitation Districts, Whittier, CA, pers. comm.

Stull, J. 1992. Environmental scientist, Los Angeles County Sanitation Districts, Whittier, CA, pers. comm.

Stull, J. 1993. Environmental scientist, Los Angeles County Sanitation Districts, Whittier, CA, pers. comm., March, May.

Velez, P. 1993. Santa Monica Bay Restoration Project, pers. comm., March.

Vojkovich, M. 1988. Calif. Dep. Fish Game, Long Beach, CA, pers. comm., 16 May.

Weisman, W. 1992. County Sanitation Districts of Los Angeles County, Whittier, CA, pers. comm., November.

Weiss, I. 1993. President, Ballona Lagoon Marine Preserve, pers. comm., March.

Welch, T. 1993. Army Corps of Engineers, pers. comm., 8 January.

Whitbeck, S. 1992. Superintendent, TWRF, LVMWD, pers. comm., December.

Yoder, S. 1993. Coastal Resource Specialist, Marine Advisory Services, USC Sea Grant Program, March.

Zembal, 1988. U.S. Fish and Wildlife Service, pers. comm., April.

Zembal, 1992. U.S. Fish and Wildlife Service, pers. comm., December.

CHARACTERIZATION STUDY INDEX

SANTA MONICA BAY RESTORATION PROJECT
MANAGEMENT COMMITTEE MEMBERS AND ALTERNATES

John Caffrey, Co-Chair
Harry Seraydarian, Co-Chair
Charles Vernon, Vice-Chair

Senator Barbara Boxer
David Thompson
Senator Dianne Feinstein
Marvin Schulman
Congressman Anthony Beilenson
Susan Little
Congresswoman Jane Harman
Ron Stone
Congressman Henry Waxman
Jay Babcock

Senator Robert G. Beverly
Thomas R. Martin
Senator Tom Hayden
Laura Cohen
Senator Herschel Rosenthal
Charles Harder
Senator Diane Watson
Anne Post
Assemblymember Debra Bowen
Steven Gray-Barkan
Assemblymember Terry Friedman
Laura Fay
Matthew LeVeque

Supervisor Deane Dana, *Los Angeles County*
Mitch Maricich
Supervisor Edmund D. Edelman, *Los Angeles County*
Don Wallace
Jennifer Roth
Mayor Judy Abdo, *Santa Monica*
Craig A. Perkins
Mayor Susan Brooks, *Rancho Palos Verdes*
Robert Katherman
Councilmember Ruth Galanter, *Los Angeles*
Lillian Kawasaki, *Department of Environmental Affairs*
Councilmember Ruth Gralow, *Palos Verdes Estates*
Councilmember Carl Jacobson, *El Segundo*
Neil C. Miller, *Manhattan Beach*
David Ludwig
Mayor Brad Parton, *Redondo Beach*
Councilmember Robert Pinzler
Mayor Carolyn Van Horn, *Malibu*
Councilmember Walter Keller
Mayor Albert Wiemans, *Hermosa Beach*
Etta Simpson
Councilmember Mark Wirth, *Torrance*
Mayor Katy Geissert

Gary Matlock, Ph.D., *National Marine Fisheries Service*
Mark Helvey
Robert Hoffman
Harry Seraydarian, *Environmental Protection Agency, Region 9*
Janet Hashimoto

John Caffrey, Chair, *State Water Resources Control Board*
David Cohen, Ph.D.
Molly Joel Coye, M.D., M.P.H., *California Department of Health Services*
Michael Kiado
Boyd Gibbons, *California Department of Fish and Game*
Don Lollock
Madelyn Glickfeld, Commissioner, *California Coastal Commission*
Bill Allayaud
Peter Grenell, *State Coastal Conservancy*
Reed Holderman
Charles Vernon, Board Member, *Los Angeles Regional Water Quality Control Board*
Robert P. Ghirelli, D.Env.

Jim Fawcett, Ph.D., *Los Angeles County Department of Beaches & Harbors*
Gregory Woodell
Robert Horii, *City of Los Angeles Bureau of Engineering*
Philip Richardson
Jack Petralia, *Los Angeles County Department of Health Services*
Paul Papanek, M.D., M.P.H.
T.A. Tidemanson, *Los Angeles County Department of Public Works*
Jim Noyes
Rod Kubomoto

Delwin Biagi, *City of Los Angeles Bureau of Sanitation*
Kenneth Ludwig
Charles Carry, *Los Angeles County Sanitation Districts*
James Stahl
Robert Horvath
Ane Deister, *Las Virgenes Municipal Water District*
Jim Colbaugh
Michael Hertel, Ph.D., *Southern California Edison*
David W. Kay, Ph.D.
Edward Karapetian, *Los Angeles Department of Water & Power*
Rod Spackman, *The Chevron Companies, El Segundo Refinery*

Dorothy Green, *Heal the Bay*
Mark Gold
Felicia Marcus, *League of Conservation Voters*
Moe Stavnezer
Mel Nutter, *League for Coastal Protection*
Sara Wan
Joel Reynolds, *Natural Resources Defense Council*
Everett DeLano
Jan Salvay, *Sierra Club Angeles Chapter*
Liz Merry
Marvin E. Smith, *Los Angeles Rod and Reel*
Marvin Scheinbaum
Lisa Weil, *American Oceans Campaign*
Iylene Weiss, *Ballona Lagoon Marine Preserve*
Pat McGuire

Susan McCabe, Chair, *Public Advisory Committee*
Evan Nossoff, Vice-Chair
Craig J. Wilson, *State Water Resources Control Board, Chair, Technical Advisory Committee*
Alan Mearns, Ph.D., *National Oceanic and Atmospheric Administration, TAC Vice-Chair*

Catherine Tyrrell, Director
Rainer Hoenicke, Ph.D., Chief Scientist
Marianne Yamaguchi, Environmental Planning Manager
Karen Caesar, Information Officer
Mary Sue Maurer, Government Relations
Stephanie McDonald, Environmental Engineering Specialist
Paul Michel, Environmental Program Analyst
Gwendolyn Monroe, Management Services Technician
Robyn L. Shipley, Secretary
Patricia Velez, Associate Marine Biologist
Guang-yu Wang, Ph.D., Environmental Specialist
Audrey Whisiker, Graphic Artist

Santa Monica
BAY
Restoration
PROJECT

Santa Monica Bay Restoration Project
101 Centre Plaza Drive
Monterey Park, California 91754
(213) 266-7516

This report has been funded wholly or in part by the United States Environmental Protection Agency using Clean Water Act Section 320 grant funds under Assistance Agreement CE009489-01-4 to the State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the U. S. EPA, the State Water Resources Control Board, or of any other funding organization, nor does mention of trade names or commercial products constitute endorsment or recommendation for use

Printed on Recycled Paper