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MODIFICATION OF SECONDARY TREATMENT REQUIREMENTS FOR DISCHARGES INTO MARINE WATERS

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HEARINGS BEFORE THE SUBCOMMITTEE ON WATER RESOURCES OF THE COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION HOUSE OF REPRESENTATIVES NINETY-FIFTH CONGRESS

SECOND SESSION

MAY 24 AND 25, 1978

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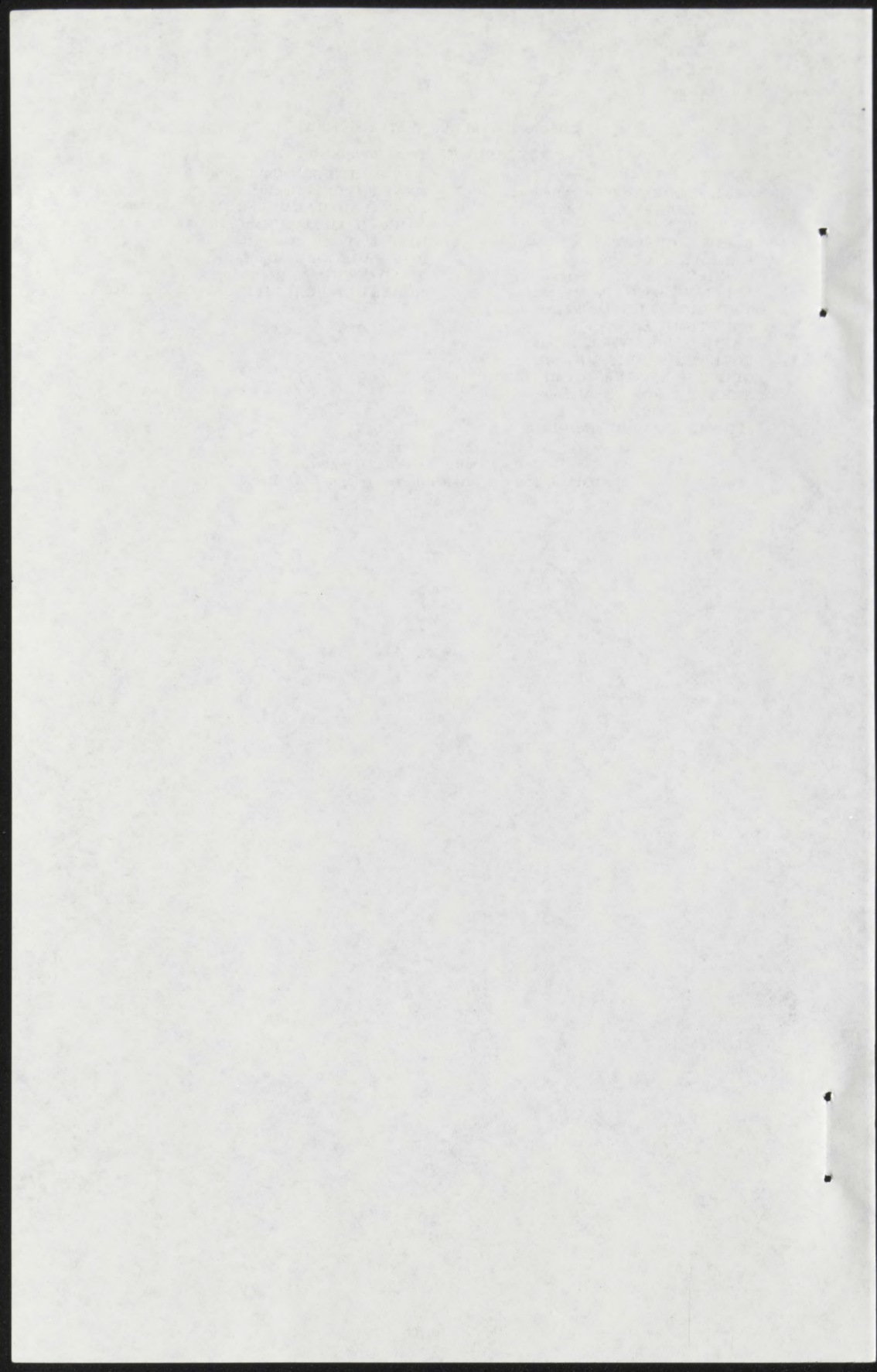
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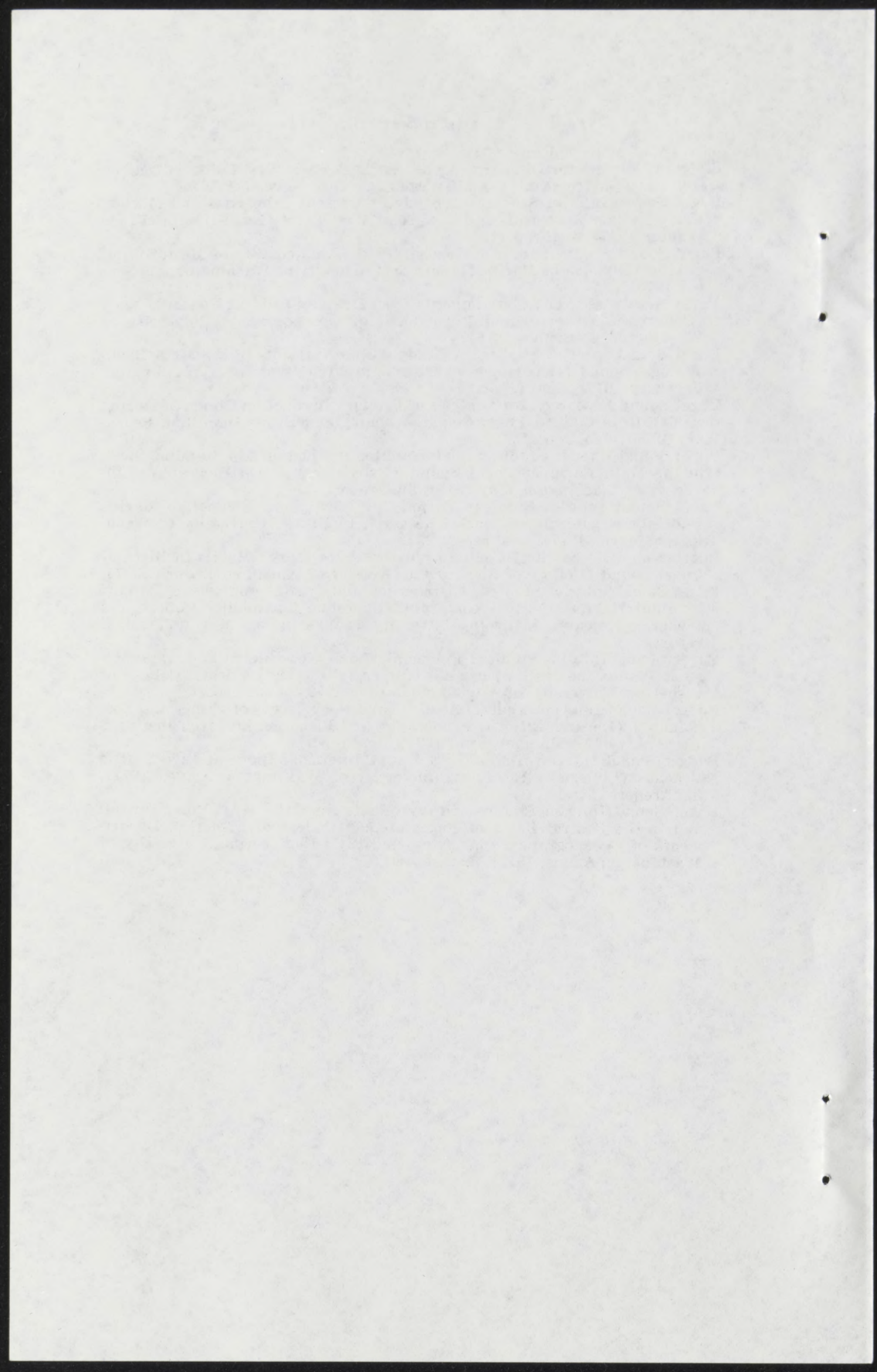
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- Puget Sound Interim Studies: A Study of Current Properties and Mixing, Using Drogue Movements Observed Near West Point (Evan-Hamilton Inc., October 1975), final report.
- Puget Sound Studies: Interim Reports for the Municipality of Metropolitan Seattle (Division of Marine Resources, University of Washington, September 1976).
- Trace Metal Research: Contaminants from Dredge Spoils off Fourmile Rock (College of Fisheries and Department of Oceanography, University of Washington, December 1976).
- Puget Sound Interim Studies: A Study of the Nutrients in the Main Basin of Puget Sound (Department of Oceanography, University of Washington, February 1977), final report.
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- Pudget Sound Interim Studies: Acoustic and Net Surveys of Fishes and Zooplankton (Department of Oceanography and Fisheries Research Institute, University of Washington, June 1977), final report.
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MODIFICATION OF SECONDARY TREATMENT REQUIREMENTS FOR DISCHARGES INTO MARINE WATERS

WEDNESDAY, MAY 24, 1978

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON WATER RESOURCES OF THE
COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:02 a.m. in room 2167, Rayburn House Office Building, Hon. Ray Roberts (chairman of the subcommittee) presiding.

Mr. ROBERTS. The Subcommittee on Water Resources will come to order.

This morning, we being 2 days of hearings on the scientific and technological consideration of modifying the secondary treatment requirement for municipalities which discharge into marine waters.

Last December, Congress amended the Federal Water Pollution Control Act to give the Administrator of the Environmental Protection Agency the authority to grant waivers of a secondary treatment requirement under certain circumstances.

EPA has moved promptly to develop proposed regulations. It is clear that the waivers will require judgments based on scientific knowledge.

Therefore, it is vital that EPA's judgments reflect the weight of scientific knowledge on matters such as the true impacts and advisability of requiring secondary treatment for municipal ocean discharges, the best type of treatment for such discharges, and the availability of scientific methodology for predicting the impacts of an existing discharge from an as yet unconstructed outfall pipe.

The purpose of these hearings is to hear from scientific experts. This morning, we are pleased to welcome before the subcommittee three gentlemen who are acknowledged experts in scientific and technological matters relating to the impacts of secondary treatment on ocean waters.

Gentlemen, I want you to know that we greatly appreciated the fact that you have traveled great distances in order to be with us and give us the knowledge that we need so badly.

It is my pleasure now to recognize the distinguished chairman of the full committee, the gentleman from California, Mr. Johnson.

The CHAIRMAN. Mr. Chairman, I want to say to you and Mr. Edelman and Ms. Kovalic and the minority that I appreciate very much the work they have done so far in following the regulations that have been published in the Federal Register dealing with this subject matter. I know that they are going to do a very fine job here assisting you in perfecting the record to show the House's position and the position of the House conferees when we were in conference with the Senate.

This is a very important matter. I am sure that they have witnesses here with the necessary expertise, and I want to welcome all of those who have come here from various parts of the Nation to testify.

I know that you and your subcommittee are going to do a very fine job in perfecting a record, with the help of our staff, both majority and minority, in working this out.

For a long time, I've been concerned that we were on a path of treatment for treatment's sake, especially when it came to requiring all ocean-discharging municipalities to install secondary treatment.

Last year, in considering major amendments to the Federal Water Pollution Control Act, Congress accepted language which provides a mechanism for these cities to apply for a waiver of the secondary treatment requirement. For the first time, EPA and the cities have a clear opportunity to focus on whether the environmental benefits of secondary treatment are offset by the costs.

It is important that any regulations implementing this waiver be fair and reasonable, reflecting scientific knowledge and expertise.

I'll be listening with a great deal of interest to the testimony of our learned witnesses. Each gentleman has a great deal of knowledge in matters concerning the ocean and wastewater treatment. We need the benefit of their expertise.

I am not going to take any more time, Mr. Chairman. I hope that you do go into this very thoroughly while we have the visiting experts here, as well as the experts of our committee and staff to develop a fine record.

Mr. ROBERTS. I thank the distinguished chairman.

All members will have permission to file statements in this record.

We have a registered quorum call. Therefore, let us recess. The subcommittee will stand in recess for 15 minutes.

[Brief recess.]

Mr. ROBERTS. The subcommittee will resume its sitting.

Did the gentleman from California, Mr. Anderson, have a statement?

Mr. ANDERSON. Thank you, Mr. Chairman. I do not have a formal statement, but I certainly want to welcome our distinguished guests and technical experts to the committee.

This is also a good time, I think, to thank you, Mr. Chairman, and our good friend and California colleague, Mr. Johnson, our distinguished full committee chairman, for your untiring efforts to arrive at a realistic solution to this issue that has such far-reaching implications to my southern California district.

As the chairman has indicated, this is a very complex issue, but I think that our excellent committee staff, both of the majority and the minority, can work both with the agency and these experts testifying today and tomorrow, to arrive at a workable solution.

This was my position as a three-time conferee on the 1977 amendments and as a member of this committee when we wrote the original act in 1972.

As one of the managers of the conference report last December, I made my thoughts on this issue known in a floor statement and colloquy with our conference committee chairman, Mr. Roberts. I will not go any further today than to state that those words stated then reflect my views today.

Mr. Chairman, I ask unanimous consent to include in this hearing record that floor statement.

Mr. ROBERTS. Without objection.

Mr. ANDERSON. Thank you, Mr. Chairman.

[The following was received for the record:]

[From the Congressional Record, December 15, 1977]

IN THE HOUSE OF REPRESENTATIVES

Mr. ROBERTS. Mr. Speaker, I yield 2 minutes to the distinguished gentleman from California (Mr. Anderson), one of the conferees.

(Mr. Anderson of California asked and was given permission to revise and extend his remarks.)

Mr. ANDERSON of California. Mr. Speaker, I rise in support of the conference report on H.R. 3099, the Clean Water Act of 1977.

In want to give my congratulations to my good friend and the chairman of this committee, Congressman Bizz Johnson, of California, whose able leadership was critical to the development of this legislation. Also, I compliment my good friend Ray Roberts, of Texas, chairman of the Subcommittee on Water Resources. It is this subcommittee which laid the groundwork for these necessary amendments.

The bipartisan support of Congressman Bill Harsha, of Ohio, and my California colleague Don Clausen, and their valuable input throughout the long proceedings were also necessary ingredients to this legislation.

There are many significant provisions in H.R. 3199. I would like to comment on just a few of them now.

* * * * *

DEEP OCEAN DISCHARGE WAIVER

A major provision of this bill is section 44 which would permit municipalities that discharge into deep ocean waters be granted a waiver from the secondary treatment requirement.

There is some confusion as to the meaning of several of the specific terms used in this section. For example, the terms "applicable water quality standards," and "balanced, indigenous population."

One of the conditions of the waiver is that there is an "applicable water quality standard" specific to the pollutant for which the modification is requested.

The law requires States to develop water quality standards according to criteria developed by the Environmental Protection Agency. "Applicable water quality standards" for the purposes of this section are approved State water quality standards. In the case of California, a revision of the State ocean plan would meet this requirement.

The other matter, that needs clarification is the concentration of dissolved oxygen, which is one of the elements controlled by secondary treatment. Dissolved oxygen is measured by biochemical oxygen demand (BOD). Because of the special characteristics of ocean waters, there is no problem of oxygen depletion. BOD is not a relevant pollutant for marine discharges and it is unreasonable to develop a water quality standard for dissolved oxygen.

Therefore, under this provision, a locality could get a modification of the BOD requirement, but a State is not required to go through the meaningless exercise of developing an "applicable water quality standard" for dissolved oxygen for marine waters.

Another waiver condition is that the modified requirement will not interfere with attaining the water quality which assures protection of public water supplies and the protection and propagation of a "balanced indigenous population of shellfish, fish, and wildlife." This term cannot be defined in the absence of a good deal of additional scientific information which may not be readily available.

The House and Senate conferees discussed the meaning of the term "indigenous." It is clear that there was confusion as to how it would be applied to the oceans. An indigenous population is one produced, growing, or living naturally in a particular region or environment and reflecting a healthy population given the presence of man. Emphasis should be placed on maintaining the current indigenous population of shellfish, fish, and wildlife. It is completely meaningless and unreasonable to assess this condition according to any other time period—particularly a historical period such as pre-Columbian times. This term is not to be interpreted in such a manner as to negate the clear congressional intent of this section that waivers be granted.

At the time the waiver decision is made, it is quite possible that neither the State nor EPA will be able to determine the potential long-term effects of the approved level of treatment under the waiver provision. Therefore, the Administrator should make his decision by focusing on the effects projected within the first 5 years. During this period EPA should fund additional studies which will measure the effect.

The decision to grant a waiver will be subject to reassessment at the end of each 5-year period. Over time both the EPA and the locality will be in a better position to evaluate the long-term impacts with the information developed by EPA and by the locality under the required system for monitoring the impact of this discharge on a representative sample of aquatic biota, to the extent practicable. Construction grant money under title II of the act can be used to establish such a monitoring system. Where requested by the locality or State, EPA is to give the locality technical assistance in the design, installation, and operation of such a system.

The requirement under the new subsection 301(h) (7) set forth in section 44 also requires clarification. This provision provides that there will be no new or substantially increased discharges above the volume specified in the permit from the treatment works getting a modification. This provision does not mean that treatment works applying for a modification are to be restricted to the current volume or capacity of their plants. In the interest of continuing the policy of encouraging regionalization, these treatment works may increase their discharges over time, as capacity permits, as long as the pollutant controls are maintained. The volume of discharge may be revised, just as any other permit condition may be altered, as warranted by changes in circumstances.

EPA is to carry out this provision in such a way that burdensome requirements are not placed on municipalities applying for such waivers. The Administrator is to issue guidelines promptly to carry out the intent of the law. Those dischargers which contemplate being able to meet the criteria established in the law will have 9 months either from the date of enactment of this section or 9 months from the date effluent guidelines are promulgated. The Administrator is to make a decision promptly on the evidence presented to him and not permit protracted deliberations. In the interim, it is the responsibility of the Administrator to discontinue any legal proceedings or enforcement actions which may have been initiated prior to the enactment of this provision.

Since this waiver is granted as part of a municipal permit under section 402 of the act, consistent with the provisions of that section, a State with an authorized permit program may grant views under this section.

Included among the discharges eligible for a waiver under this section are the cities of Los Angeles and Avalon, Calif. The following is a listing of other eligible communities:

LIST OF OCEAN OUTFALLS TO TERRITORIAL SEAS AND BEYOND

Crescent City, CA.
Westport, CA.
Mendocino, CA.
Mendocino, No. 2, CA.
Bolinas, CA.
San Francisco (Richmond Sunset), CA.
North San Mateo, CA.

Pacifica, CA.
 Montaro, CA.
 Granada, CA.
 Half Moon Bay, CA.
 Davenport, CA.
 Santa Cruz, CA.
 East Cliff, CA.
 Aptor, CA.
 Watsonville, CA.
 Marina, CA.
 Seaside, CA.
 Pacific Grove, CA.
 Monterey, CA.
 Carmel, CA.
 San Simeon, CA.
 Morro Bay, CA.
 Shell Beach, CA.
 Pismo Beach, CA.
 Avila, CA.
 South San Luis, CA.
 Goleta, CA.
 Santa Barbara, CA.
 Montecito, CA.
 Summerland, CA.
 Carpinteria, CA.
 San Buenaventura, CA.
 Oxnard, CA.
 Port Hueneme, CA.
 City of Los Angeles, CA.
 City of Los Angeles (Terminal Island), CA.
 Avalon, CA.
 Sunset Beach, CA.
 Orange County Sanitation District, CA.
 Laguna Beach, CA.
 South Laguna, CA.
 Dana Point, CA.
 San Clemente, CA.
 Oceanside, CA.
 Encinitas, CA.
 Cardiff, CA.
 San Diego, CA.
 Carlsbad-Buena Vista, CA.

I wish to emphasize that I do associate myself with the remarks of my colleagues Mr. Johnson of California, and Mr. Roberts, of Texas, in regard to this provision. I would like to ask a question of Mr. Roberts concerning this provision. "Mr. Roberts, do you agree that the city of Los Angeles and Avalon, Calif., are intended to qualify for a waiver under section 44?"

Mr. ROBERTS. Yes, it is contemplated that these communities qualify for a waiver of the secondary treatment requirement under section 44.

Mr. ANDERSON of California. Thank you, Mr. Roberts.

Mr. DON H. CLAUSEN. Mr. Speaker, will the gentleman yield?

Mr. ANDERSON of California. I yield to the gentleman from California.

Mr. DON H. CLAUSEN. I thank the gentleman for yielding.

The answer to that is yes, but it does not only apply to southern California; it also has application to the entire west coast.

Mr. ROBERTS. The gentleman is correct.

Mr. ANDERSON of California. It applies to the coast of California, Hawaii, Puerto Rico, American Samoa, the Virgin Islands, and estuaries and waters such as Cook Inlet. But I wanted to make sure that the cities of Los Angeles and Avalon were specifically included, also basically the southern coast of California.

Mr. ROBERTS. That is correct.

* * * * *

Mr. ANDERSON. And lastly, before the witnesses testify, I would like to refresh my colleagues' memory of a colloquy last September between myself and EPA Administrator Costle and his assistant, Tom Jorling.

I asked who might stand to qualify under the language of the Senate amendment. And Mr. Jorling responded: "That does qualify, in a sense, California and the other areas in southern California."

Mr. Costle then added: "Particularly Los Angeles."

Then, Mr. Jorling: "We think, however, it is much too loosely written and potentially qualifies areas * * * which should not receive the relief that is desired."

Mr. Chairman, even though this exact Senate language was adopted by we conferees, we are now hearing that the agency's proposed rules are written in such a way so as to exclude any waivers from being granted.

I find this curious when both Mr. Costle and Mr. Jorling told me the language was too loose and would open up the door for waivers in unintended areas.

This is just an observation, Mr. Chairman, and thank you for yielding.

Mr. ROBERTS. I thank the gentleman from California.

Our first witness today is Dr. Erman Pearson. Dr. Pearson is a professor of sanitary engineering at the University of California.

He is an internationally-known expert on designing ocean outfalls and assessing their impact on the ocean. While I am talking, I might as well make a bad pun and say we frequently have a wide world of difference on subject matter, but we have witnesses from a wide world.

Dr. Pearson just flew from Sweden. Dr. Craven flew from Hawaii. So we have about half of the world covered here today. They just got in, and we are delighted to have all of you.

Dr. Pearson, I understand that you are a guest professor over at the Royal Institute in Sweden, and we are awfully pleased to have you come here today.

If you will, proceed with your testimony. Then we will have questioning of the individuals as we go along.

TESTIMONY OF DR. ERMAN PEARSON, PROFESSOR OF SANITARY ENGINEERING, UNIVERSITY OF CALIFORNIA, BERKLEY; CURRENTLY GUEST PROFESSOR AT ROYAL INSTITUTE OF TECHNOLOGY, STOCKHOLM, SWEDEN

Dr. PEARSON. Thank you very much, Mr. Chairman, and ladies and gentlemen. I am very pleased to be invited to be here. Even though it is a little bit of stress to make the trip, I am pleased to do it. I can recall, I think about 4 years ago, I made a similar presentation before a House committee—I think it was Oceans and Atmosphere at that time—about this general subject, and I prepared a couple statements that are in the record. That was in 1974. I do not remember the exact hearings and documents that came out of that, but it was well recorded.

My position today can be referred to my statement of 4 years ago, only I would say today, my comments just reinforce, with more fact

than was available then, my general view at that time. That is in the record. I do not have a prepared statement, but that is in the record, and my comments today will add to that, Mr. Chairman.

Mr. ROBERTS. Without objection, we will get copies of that and put it in the record. Thank you, sir.

[The following was received for the record:]

STATEMENT OF DR. ERMAN A. PEARSON, PROFESSOR OF SANITARY ENGINEERING,
UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF.

INTRODUCTION

Mr. Chairman and members of the Subcommittee on Oceans and Atmosphere, it is a pleasure to appear before you to discuss problems of ocean pollution and coastal waste management. I am Dr. Erman A. Pearson, Professor and Head of Sanitary Engineering at the University of California at Berkeley where I have been engaged for over two decades in teaching, research and professional engineering practice devoted in major part to marine disposal problems. Interestingly, the position I occupy is concerned with the engineering of water and wastewater management systems for the protection of public health and environmental quality and has been in existence for over seventy years. I come before you as a "practicing ecologist" with an extensive background of experience with environmental quality and not as a representative of the "instant ecologist" fraternity, many of whom have just discovered the environment with accompanying cries of alarm. I am deeply concerned about the quality of our environment, and I have dedicated my professional career in efforts to achieve the maximum environmental quality improvement for every dollar spent on its behalf. It is with this continuing objective that I appear before you today.

A few words about my background. I was raised in the water business, my parents were owners of a private water supply utility. I am a graduate of the University of Washington with a doctorate in sanitary engineering from the Massachusetts Institute of Technology in 1949. In the mid 1950's I was appointed Chairman of a Marine Research Consulting Board to the State of California Water Pollution Control Board where we advised on the appropriate character and conduct of coastal water quality studies to help guide the State in its coastal water quality control program. I organized the first International Conference on Waste Disposal in the Marine Environment which was held at UC Berkeley in July, 1959, and the Proceedings of the Conference were printed and distributed in book form. I have served as a member of the Governor's, and later the Legislature's Advisory Commission on Marine and Coastal Resources throughout its existence (8 years). I am a member of the National Academy of Engineering's Marine Board. I have served as Co-Chairman of a joint National Academy of Sciences/National Academy of Engineering (NAS/NAE) Workshop on Waste Management Concepts for the Coastal Zone—"Requirements for Research and Investigation"—which resulted in a NAS/NAE publication in 1970. I have recently served as Area Chairman of the Input Panel for the NAS sponsored workshop on the Input Fate and Effects of Petroleum in the Marine Environment held in Airlie, Virginia, 21-25 May, 1973.

During the past twenty-odd years I have been actively engaged as a consulting engineer and/or as a member of boards of consultants for many coastal waste disposal projects. In the United States I have advised on waste management systems for the Cities of Los Angeles, San Diego, Honolulu, San Francisco Bay Area, and New York. I have also been a consultant on marine waste disposal management in Accra; Ghana; Bilbao, Spain; Bridgetown, Barbados; Cork and Waterford, Ireland; Durban, South Africa; Göteborg, Sweden; Istanbul, Turkey; Maracaibo, Venezuela; and Rio de Janeiro, Brazil among others. I also have had the good fortune to spend a sabbatical year in Sweden in 1970-71 serving jointly as a Visiting Professor at the Royal Institute of Technology, Stockholm, and as an Adviser to the Swedish Environmental Protection Board (Statens Naturvårdsverk). As you may observe, my experience has covered a broad scope of environmental quality activities ranging from teaching and research to engineering practice in system design.

STATEMENT OBJECTIVES

This presentation is directed toward three main objectives which can be summarized as follows:

1. To report that although many questions remain unanswered and much continued study is needed, in urban areas such as southern California where well-engineered marine wastewater disposal systems have been constructed, the condition of the nearshore ocean waters is generally very good as shown by the findings of a recent, locally funded, multi-million dollar study of the coastal ecology.

2. To suggest that this Subcommittee review carefully and cautiously, requests for the complete banning of treated wastewater discharges (including sludges) to the ocean or blanket requirements regarding the degree of treatment of all municipal and industrial wastewater.

3. To recommend strongly that this Subcommittee provide leadership and guidance to appropriate governmental agencies, including the Environmental Protection Agency, concerning the development of realistic objectives and requirements for wastewater treatment and disposal considering both wastewater characteristics as well as disposal locations and requirements.

SOUTHERN CALIFORNIA CONDITIONS

Marine municipal waste disposal practices today in the Southern California Bight (essentially from Point Conception south to the Mexican border) consist mainly of mechanical (primary) treatment (with sludge digestion) with the liquid effluent discharged through submarine pipelines (from 1 to 5 miles offshore) with long (thousands of feet) multi-port outlets (diffusers) at depths of about 200 feet. These dispersion systems are designed to achieve an average initial dilution (at the source or outlet) of in excess of 100 to 1 (100 parts sea water to 1 part wastewater).

Concern about the effect of these wastewater discharges upon the local ecology brought about the formation of the Southern California Coastal Water Research Project (SCCWRP) in 1969 as a local government agency organized by a joint power agreement between the five government agencies responsible for managing most of the municipal wastewater (1 billion gallons per day) discharge into the ocean off southern California.

The agencies are Ventura County, the City of San Diego, the City of Los Angeles, the County Sanitation District of Orange County, and the County Sanitation District of Los Angeles County.

The agencies entered into the joint agreement since it was believed that their previous research programs would benefit from the addition of a project with regionwide focus.

From the outset, control of the \$1.1 million program was delegated to a commission of local civic leaders and elected officials in order to reflect—in an unbiased manner—the current public interest in environmental quality and to establish an atmosphere free from partisan pressures. This arrangement has given the project freedom from control by other agencies and freedom from political pressure fostering a broad and balanced viewpoint.

The basic goal of the SCCWRP undertaking is to increase the understanding of the ecology of the coastal waters off southern California and to analyze the effects of man's activities (especially municipal wastewater discharge) on the marine environment.

Overseeing the work is a consulting board of experts headed by Professor John D. Isaacs, Scripps Institution of Oceanography, Chairman, and Members, Richard K. C. Lee, M.D., former Director of Public Health for the State of Hawaii, Professor Erman A. Pearson, Sc.D., University of California, Berkeley, Professor Donald W. Pritchard, Ph.D., Director of Chesapeake Bay Institute and John W. Ryther, Ph.D., Woods Hole Oceanographic Institution. The Project Manager is George E. Hlavka, Ph.D.

The SCCWRP has just recently released a 531-page report which is based upon three years research which states in part that 'the health of southern California coastal waters and inhabitants are such that there is little cause for serious concern.

In the interest of brevity, the following specific quotations have been abstracted from the Conclusions and Recommendations (Chapter 12) of the report with respect to specific waste constituents and their implications for water quality management.

(a) *Plant Nutrients*.—There is now no justification for altering present treatment and discharge practice with regard to the gross plant nutrients introduced into southern California waters.

(b) *Particulate Material*.—Because of the generally minor and reversible nature of the effects and the uncertainty as to the actual consequences of the most well-intentioned corrective actions, there is presently no justification for any major alteration of waste management or discharge practice from the effects of particulate materials. There is need for further study of the distribution of potentially irritating substances, the nature and causes of fin-erosion disease, benthic community alterations, and possible secondary effects of wastewaters on kelp.

(c) *Floatable Material*.—The present practice of wastewater treatment and discharge should be reviewed and modified to minimize the discharge of all types of floatable materials.

Further studies on floatable materials associated with wastewater discharge are necessary.

(d) *Microorganisms*.—Present southern California practice of wastewater discharge and the achievable bacteriological standards for bathing waters more than adequately protect those using southern California coastal waters for water contact activities. The present established practices and standards for shellfish sanitation control are adequate to protect the public and the utilization of this resource. Their application and enforcement should be continued.

With the exception of further control of the discharge of floatable materials and their associated sewage microorganisms, there is no basis for alterations of present southern California waste discharge practice for reasons of bacterial and viral infection or hazard or resource damage.

Mexican practice of sewage discharge should receive further study.

(e) *Trace Elements*.—There is no substantive evidence that would support major changes in present wastewater processing and discharge practice for reasons of its trace element content. Nevertheless, improved control of the discharge of highly toxic metals is a prudent and meaningful step in wastewater management.

Inputs of trace elements from direct industrial discharge, ship antifouling treatment, dredge spoil, runoff, aerial fallout, advection and other sources should be better quantified.

(f) *Trace Organics and Pesticides*.—There is ample evidence to require the elimination of chlorinated hydrocarbons and other persistent organics from wastewater to lowest practical attainable levels. Strict control at the source is strongly recommended.

The thoughtful monitoring of effluents and the organisms of southern California for chlorinated organic material, other halogenated compounds and other organics is essential, and presently unsuspected substances must be considered in an active program.

(g) *Summary*.—1. The application of inland wastewater disposal policies and practices to marine waste disposal, such as in the Southern California Bight, is technically unsound. For example, typical inland requirements for removal of biochemical oxygen demand, suspended solids, and nutrients from municipal wastewaters have little technical justification or relevance to marine ecological problems.

2. To the best of our knowledge no potential effects other than those indicated herein will require major investigation.

3. Similarly, no substantial modification of present wastewater disposal practices, other than those recommended herein, is justified at present. However, the investigations of the specific problem areas as recommended may indicate the desirability of future additional modifications in wastewater disposal practice.

4. Routine monitoring and competent investigations of specific problems should continue, to determine man's general effects (including those of wastewater discharges) on the environment of the Southern California Bight.

Those interested in the detailed findings of this investigation are referred to the entire report including its 120 specific findings and the full Chapter 12 on Conclusions and Recommendations.

HAZARDS OF COMPLETE BANS ON BLANKET REQUIREMENTS

It appears popular today to yield to the clarion call for "no waste discharge." It is not exactly clear what such terminology means but it appears likely that such a goal will not be attained as long as man inhabits the earth. Nonetheless,

the prime objective of waste management should be to limit the discharge of waste materials so that the minimum adverse ecological effects occur; and, wherever possible, the system design should produce beneficial environmental effects. All too often the latter has been neglected as a real possibility. It must be recognized that decisions taken to ban the disposal of waste material to a particular sink, such as the ocean, generally results in the transfer of the waste, possibly with a change in character, to one of the two remaining ultimate sinks—to the land or to the atmosphere.

Let us examine briefly the likely impact of a complete ban on the discharge of digested sludge (treatment process underflow) to all water bodies including the ocean. A ban on the disposal of sludge to inland rivers and lakes used for domestic water supply appears to be sound and logical. However, the extension of such a policy to the oceans does not appear to be logical. Many of those advocating the ban on digested sludge disposal to the ocean advocate strongly the recovery of such materials for application to agricultural land as a soil conditioner. This is done to make use of the humus and nutrient content of the digested sludge. Yet, one of the major objections to ocean disposal of such materials is the trace toxic substance content (largely trace metals) of the sludge, and the entrance and possible concentration of these materials in the food chain of the ocean. If this is a legitimate concern about ocean disposal of municipal sewage sludge, what should be the concern about agricultural or land application of these materials. In my view, following similar logic the concern should be greater about land disposal. Why? Studies of digested sludge discharge to the ocean through well-designed systems, such as for the City of Los Angeles (a 7 mile 290 foot deep outfall), indicate that very little sludge solids are found near the outfall site. Most of the solids are very fine particles in the micron size range and are mixed and transported over large distances. These solids settle slowly over large areas—theoretically and ultimately over a major fraction of the ocean bottom. This area can be expected to be a substantial fraction of the entire land surface; hence, the concentration of sludge solids (grams/meter²) can be expected to be very low. This neglects the continuous covering of these solids by the normal oceanic sedimentation processes of which the sewage sludge component is only a very minor part. In time as the result of sediment deposition, a substantial portion of the sludge solids are removed from contact with the water, biota, and ultimately, man. One can therefore hypothesize that the ecological effects would be very minor.

What happens if sludge disposal is practiced on agricultural land as advocated strongly by the "organic farmer?" If the sludge contains appreciable toxicants, these materials are concentrated in the surface mantle to a degree far greater than in the ocean. This is due to the fact that the mass rate of application to land surfaces (grams solids/meters²-year) is much greater than to the ocean because of the very limited land area for agricultural application of sludge solids—at least compared to the distribution on the ocean floor. Also agricultural tillage practice retains the solids and toxicants (if any) in the surface soil mantle where it has more direct contact with plants, animals, and ultimately man, than in the ocean. Thus, which disposal method has least cost and minimal ecological consequences and health risks? I contend that well-engineered digested sewage sludge solids disposal to the ocean, including effective initial dispersion of the solids has less ecological consequences and health risks than disposal on land. From an ecological and cost standpoint, incineration and disposal of a fraction of the problem to the atmosphere has not been considered and it isn't considered seriously in California.

Specification of a blanket waste treatment method policy for all coastal waste dischargers poses a similar dilemma in achieving optimum benefits for each dollar spent for ecological improvement. The recent EPA requirement of secondary treatment for all waste discharges whether it be to the open ocean or Podunk Creek poses real cost-consequence problems. As mentioned previously, essentially all of the major Southern California waste dischargers employ today only primary treatment with effective long deep outfall dispersion systems. Secondary treatment is defined by EPA as 85 percent removal of biochemical oxygen demand (BOD) or 30 mg/l of BOD and suspended solids (SS) in the effluent, whichever is more restrictive. It is recognized that secondary treatment may also increase slightly the removal of heavy metals and toxicants over that removed by primary treatment; however, the increased removal is minor and the cost is great. Also, secondary treatment generally doubles the actual unit cost (\$/million gallons treated) of primary treatment, and what are the benefits?

As has been demonstrated in Southern California practice, BOD (oxygen demand) and SS (suspended solids) concentrations are not problems of consequence in well-designed marine municipal waste disposal systems. This stems from the fact that open ocean disposal accomplishes high dilution of the waste with ocean water-dilution in excess of 100 to 1. This dilution results in concentrations of the constituents in the ocean/wastewater mixture at the outlet equivalent to removals of about 99 percent by treatment without dilution. Regrettably, the secondary treatment, minimum dilution system was tried in California in the early 1950's, it failed, and the current reduced treatment-high dilution systems were designed, built and have operated most satisfactorily to date as documented by the SCCWRP report (3).

A possible and likely negative result from a blanket secondary treatment requirement for all coastal cities is its impact on the development of regional waste management systems. If all cities are required to have secondary treatment regardless of receiving water conditions (including effective dilution on water quality), what incentive will there be for a city located at the upstream (head) of an estuary to move their secondary treated waste discharge location downstream at added expense simply to increase the physical dilution of their waste? Or similarly, why should a city transport its waste out of the estuary, where dilution of the waste is minimal, to the open ocean where high dilutions are possible? With blanket treatment requirements there is no economic incentive for a city to transport its waste to areas of high dilution nor to join with other municipalities to accomplish the same objective. Instead the incentive is on "going it alone," applying secondary treatment at all locations where wastes are generated. There will be little if any effort devoted to the transport of wastes out of estuaries or areas of low dilution capabilities. Instead, we will overload and possibly destroy our estuaries before this error is realized or admitted. Historically, most of our severe water quality problems have occurred in estuaries rather than in the open ocean associated with well-engineered outfalls. Yet we seem to be committing ourselves to a policy that will destroy our estuaries before we seriously consider the real advantages of engineered treatment and ocean dispersion systems with accompanying high waste dilutions.

Another possible approach to increase the incentive for the development of regional systems in estuarine-coastal waste management is as follows. If secondary treatment is to be required for open coastal waste disposal systems with high dilutions (i.e., $>100:1$), then treatment markedly higher than secondary should be required for estuarine dischargers where physical dilutions are minimal—often in the range of 10 to 30:1. But what should that treatment be? Will the increase of BOD and SS removals from 85 to 95+ % solve the problem? But what if BOD and SS are not the critical estuarine problems? Moreover, it appears that BOD and SS are not the major problem in many estuaries, such as in San Francisco Bay today where BOD and Suspended Solids concentrations are of little consequence. Instead, toxicity and floatables appear to be major problems, and treatment requirements and the required funds should be directed to solving specific water quality problems—not just adding more and more classical treatment processes to increase removal of BOD and SS. Logically then, if secondary treatment is to be required for open ocean waste disposal systems, a higher level of treatment (and likely twice the cost of conventional secondary treatment) should be required for estuarine discharges. Are the costs of adding more and more sophisticated treatment processes for BOD and SS removal justified and are the benefits tangible? Based upon present information, this trend, though supported by some designers and equipment suppliers, may not improve significantly environmental quality, and its cost/effectiveness is very high. And significant improvement in environmental quality will not occur until such time as waste treatment policies, regulations, and designs are directed to specific water quality problems rather than by a "lumper" treatment method approach. It is recognized that the "lumper" approach of specifying traditional treatment method requirements "across the board" may appear to be equitable and easy to enforce. However, will it solve the real pollution problem? I fear that we will run out of funds for environmental improvement following this approach long before we resolve our important water quality problems.

Two additional points should be made regarding the uniform treatment method requirement approach.

Does it make much sense to require 85 percent removal of the BOD or whatever, from a 10,000 gallon per day flow—a few pounds per day at a cost per unit of flow, or per capita, several times that required for 85 percent removal from

a 100,000,000 gallon per day flow? In the latter instance the removal is measured in tens of tons per day.

Increasing reliance on sophisticated treatment processes without concern for terminal dilution for the treated waste stream in the environment places real protection of the environment in a precarious position. I have observed few, if any, treatment process systems that performed uniformly and continuously as predicted in design or that did not on occasion either fail or require shutdown for maintenance or other reasons. Without adequate terminal dilution for these periods of upset or decreased performance, what happens to the pollutant concentrations in the receiving waters? They increase markedly and of course additional stress is placed on the environment. With high terminal dilutions such as experienced with present day ocean disposal systems in California, this stress is markedly reduced.

DISCHARGE OF SEWAGE FROM SEA OUTFALLS

PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM HELD AT CHURCH HOUSE, LONDON,
27 AUGUST TO 2 SEPTEMBER 1974

* * * * *

Paper No. 40

CONCEPTUAL DESIGN OF MARINE WASTE DISPOSAL SYSTEMS

(Erman A. Pearson, *Professor of Sanitary Engineering, University of California, Berkeley*)

Increasing public concern about environmental quality coupled with limited factual information about waste discharge effects and a general lack of awareness of the objectives and performance of conventional waste treatment systems all are leading to increased confusion in the development of rational coastal waste management systems. There appears to be a general belief in the minds of the public, conservationists, and even some scientists and regulatory agencies, that all waste treatment systems accomplish the same objectives, that waste treatment is uniformly good depending only upon the degree of treatment, and the higher the degree of treatment for a given discharge location the better the results. Unfortunately, generalizations of the type indicated may lead to system designs that are inappropriate on a conceptual basis and that might result in irreparable ecological damage.

The estuaries and coastal regions of nations are the ultimate recipients of the major fraction of the conservative (non-decayable) waste materials discharged to the inland lakes and rivers directly connected to the sea. In addition there is a substantial additional waste load of both conservative and non-conservative pollutants discharged directly to the estuaries from the metropolitan areas located on the periphery of estuaries. Obviously the conservative pollutants as well as a fraction of the non-conservative pollutants reach the coastal area in a relatively short time. The fraction of non-conservative materials reaching the coast is determined by the waste residence time in the estuary (a function of discharge location, advective flow, mixing, and tidal exchange) and the decay rate of the pollutant.

Unfortunately, the subject of estuarine and marine waste disposal has not received as much attention as inland waste disposal practices and the advantages and disadvantages of traditional inland waste disposal practices in the marine area have not been elucidated clearly. Of the effort expended on estuarine problems, the major fraction has been devoted to physical-hydraulic aspects of the problem rather than to the bio-chemical aspects of pollutant decay and effects on the ecology of both conservative and non-conservative pollutants.

ESTUARY, BAY, OR OPEN COAST DISCHARGE DILEMMA

A major problem in coastal water quality management is determination of the appropriate degree of wastewater treatment and the preferred location of the treated wastewater discharge. Consider an estuary or bay with a significant number of municipal and industrial wastewater discharges located around the periphery of the water body. Historically, the general trend in wastewater management has been to invest heavily in treatment processes—frequently as much as can be financed, and to pay little attention to the location and type of

dispersion system for the treated effluent. In the past the choice has been between minimal treatment and primary, or primary and secondary (biological) treatment; however, in the U.S.A. today, the choice appears to be between secondary (the politically determined minimum treatment) and some form of advanced (tertiary) wastewater treatment (AWT).

The fundamental question remains, however: is it better to provide advanced (secondary) treatment and discharge the effluent directly to the estuary or bay, or is it preferable to employ a lesser degree of treatment (primary) and discharge the waste to a distant area that has high dilution capabilities (i.e. $\geq 100:1$)? The latter alternative would use the incremental cost between primary and secondary wastewater treatment to transport the effluent seaward, or to the open coast, to a disposal location less sensitive ecologically and where much greater volumes of diluting water are available.

Unfortunately, there appears to be a developing attitude of regulatory agencies, at least in the U.S.A., to favor increasing the degree of treatment and to give little if any consideration to the location of the ultimate discharge, the degree of initial as well as subsequent dilution of the waste, and the decay of the pollutants in the receiving water. This trend appears to be supported or encouraged by many if not most, of the consulting engineers. If the foregoing concept becomes established and widely used, there will be little if any economic or ecological incentive to use the incremental cost between various levels of treatment to transport the lesser treated effluent to a disposal site where there are maximum diluting capabilities for the effluent and/or where the effluent will have the least adverse effect on the ecology.

If one is concerned about pollutant concentrations in the environment and their effects, one must give serious consideration to determination of waste discharge locations where the residual pollutant concentration will have minimal ecological (including human) impact. To accomplish this, it should be obvious that quantitative information must be available on pollutant mass-emission rates and concentrations, on the efficacy of pollutant removal processes, and on the physical, chemical, and biological characteristics of alternative disposal sites. The practical facts are that such information is not generally available to permit rational assessment of alternative treatment and dilution combinations. However, this lack of such information in no way justifies the absence of rational qualitative assessment of the consequences and costs of the various alternatives.

The available initial dilution for treated municipal and industrial wastewaters located around the periphery of a bay or estuary and discharged directly thereto ranges from near zero at the head of a neutral estuary (advective flow ≈ 0) to about 20-30 for combined mid-bay or estuary discharges, to possibly as much as 30-50 for a well designed outfall discharge to a large bay. Obviously, the actual dilution of wastewaters in a given restricted body of water depends upon the waste flow rate, the advective flow, and effective tidal/turbulent exchange. For example, if all the estimated 1990 municipal and industrial wastewaters generated around the periphery of San Francisco Bay were collected and discharged in the Central Bay in front of the Golden Gate, the average dilution of the wastewaters would be in the order of only 30-40; and San Francisco Bay is a large estuary with appreciable advective flow (principally the Sacramento River) and tidal exchange.

However, disposal systems located along open coasts (such as along the California Coast including the San Francisco Bay Area) can be designed for essentially any likely magnitude of discharge (up to at least $2 \times 10^6 \text{ m}^3/\text{day}$) to achieve immediate initial dilutions in the order of 150-200. It should be noted that conventional secondary waste treatment systems (except for disinfection processes) achieve as a maximum, average pollutant removals of 90-95 percent (equivalent to dilutions of 10-20) and that primary treatment achieves as a maximum about 65 percent pollutant removal (equivalent to a dilution of 3). If one considers a terminal dilution of 150-200 with the primary treatment option and about 10 with the secondary system, the total equivalent dilution (removal plus terminal dilution) for the primary option is 450-600 compared to 100-200 for the secondary system. It should be obvious that the resultant effect on the receiving water will be less for the primary treatment (high terminal dilution) system than for the secondary treatment (low terminal dilution) alternative. The foregoing simplified comparison relates to pollutants subject to removal by the processes used. How about the possible effects from pollutants whose removal by the treatment processes used is minimal? Obviously, the high-dilution alternative provides the greatest degree of environmental protection (i.e. lowest pollutant concentrations).

ADVANTAGES OF COASTAL ALTERNATIVES

Consider comparison of a typical treatment-disposal system discharging to an estuary/bay with an open-coast treatment-disposal system using one level of treatment lower than that used for the estuary/bay system. For an equal total cost system, the incremental cost between the two levels of treatment can be used to construct an interceptor sewer to the open coast. In general (some exceptions) the coastal alternative produces the lower receiving-water pollutant concentration and hence the least ecological effects. Moreover, the coastal discharge location can be selected so that the area presumed to be affected to some degree is one of lesser ecological significance than would be found in the estuary/bay system.

TYPICAL ESTUARINE-COASTAL EXAMPLE

Figure 1 and Table 1 present an idealized but representative example of the possible choices in estuarine waste management with respect to disposal location, likely initial waste dilutions obtainable, and pollutant concentrations at each location dependent upon the degree of treatment employed. It is of interest to note that the average waste concentrations in the receiving water at the immediate point of discharge are lowest for the case with the least degree of treatment. Similarly, the degree of treatment (percentage removal) required at each of the discharge locations to produce the same pollutant concentration near the source is shown in the final line of Table 1. To achieve a pollutant concentration of $C_0/150$ in the receiving water requires no treatment at Location C (open ocean), 80 percent removal at B (mid-estuary), and 93.3 percent removal at A (landward end of estuary).

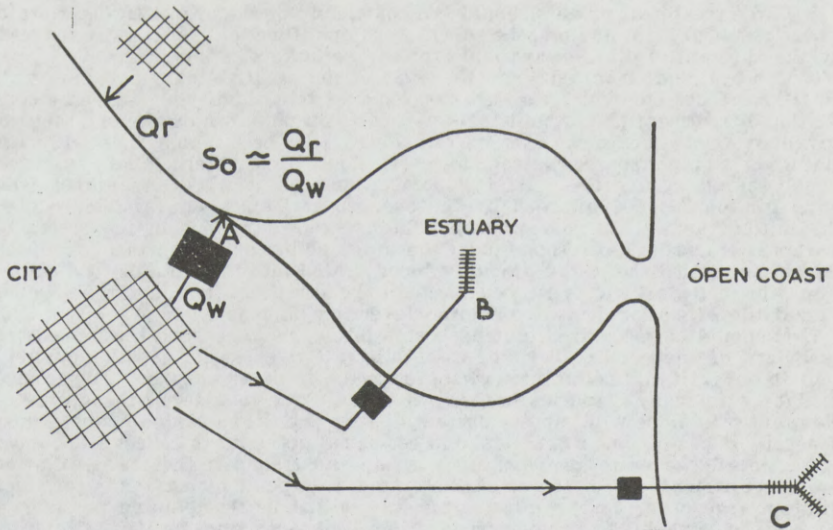


FIGURE 1.—Idealized estuarine-coastal disposal alternatives.

TABLE 1.—WORKED EXAMPLE FOR SITUATIONS SHOWN IN FIG. 1

Discharge location	A	B	C
Initial waste dilution, S_0 (at minimum river flow).....	10	30	150.
Approximate pollutant concentration near source, at diffuser, with no treatment (C_0 =concentration in untreated waste)...	$C_0/10$	$C_0/30$	$C_0/150$
Treatment.....	Secondary.....	Intermediate.....	Primary.....
Assumed percentage removal.....	(90).....	(75).....	(33).....
Approximate pollutant concentration near source.....	$C_0/100$	$C_0/120$	$C_0/225$
Treatment (percentage removal) required for equal pollutant concentration, $C=C_0/150$, at each location.....	93.3.....	80.....	0.....

Two points need to be emphasized. First, other than for disinfection processes, there are no conventional waste treatment processes that remove, on the average, 93.3 percent of BOD, COD, suspended solids, toxicity, or other significant pollutants; secondly, for open-ocean disposal (average initial dilution of ≥ 150) no treatment would be required. Obviously, this kind of system would not be tolerated generally. Thus, it would appear from just the standpoint of initial waste concentrations in the environment, the ocean disposal system has substantial advantages. These advantages become particularly important if the ocean disposal system can be built and operated at about equal or lesser costs than either of the estuarial disposal schemes.

ADVANTAGES OF COASTAL ALTERNATIVE

1. For the conventional levels of treatment commonly used, the coastal alternative produces the lowest pollutant concentrations in the receiving waters.
2. Generally, the coastal discharge location can be selected in an area of non-critical or of limited (lesser) ecological significance in the area; whereas the estuarine region is one of the most important and critical areas with respect to both the anadromous and marine fishery as well as the local ecology.
3. The residence time of pollutants in the estuary, the critical region, is reduced; hence, all effects of pollutants are minimized.
4. If pollutants of unknown character or origin occur, for which the treatment process may or may not be adequate, the coastal system affects substantial reduction in the pollutant concentration by dilution, thereby providing a safeguard to minimize the effects of any changes in the future.

5. If the treatment process should fail completely or the operation deteriorate as the result of many factors, the effect of such malfunction is markedly reduced by the substantial dilution available for the pollutants of significance.

6. Concern is often raised about the effect of conservative toxic materials such as DDT, PCB's, etc. which also are not removed to a significant degree by conventional treatment plants built to date—and to an unknown degree by proposed advanced waste treatment systems. Obviously, the best management of such materials is proper source control. However, should such materials gain entrance to the sewage system the coastal disposal system has marked advantages. The high dilution (≥ 150) afforded by the open coastal dispersion system reduces the initial (as well as subsequent) pollutant concentrations in the receiving water environment. Correspondingly, the lower pollutant concentration reduces the rate at which the pollutant can be incorporated into the biota or food chain. Thus, the biological effects can be expected to be less, as a function of time, which should allow time for correction before irreversible damage is done.

7. It should be recognized that upstream development (beyond the immediate periphery of the estuary/bay) of essentially all river systems will inevitably contribute significant pollutants (waste residuals) to the estuary/bay. Experience to date with many estuaries has shown that, in the long term, the upstream pollutant load alone will impose substantial stress on the estuarine region. Thus, generally it has become a practical and ecological necessity to collect all or most of the locally generated estuarine/bay waste and transport these wastes, after proper treatment, out of the estuarine system to a point of maximum terminal dilution (the open coast). Only in this way will it be feasible and possible to protect the estuarine bay region from serious ecological damage. It is of interest to note that recent (November 1973) proposed California water quality control policy states that the objective is "ultimate elimination of municipal and industrial waste discharges (other than cooling water discharges) to bays and estuaries, other than the San Francisco Bay-Delta system."

8. One occasionally encounters the hypothesis put forth by advocates of advanced or complex treatment processes that the transport-dilution system to open-coast disposal sites is an unwarranted expenditure because it detracts from the possible economic feasibility of wastewater reclamation. This is indeed a weak, if not completely erroneous, hypothesis for the following reason. If wastewater reclamation is to be practiced, the net result is the generation of more, not less, pollutants for disposal. This should be obvious if wastewater reclamation practices are to provide waters safe for the user or beneficial use. What happen to the residual (non-reclaimable) pollutants? Some can be recovered and disposed of as semi-solid wastes on land. Yet, a significant fraction of the non-reclaimables must be disposed of to the environment after suitable treatment. Indeed, a well-designed transport-dispersal system to discharge locations with high diluting capacity is an adjunct, if not a necessity, for economic and ecologically feasible wastewater reclamation systems.

9. An additional advantage of the coastal system is its flexibility and economy to meet future changes in water quality requirements to deal with problems either non-existent or unrecognized at present. Improvements in waste treatment technology can be applied when they become available and are needed to deal with new pollutants or newly discovered pollutant effects. And it will not result in the abandonment of expensive traditional treatment systems not relevant with respect to current technology and problems. An example is the current need for toxicity removal processes as contrasted to traditional emphasis on building plants to upgrade (from 90 to 95 percent or 95 to 98-99 percent) removal of BOD and suspended solids; when, as in the case of open coastal disposal of municipal wastewaters, BOD and suspended solid removal at these level are not of any practical significance.

The OPEN COASTAL PROBLEM

The conceptual planning of waste disposal systems for dischargers located along an open coastline is very similar to that facing dischargers located along an estuarine or bay system. Assuming that arbitrary and irrational regulatory requirements do not determine the treatment option with little if any regard to disposal location or dilution possibilities available, the problem is one of determining the optimum combination of wastewater treatment and disposal/dispersion system that will meet rational and realistic water quality objectives.

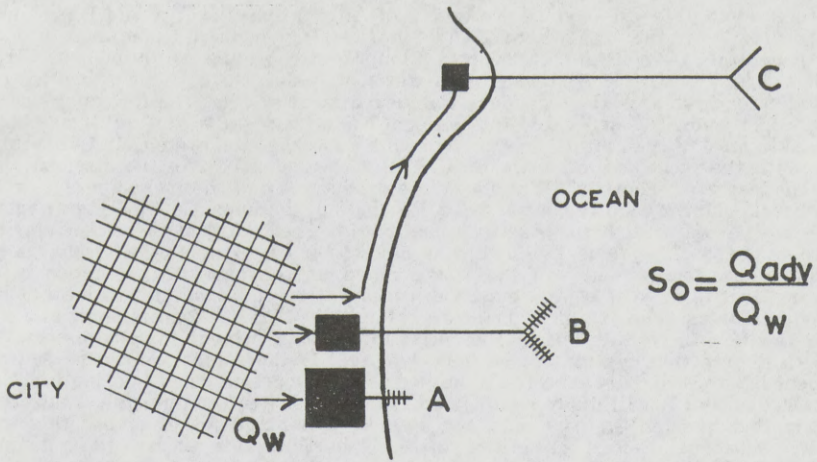


FIG. 2.—Idealized open-coast disposal alternatives

TABLE 2. WORKED EXAMPLE FOR SITUATIONS SHOWN IN FIG. 2

Discharge location	A	B	C
Initial dilution at source, S_0 (Value assumed).....	5-20 (10)	60-80 (70)	100-200 (150)
Pollution concentration at source, conservative substance (C_0 = concentration in untreated waste).....	$C_0/10$	$C_0/70$	$C_0/150$
Treatment (percentage removal).....	90	75	50
Assumed transport time to beach (h).....	0	12	24
Pollutant concentration at beach:			
Conservative substance.....	$C_0/100$	$C_0/336$	$C_0/450$
Non-conservative substance:			
$T_{90} = 4$ h ($k = 0.58$ h ⁻¹).....	$C_0/100$	$C_0/3.4 \times 10^3$	$C_0/4.5 \times 10^3$
$T_{90} = 1$ h ($k = 2.3$ h ⁻¹).....	$C_0/100$	$C_0/3.4 \times 10^{14}$	$C_0/4.5 \times 10^{26}$
$T_{90} = 12$ h ($k = 0.19$ h ⁻¹).....	$C_0/100$	$C_0/3.4 \times 10^3$	$C_0/4.5 \times 10^4$
$T_{90} = 240$ h ($k = 0.23$ day ⁻¹).....	$C_0/100$	$C_0/378$	$C_0/567$

HYPOTHETICAL EXAMPLE

Figure 2 presents an idealized set of waste disposal alternatives for a municipality located on the open coast. Three alternative systems are compared as follows: A, conventional secondary treatment, 90 percent removal of pollutant, discharge near shore, average dilution 10; B, intermediate treatment, 75 percent removal of pollutant; discharge some distance from shore, average dilution 70; C, primary treatment, 50 percent removal of pollutant; discharge offshore with high average dilution 150.

The waste concentrations near shore are compared for each alternative, in terms of the untreated waste pollutant concentration, C_0 , in Table 2. The residual waste concentrations consider removal by the various treatments, the initial dilution at the source, and the combined effects of treatment, initial dilution, and dilution during transport. It is apparent that System C, with the minimum treatment (50 percent removal) and high initial dilution, produces the minimum waste concentrations considering only treatment and dilution processes such as would affect the concentration of conservative (nondecayable) pollutants. It should be noted that the pollutant concentration at the source for Alternative C is $C_0/300$ (50 percent of $C_0/150$) which is a lower concentration than for Alternative A, $C_0/100$ (10 percent of $C_0/10$). Thus it appears that Alternative C is the preferred solution with respect to pollutant concentrations in the environment.

If one is concerned with non-conservative (decayable) pollutants in the waste discharge, and this historically has been the focus of all biological treatment

processes to date, the obvious preference of Alternative C over A and B is shown in Table 2 for the case where T_{90} is 4 h (i.e. 90 percent disappearance in 4 h, exponential rate constant $k=0.58h^{-1}$). Compare a shoreline pollutant concentration $C_0/4.5 \times 10^8$ for System C with those of $C_0/3.4 \times 10^8$ for System B and $C_0/100$ for System A, the secondary waste treatment system. The foregoing decay rate is a typical design value for coliform bacteria in sea water and it has been used in most of the recently designed marine waste disposal systems in California.

With the recent adoption in the U.S.A. of the federal E.P.A. requirements of secondary treatment for all public waste discharges and the inclusion of a fecal coliform effluent requirement of 200 MPN/100 ml, the impact of this requirement on marine waste disposal practice remains to be seen. Most of the recent marine waste disposal systems in California have been based upon the discharge of non-disinfected effluent and they have relied on coliform disappearance rates equivalent to a T_{90} of approximately 4 h to meet the coliform standards in body-contact areas. The justification of an effluent-disinfection requirement, at least in the U.S.A., considering the potential increase in effluent toxicity associated with disinfection, remains to be demonstrated. If the effluent coliform requirement is enforced, it is expected to have marked impact on outfall design practice in California. It will likely result in considerably shorter and much less effective outfall dispersion systems than are used at present. Whether or not this will have a beneficial effect on marine waste disposal practice remains to be demonstrated. Unless substantial dilution requirements ($\geq 100:1$) remain in force as a special requirement, there is no doubt in the writer's judgement that sole reliance on arbitrary effluent criteria of the type indicated will be a step backward in marine waste disposal practice, at least in California. Also it will unlikely have adverse if not disastrous ecological effects.

TREATMENT, TRANSPORT, AND DISPERSION SYSTEMS

To evaluate properly the role and economic justification of the optimum combination of treatment, wastewater transport to a suitable site, and the appropriate dilution-dispersion system, it is necessary first to consider the unit costs of each component of the system.

TREATMENT

Table 3 presents a summary of 1973 California unit costs for various levels of treatment and size of plant. These values include all costs: capital (based on a 20-year life and 5 percent interest rate), operation, and maintenance. The design flows shown are equivalent to 1, 10, 100, and 1000 million U.S. gallons per day. It is seen that for 10 mgd (37,800 m³/day) and 100 mgd (378,000 m³/day) the 1973 unit cost increments between primary and secondary treatment with filtration are about 4.1 and 1.9 cents/m³ of waste treated, respectively. Similarly the unit cost increments between secondary and advanced waste treatment (physical, chemical, biological—Alternative B) for the same size plants are about 5.2 and 3.3 cents/m³ respectively. Conceivably the incremental unit cost between the two levels of treatment could be used to transport the waste to a disposal site where the dispersion system could handle without impairment the lesser treated effluent.

TABLE 3.—ESTIMATED TOTAL UNIT COSTS (U.S. CENTS PER M³) OF WASTEWATER TREATMENT IN CALIFORNIA DURING 1973—COSTS INCLUDE CAPITAL COSTS, BASED ON 20-YR LIFE AND 5-PERCENT INTEREST RATE, AND DISPOSAL OF WASTE RESIDUALS

Treatment system	Plant design flow (m ³ /day)			
	3,780	37,800	378,000	3,780,000
Primary.....	7.4	3.3	1.8	1.5
Intermediate: Chemical, filtration, chlorination.....	13.0	7.4	3.7	2.6
Secondary: Activated sludge, filtration, chlorination.....	13.0	7.4	3.7	2.6
Advanced:				
(A) Chemical, filtration, activated carbon, chlorination.....	24.0	11.4	6.5	4.6
(b) Activated sludge, chemical filtration, activated carbon, chlorination.....	25.9	12.6	7.0	5.3

TRANSPORT

The cost of interceptor sewer/transport systems depends primarily upon the surface and subsurface conditions along the route. Table 4 presents 1973 construction cost estimates for dry-trench construction of interceptor sewers of suitable size to handle the three levels of flow considered.

TABLE 4.—ESTIMATED UNIT COSTS OF INTERCEPTOR SEWERS, DRY-TRENCH CONSTRUCTION, IN 1973

Design flow		Sewer size		Construction cost \$/m
m ³ /day	(mgd)	cm	(in)	
3,780	(1)	25.4	(10)	60
37,800	(10)	91.5	(36)	206
378,000	(100)	245.0	(96)	672

OUTFALL

The costs of outfall construction vary considerably because of differences in surf and bottom conditions. The cost of the onshore-surf section is high where the outfall must be buried for protection of the pipe; hence the average cost depends upon the length of the outfall and the ratio of the offshore to onshore sections. Table 5 presents reasonable estimates of the average construction costs per unit length of outfall for the sizes of outfall suitable for the three ranges of flows considered. The values reported are in the middle ranges of construction costs (adjusted to 1973 prices) for outfalls built along the Pacific coast during the past 20 years.

TABLE 5.—ESTIMATED UNIT COSTS OF SUBMARINE OUTFALLS, CALIFORNIA CONSTRUCTION PRACTICE, 1973

Design flow		Sewer size		Construction cost \$/m
m ³ /day	(mgd)	cm	(in)	
3,780	(1)	15	(6)	330
37,800	(10)	61	(24)	1,395
378,000	(100)	194	(76)	2,720

TREATMENT/TRANSPORT/OUTFALL TRADEOFFS

In the conceptual design of a wastewater disposal system, one should consider various levels of treatment or pollutant removals, possible transport distances/disposal sites, and outfall-diffuser lengths to produce the minimal impact on the environment. The incremental unit costs between the various levels of treatment can be considered as available for waste transport or outfall construction. Thus, one can compare the effect of high levels of treatment and discharge with minimal dilution close to the source of waste generation with reduced level of treatment and disposal in an area of lesser ecological significance with high initial dilution. Obviously, a rational comparison entails quantitative comparison of both sides with respect to both dilution possibilities and ecological characteristics.

The rational comparison of alternative disposal sites and treatment levels is infrequently done, in part because of the lack of definitive data on dilution capabilities and ecological characteristics of the alternative sites as well as on pollutant parameters and process-removal characteristics. The latter is especially true for the developing parameters such as toxicity and biostimulation. However, a simple economic comparison of different levels of treatment with incremental costs between levels used to estimate break-even land transport distances (interceptor sewers) or lengths of submarine outfalls can be very helpful.

Table 6 presents a summary computation of the distance the treated wastewater can be transported in interceptors or taken to sea in outfalls (such as are

constructed on the Pacific coast) for the same cost as the incremental cost between two levels of treatment—in this case between primary treatment and secondary treatment including effluent filtration.

TABLE 6.—LENGTHS OF INTERCEPTOR SEWER OR SUBMARINE OUTFALL THAT CAN BE CONSTRUCTED FOR INCREMENTAL COST BETWEEN PRIMARY AND SECONDARY WASTE TREATMENT

Design flow		Incremental unit cost, primary to secondary ^a (cents/m ³)	Total annual incremental cost, primary to secondary (\$)	Equivalent interceptor ^{b,d}		Equivalent outfall ^{c,d}	
m ³ /day	(mgd)			Unit cost (\$/km)	km	Unit cost (\$/km)	km
3,780	(1)	5.6	76,650	3,250	23.6	19,130	4.00
37,800	(10)	4.1	565,750	11,300	50.1	81,400	6.96
378,000	(100)	1.9	2,555,000	36,900	69.3	159,000	16.1

^a See table 3 for process description.

^b Based on useful life of 50 yr.

^c Based on useful life of 40 yr.

^d Assuming interest rate of 5 percent; excluding pumping, operational, and maintenance costs.

It can be noted that for a flow of 37,800 m³/day a secondary plant has the same unit cost (\$/m³) as a primary treatment plant with a 50.1 km of submarine outfall interceptors or with 6.96 km of open-coast submarine outfall. Obviously, a similar break-even cost solution would be a primary plant with 25 km of interceptors and 3.48 km of submarine outfall. For a 378,000 m³/day plant the incremental cost of going from primary to secondary would permit building 69.3 km of interceptors or 16.1 km of submarine outfall or appropriate combinations of the two to reach a disposal area that would permit or be enhanced by a properly discharged primary effluent. Obviously, if suitable disposal sites were closer to the city than these estimated distances, the primary treatment, transport, and outfall alternative would be more economical than the secondary treatment system.

It should be noted the computed lengths of interceptor sewer and outfall are in addition to the interceptor and outfall lengths required with the secondary treatment solution.

The analysis in Table 6 does not include pumping or interceptor/outfall operation and maintenance costs. In a practical comparison, these costs should be included if pumping is required—the example assumes gravity flow. Inclusion of these costs does not change significantly the break-even lengths, at least for the two largest flows—it reduces the equivalent lengths about 10 per cent. For the flow of 3780 m³/day the length may be reduced as much as 20 per cent.

Certainly the data presented in Table 6 indicate that a reasonable investigation of possible disposal sites is warranted before secondary treatment systems are designed to discharge effluents to the local environment. Also, it should be noted that the preceding analysis is based upon a comparison of primary treatment and secondary waste-treatment removals and costs. Obviously, where regulations do not require primary (or any) treatment as a minimum, a similar comparison can and should be made for the alternative costs and consequences between no or minimal treatment (screening) and primary treatment systems.

CONCLUSIONS

Rational analysis of coastal waste disposal systems requires consideration of the efficacy of several treatment levels with respect to pollutant removal and costs, the cost and consequences of transporting adequately treated wastewaters to disposal sites with high diluting capabilities and/or low levels of ecological significance, and the effects of the resulting pollutant concentrations in the receiving water environment.

In creasing levels of wastewater treatment with disposal to local, high-value receiving waters may be the most expensive solution and also the one with the greatest ecological hazard. The possibility of treatment process malfunction or failure and unknown or unremoved pollutants may also have serious ecological consequences.

One should consider the incremental costs between the several possible levels of wastewater treatment, and the use of the incremental cost for transport sys-

tems or outfalls to convey the wastewater with the lower level of treatment to a disposal site of high wastewater diluting capacity and/or a low level of ecological significance.

In an example computation, it is shown that for the incremental cost for a 10 mgd (37 800 m³/day) plant between primary treatment and secondary treatment, including filtration, an interceptor sewer 31.1 miles (50.1 km) in length or a marine outfall some 4.32 miles (6.96 km) in length can be constructed at 1973 prices. Obviously, the break-even cost solution would entail some appropriate combination of interceptor and outfall. Moreover, for most alternative solutions, primary treatment with transport to an area of high dilution capability would result in the lowest pollutant concentration in the environment. Thus, it would be reasonable to conclude that this solution would have the least ecological consequences, certainly for non-conservative pollutants. It would also be true for conservative pollutants or any pollutant not significantly removed by conventional treatment processes.

Ecologically sound solutions to waste treatment/disposal problems require the analytical evaluation of pollutant discharges, treatment efficiencies and costs, the consequences and costs of land transport and marine outfalls to convey wastes to areas of high dilution and low levels of ecological significance, the resulting concentrations of pollutants in the receiving waters and their effects. Only in this way can marine waste disposal solutions be developed on a rational and economic basis.

REFERENCE

1. California State Water Pollution Control Board. Proposed water quality control policy for the enclosed bays and estuaries of California. Sacramento, Calif., November 1973.

Dr. PEARSON. I thought I would just tell you a little bit about my activity, not by way of making qualifications of myself, but because I think you will perceive from my activity a little bit of the point I am going to try to make to your committee today, that this issue that you are discussing, secondary treatment, needs to be sharpened much more than it is today.

And our view—that is, the U.S. view, and EPA—and you might say the profession in the United States, is not quite the same view toward this general subject that exists around the world.

I currently have been and am today active in a variety of places where I can tell you a little bit the differences in the perception of this issue of secondary treatment as it is viewed by different societies and different peoples. And these people range from what you might say the developing world to those that are equally as sophisticated, if not more so, than we are.

So I think it might be helpful to, if I can do anything without a lot of preparation today, give you my experience from working around the world and what it is specifically, in Sweden and a few other spots, to indicate why the secondary treatment issue is kind of a fuzzy one, and it needs to be sharpened and examined in more detail than just secondary treatment for marine disposal.

Now, by way of comment, you have a written statement, but I want to say not only am I a guest professor at the Royal Institute—and that is supposedly halftime—but I am also a halftime consultant to the Swedish Water and Waste Water Association. And I want to put this in the record, Mr. Chairman, if you will allow me, because when I come back, I am going to do some work hopefully to develop in this country something like the Swedish Water and Waste Water Association, because I think it is sorely needed.

What it is, is an association financed by the municipalities and the Government of Sweden, to provide help—technical, scientific, admin-

istrative, and legal help—to the cities of Sweden with their very significant water and waste water problems.

And I can tell you, Sweden's concern about water and waste-water problems excels ours, because they spend a lot more—at least several times as much—as we spend in the United States in the management of their water problems.

And when I talk about spending, I will have to use some numbers, crowns per cubic meter, but we can put this in dollars per million gallon, something that we can relate to ourselves. But generally, I can say that Sweden spends at least twice as much, and this represents a total cost, capital operation and maintenance for water management. So they have been concerned about it, still are, and it is a very expensive item there, and they are paying this with some reservations, because they are not so sure that what they have done or are doing is necessarily what is needed or right. And I think in this context, this is somewhat the way we ought to be looking and are looking at these questions. Are we spending money in a cost-effective way, or are we just spending it to solve, say, traditional views—building things, concrete and steel monuments, that may or may not have the desired environmental effect.

So I think this is a part of my comments that is going to work its way through the general statement I will make here without much preparation—and I apologize for not being very well organized in my presentation today.

But I thought I would just summarize my involvement in projects presently in three places of the world, and one that I have had many years' involvement and still going on.

I am going to talk about Gothenburg, or Goteborg, Sweden, on the left coast of Sweden. I am going to talk about the Mediterranean, specifically the part of the Mediterranean that I am sure most of you know—Venice, Trieste, and that part of the Adriatic from the Po River around. Then, I am going to just liken that Italy situation to what we face, kind of like the east coast and the gulf coast, rather than the California coast. And I will say a couple words about Rio de Janeiro, Brazil, and Los Angeles/Hyperion.

So I hope I can impress on you the differences in view or perception these places have on waste treatment or pollution.

Let us first start in Sweden. The objectives of waste treatment in Sweden are basically three things: the removal of oxidizable carbon; the removal of suspended material; and last, but most important, removal of phosphorus. And they believe, and have believed, that phosphorus has been one of their major problems in the so-called eutrofication of their waterways.

And the city of Gothenburg, or Goteborg, on the west coast, up until about 7 or 8 years ago, did not have any waste treatment at all, and then they had to plan a system and build it. They now have what we would call a high-rate activated sludge, or a high-rate secondary treatment plant.

The objective of that, of course, is to pick out organic carbon and suspend it, naturally; and hopefully, some of the phosphorus. But the person that was responsible for this for the Swedish Government—in other words, the town engineer for Goteborg—unlike most Swedes, bucked the Swedish system. That is, he did not want to build what

the rule in Sweden is—you build plants to take out phosphorus, 90 percent or better—because he did not perceive that phosphorus was the problem.

And correspondingly, he built a plant that satisfied the bureaucrats, or the Government, but did not achieve what they like to think is necessity, like we talked about secondary treatment. He built something less than that, because he did not think that was the right thing to do. And that case is right now in the water courts in Sweden, and I have been asked to testify—in fact, the middle of next month, if it is possible, and there is some question about that, because it is the last case before the water courts in Sweden, and the engineer who opposed building these phosphorus removal plants, it looks like he might win on the basis of it is not needed. And I say it is not needed because they have studied this problem. And I have brought with me, just to show you—I am not going to read them—two copies of annual reports that they have made of the area around Goteborg, Sweden. This is the Gote-Elbe estuary, and the archipelago, that is the shallow water area outside.

They have built this plant. It is operating. But they have studied it, and they are trying to decide they should not go ahead with what the Government originally wanted, which was complete phosphorous removal, but maybe they should do something else.

But it is still being debated, and hopefully, it will be resolved in the next month. Now, I mention this because the whole emphasis is on phosphorus removal. And if you know anything about Sweden, one of its attractions on the southwest coast, and of course, the whole Norwegian coast, too, is its fisheries, largely shell fisheries, and of course, the growth of these is related to nutrients in that body of water.

And the question is: should you remove phosphorus before you put the waste into the area, or should you not, and what are the bad or good consequences if you do?

Well, this is controversial, but the public opposed this because they thought you ought to build all the treatment that you can afford, and that in Sweden was believed to be complete 90-percent phosphorus removal.

OK. We do not have that phosphorus syndrome, at least, yet; it may come. Some parts of our inland waters, we have possibly phosphorus problems. But it has been studied in the State of California that there is no known water body in the State that is phosphorus limited. So that, to build plants to take out phosphorus, if phosphorus is not the limiting constituent, is hardly a cost-effective approach to waste management.

Now, I mention this phosphorus bit unrelated to secondary treatment, because secondary treatment removes little phosphorus. So it just shows that some parts of the world look at the problem quite differently than we do.

Now, the question is, what does secondary treatment do, and does it focus on the problems of concern. Well, that brings me to Italy.

I have brought with me, and I am going to read just a couple excerpts of a Swedish report on the Mediterranean, where they have collected a number of reports on the Mediterranean Sea, and this is—

Mr. CLAUSEN. Would you identify the report?

Dr. PEARSON. Yes; I will. This is a publication called, "Ambio." This is a publication by the Royal Swedish Academy of Sciences. This issue is November 1977, and it is devoted to the pollution of the Mediterranean Sea, and there is a collection of papers on the subject.

Now, I have asked some natives here, and apparently, this subject of Mediterranean pollution is not considered much in the United States. But I am telling you, Europe is very much concerned about it because the Mediterranean is the playground of Europe.

And correspondingly, those of you how have spent some time on Italy's shores, or in the Mediterranean, appreciate the value of that as a recreational resource, as well as a fisheries resource, too.

Now, this report—and I am just going to highlight—it focuses on the state of pollution in the Mediterranean Sea. And the subtitles, or subheadings are: Metals, Mercury, and then Cadmium, Copper, Lead, Zinc, then Pesticides and PCB's, and then Sewage—that is a separate heading—Oil, Thermal Discharges, Radioactivity. Those are the subheadings in what they think about pollution.

Now, I want to just read one paragraph out of the summary of this report. It says, "While the Mediterranean appears to be sickly in certain areas along its fringes, where the impact of man is greatest, the large, open masses of Mediterranean Sea water do not seem to be much different than from other oceans, except perhaps for oil tarballs floating in the water, or the elevated levels of mercury found in migratory fish, such as tuna and swordfish."

In other words, their concern is things that essentially have nothing to do with secondary treatment; or, the impact of secondary treatment is only minimal with respect to those particular problems.

And so, the point I want to make is that what is secondary treatment; it is a general treatment for removing oxygen-demanding properties with suspended solids thrown in. But it does not remove significantly nutrients, metals, PCB's, DDT's, or any of these others.

And the question is, there is no doubt but that we have problems, but is secondary treatment the place to put your money if you are going to try and clean up what kind of pollution problems you face.

So I would just like to leave with you that we ought to spend our time and effort focusing on the problems that we know or that we can perceive, rather than use and rely on blanket, traditional kinds of treatment processes, and spend our money building things that may have fit the time they were first thought, but not necessarily fit the real environmental problems of today.

I apologize for the time I have taken, but I just wanted to leave with you that secondary treatment is misunderstood as to what its role in controlling the environment is. And we ought to focus on what the problems are, not just requiring unilaterally secondary treatment.

Now, this is particularly important if, like in Sweden, and like we have, too, where many of your waters are inland waters, where wastes go into potential drinking water supplies.

But when you put it into the sea, you have a different set of problems to deal with. And the circumstances that apply for land-based operations, and the impact on water and what man drinks from a health standpoint, is one kind of a problem. Putting waste in the sea is quite a different type of problem. And we should not just use the same kind of a system in both places.

In other words, we ought to give more specific treatment in our thoughts about the problem.

I think that is enough for a general statement. I do not want to take more time, but I would be pleased to respond to any questions that you may have relative to what I have said or other.

Mr. ROBERTS. Thank you, Dr. Pearson. That was most interesting and we would probably keep you here all day if we could.

The gentleman from California, Mr. Johnson?

The CHAIRMAN. Thank you, Mr. Chairman.

Dr. Pearson, the first time that we came together, I think, was on the situation at Lake Tahoe, where we were dealing with pristine waters in the High Sierras. I want to report to you that many of the things that were brought out now have been pretty well dealt with there, and we have a pretty fine system now that pleases most people at Lake Tahoe, including the State of California and the State of Nevada.

I am very happy to have the experience of hearing you again on your new assignment in Sweden and your consulting services throughout the areas that you spoke about.

Certainly, that is very interesting information for the record. And I know that what you have said already pretty much opens up the question that we have been dealing with here, as to whether we should be building secondary treatment or not, to cope with some of the mandates that have been leveled on the districts and municipalities that have been involved.

As I understood you to say, you will be completing your assignment overseas soon, and you are coming home to set up some sort of an organization to deal with this problem, similar to what is now in operation in Sweden. Did I understand that correctly?

Dr. PEARSON. Well, I will try to get our municipal associations or agencies to do some work like the Swedish Water and Wastewater Association, because our association, like AMSA, the Association of Metropolitan Sewage Agencies, does not have an operating organization. It is more for information and general—I guess I should not use the term “lobbying”—but general influence of what is going on in the business.

They do not do much, as far as I know, in a technical way, to help cities solve their problems, or even organize research problems or approaches to real problems, rather than leaving it up to professors.

Now, do not misunderstand me. I am a professor, too. But one of the problems in solving these problems is that professors generally tend to work on things they are interested and that may or may not be relevant to the kind of problems that are ongoing in the profession that have to be faced by people working every day in the business.

So, many of the problems that are in the real world that cities have are not organized very well in their research approach. It is either up to professor types in the ivory towers—and I am one of them—or the consulting engineers, or equipment firms, that have another motive in it.

And this Swedish Water Association is to try to provide technical guidance and planning, as well as administrating, a research program in cooperation with the member cities to solve some of these practical problems.

And I think that is what is needed, and I am going to do what I can to see if we cannot get our associations to do something like this, too, rather than just be advisory from, let us say, a political administrative standpoint.

The CHAIRMAN. I might say, our main concern right now is the time limits that we are up against to provide the secondary treatment. Some of us who are on the committee felt we should have more time, more research and study made, before they are mandated to build these secondary treatment plants, because cost is one thing; if we need them, fine. But we might not need them. Or, they might be, through research and development, a different type of facility, as you stated.

Some of the problems are not met with ordinary secondary treatment.

So those are the things that we are trying to cope with at the present time, with the regulations coming down on us and the due date coming down on us. We are trying to seek out information here to see whether the committee's position in the House of Representatives was right, or they were wrong. We think time will tell, and we think we should have a little more time to deal with this problem.

That is all, Mr. Chairman.

Mr. ROBERTS. Thank you.

The gentleman from California, Mr. Clausen.

Mr. CLAUSEN. Thank you, Mr. Chairman.

Dr. Pearson, I appreciate very much the forthrightness and the candor of your comment. Would it be of any value for some of the committee membership to visit what you are doing there in Sweden? Would it be of any value to the committee itself?

Dr. PEARSON. Well, Mr. Chairman, I can respond to that with some substance. In Stockholm in the middle of June, there is going to be an International Conference on Water Research, in which the Swedes—in fact, the current president of this organization that is fostering this research is located in Sweden. It is going to be there in June. And these are preprints, four volumes, of the papers that are going to be presented and discussed in June this year, the 12th, to the 16th.

And the organization that is doing the organization of the conference, v/a/v the Swedish Water and Wastewater Association, is handling this, so I know completely what is going on.

And I looked at the preregistration list of the people that are going to attend this, and I regret to say that there was only about, I think 2 weeks ago, about 35 people from the United States going to attend this.

Now, if you will permit me, Mr. Chairman, I would like to amplify one point here. In Sweden, there are over 600 operating advanced wastewater treatment plants.

Now, I think we all know what advanced wastewater treatment plants are. It is a combination of mechanical, biological, and chemical—in other words, further than secondary treatment. There are 600 of them operating. That is a country of 8 million people, plus or minus. We are 210-whatever, and we have in the whole United States as far as I know, less than one-tenth that, less than 60 plants. We have got a lot of them planned, most of them for different reasons than the

Swedes have built them. They have built them to remove phosphorus, because they suffer what I call—pardon me, and I regret it will be in the record—the phosphorous syndrome. That is, they look at phosphorus as being evil. And this has been “sold” because of some scientific views that phosphorus is abominable, and should be removed.

Well, this is not the case in many places, certainly not in the Mediterranean—maybe not even in some parts of Sweden. Some of the lakes, it may be the problem. But to use blanket policies of saying we ought to remove phosphorus and guide our program in that way is foolhardy.

So to answer your question, yes, I think somebody from the United States, from your committee, should attend this conference and see and hear the views from other parts of the world, because I could tell you that not many parts of the world look at secondary treatment as the answer or necessarily appropriate.

Some look at it more, some less. You would have a very difficult time selling—pardon the crude word—selling secondary treatment to the United Kingdom. They think this is nonsense. Now, I am not saying that is right, but I am saying we need to get a broader view than we have had in our expenditures for this, and we ought to use our resources to find out what these people know and profit from their experiences.

That is why I say yes, we ought to have a lot of people there to see not only what the Swedes are doing, but people that are participating in this as well.

Mr. CLAUSEN. I have three questions, so I would like to extract maybe a little bit shorter response to each one of these, so I can yield to the other gentlemen.

Do we have the capability to determine what level of waste discharge to the ocean is consistent with our environmental needs?

Dr. PEARSON. Yes; within what I call engineering limits of precision; yes.

Mr. CLAUSEN. Do we know enough about toxics? Will pretreatment be adequate to control toxics?

Dr. PEARSON. We do not know as much as we should, and this should be studied more. But we know enough to make much better approach than we have done today.

In other words, secondary treatment is not going to deal with that problem. In fact, in some cases, it may accentuate the effects. So that does not deal with toxics.

Mr. CLAUSEN. But do you believe that pretreatment would be adequate to control toxics?

Dr. PEARSON. Well, pretreatment, coupled with source control, yes. But you must identify what the problems are, and these are not the same universally.

So my point is, we can deal much better than we have dealt today. That is not to say you have got a complete scientific answer for it, but we can do better than we are doing today.

Mr. CLAUSEN. Finally, then, would this summarize what I think we hear you saying: Be site specific in determining treatment needs, but do not require the same everywhere.

Dr. PEARSON. My answer is an absolute necessity: If you want to be cost effective, you have to be site specific. In fact, I said this in my testimony 4 years ago. There is no place in cost effective management of

the environment to use blanket rules and expect them to make any sense on a blanket basis.

Mr. CLAUSEN. But you have to recognize that there are variables with those particular sites, and that, in order to be cost effective, as you state, you should not apply a standard to every given situation.

Dr. PEARSON. Yes, I believe you should not employ a standard for every installation.

Mr. ROBERTS. Dr. Pearson, let me throw out one specific illustration, because I want to ask Dr. Craven the same thing. I went out to Honolulu where they were dumping in 600 feet of water, but in a trench, so it was really 1,500 feet. And yet, the EPA insists that we may have to have secondary treatment out there. Now, the tides and the currents are such that the next island it could touch would be New Zealand. Does that make sense to you?

Dr. PEARSON. Mr. Roberts, would you repeat that? The combination of my hearing and the noise level—I heard, but I did not completely understand.

Mr. ROBERTS. The outfall from Honolulu is in 600 feet of water, but it is on a trench that is 1,500 feet deep. The tides and the currents are such that the next island their effluent could touch would be New Zealand, a pretty good piece away.

Now, could there be any reason for requiring secondary treatment in a situation like this?

Dr. PEARSON. My answer is no. For your information, I think I was responsible for organizing the general Oahu study, to provide the basis for the direction in which they have gone.

Mr. ROBERTS. Thank you, sir. That was the information I was seeking.

The gentleman from California, Mr. Anderson.

Mr. ANDERSON. Thank you, Mr. Chairman.

I think you have somewhat answered my questions just previously but I wanted to clarify the thrust of your remarks. Your feeling is that secondary treatment is not necessarily needed in some ocean areas—and, of course, I am thinking now about the Los Angeles-San Diego area, where we have again a similar deep, quick falloff, and a fairly fast current—that secondary treatment is not necessary in areas like that, but that we should concentrate more on inland areas and areas where there are different kinds of terrain.

Is that the thrust of your testimony?

Dr. PEARSON. That is part, but that is not the total. My point is that we should consider grossly different kinds of problems, where we have waste water going into drinking water supplies, or potential drinking water supplies, as to when we put waste water into, say, the marine environment, where the use is for recreation or general ecology maintenance—that is, to maintain a good environment. These are two different kinds of problems. And secondary treatment alone is not the main difference.

For example, if I can expand on that, Sweden in my view could better justify their program for building most of the 600 advanced waste treatment plants on the general problem of removing, say, pollutants that might have an adverse effect on man, because much of their waste waters go into inland lakes and rivers that are used as water supplies.

And correspondingly, there is need for a little more conservative in that kind of waste management than if you are putting the waste water into the environment, into the marine waters, because no one at least is going to drink that—unless they have good resistance to salt.

In other words, you have a different kind of a problem; a human organism and his effects. And you know, we are concerned—I read much more now than in Scandinavia—about the trihalomethanes in drinking water—that is, trace organics—and their effect.

Now, I know this is not the purview or concern, I guess, of this committee. But if you are putting waste waters in drinking water supplies, you have got to think something about the specific pollutants that may be the carryover, one to the other.

And remember, the separation of waste water and water supply is only for political or other reasons, social reasons. It is water all; it just differs in quality, and sometimes the quality is not significantly different.

You have to be specific in characterizing what quality aspects are important, and that is why I do not like the blanket secondary treatment problem. You have got to look at the problems of concern.

You know, I am a typical professor, and I talk too much, but I could give you an illustration that I think drives this home, if you will permit it.

The drinking water for most of Los Angeles, the metropolitan water district, the Colorado River, has more total impurities in the drinking water than the sewage, untreated, from a substantial part of San Francisco.

Now, we have some Californians. What do I mean? I am talking about total impurities. In a metropolitan water district, it is salt, mostly, because it leaks out from the land. But it is total impurities.

Now, it is a different kind of impurities in sewage, but in terms of mass, it is a bigger number. So it is not just sensible to use as a lump approach—engineers frequently do this, and we have to practically do it, too—but we have to look a little more discerningly at what the problems are.

And if you want to go into this, I can put a specific relationship on the board that will even do more, I hope, to drive this point home.

But we have to concern ourselves not with secondary treatment per se, but what is needed to take the things that we would perceive or have good evidence that have an adverse effect on the use of the water, whether it be the ecology, or if you are going to drink it. That is the way our focus ought to be—not in just building this kind of a structure, because that was done historically.

Mr. Anderson. Thank you, Mr. Chairman.

Mr. ROBERTS. Does the gentleman from Louisiana, Mr. Livingston, have a question?

Mr. LIVINGSTON. I have no questions, Mr. Chairman.

Mr. ROBERTS. Does the gentleman from Minnesota, Mr. Oberstar, have a question?

Mr. OBERSTAR. Thank you, Mr. Chairman.

Thank you very much, Dr. Pearson. You have certainly challenged our thinking and stretched our imagination with your presentation. Your Swedish experience goes contrary to the thrust of water pollution treatment in this country.

I know you were dealing with ocean outfall in your remarks. But the experience that we have had in this country is that phosphorus is the limiting element in freshwater lakes.

What is it that is different about introduction of phosphorus into marine outfall areas that makes it less a threat, and has influenced the thinking of your Swedish colleagues?

Dr. PEARSON. Well, first, I will comment on that question, but only after saying that you should address that question to Professor Reither, who is an expert biologist, and who has spent his career studying on algal growth, enrichment, and the relations between that and nutrients.

But I would respond generally that even in Sweden, where they have spent their money to remove phosphorus, subsequent studies show that many places, maybe it was not phosphorus that was limiting. In fact, it is not clear just what it is. Maybe it is nitrogen; maybe it is something else. But it may not be—in fact, studies in Sweden today show it is not all phosphorus.

But nonetheless, they have spent money and built plants that are still being evaluated today primarily on the basis of how much removal of phosphorus they do.

Now, I say that concept needs to be sharpened up there too. It is a little bit like we are talking about secondary treatment. We are talking about is that the panacea to solve the problem. And my point is it is not.

We ought to focus on what the problems are as best we can refine them, and then work in that respect, and we know enough about what we ought to focus on—not in the most sophisticated way, but at least from an engineering standpoint. And just going at the blanket approach of secondary treatment is not the way to go, in my judgment. And I am speaking as an engineer, not as a scientist.

Mr. CLAUSEN. Would the gentleman yield?

Mr. OBERSTAR. I would be glad to yield in just a moment. I do not have any quarrel with your view that we ought not blindly rely on one technology or one approach. I am trying to get at the reasons that underlie that assumption.

And what I was curious about was the distinction you seem to be drawing between freshwater and saltwater discharges.

I will be glad to yield to my colleague.

Mr. CLAUSEN. In alluding to the fact that we are concentrating too much on secondary treatment and not on the specific sources, while we are at this point in the record, could you spell out what you think they should be concentrating on in the way of specific sources?

Dr. PEARSON. The specific problems are quite variable, but today, in most developed areas, like the United States, there are not many remaining BOD problems—in other words, organic carbon problems. There are not many remaining gross suspended solids problems.

In other words, most of those have already been resolved one way or the other. But we have a lot of unknown things that we are not clear about as much as we would like. And this is the area where attention must be.

If I can take a minute, sooner or later you get to some kind of a general expression that relates effects—I think I can speak loudly enough—the effects of pollutants to some kind of a function of the con-

centration of the substance, the pollutant of concern. And (t), that is the time of exposure.

The effect is based upon a complex—and we do not know that mathematical expression very well. But the point I want to make, to change the concentration of the pollutant in the environment, you have got essentially three kinds of things that you can do.

You can remove the source of it, by source control. And generally, you cannot get complete removal of anything by source control.

Then, the next thing you can do is treat the wastewater to reduce the concentration in the waste; that is removal.

And the third thing you can do is disperse the waste in the environment; in other words, you dilute, to reduce the concentration, so you minimize the effect.

Now, it does not make any difference what kind of effect you are talking about; if you are talking about oil and grease from your children's feet from walking on the beaches, or if you are talking about toxic effects, either acute or chronic, they are all some way or another related to concentration and the time of exposure.

And you can manipulate the concentration by controlling the source and the kind of treatment, and how you disperse what is left in the environment by dilution—that is something we now call dispersion—the effect on the environment; in other words, what the organism sees as that ultimate concentration. And this is based on how much time the organism spends in the area, or how that concentration pattern affects it. And you can manipulate this physically, by how you put the waste in the water—whether you put it by the shore, the beach. That affects one kind of organism, and the time of exposure. If you put it out in the sea, it has a different problem. And correspondingly, some of these pollutants change with time; they decay.

So you can reduce the concentration of an organism by source control, treatment, dilution, and the time that that material goes in the environment before it affects the organism concerned.

So what we have got to deal with are the specific things that we know something about. And I read that list of items in the Mediterranean. Most of those—the metals, PCB's, DDT's—there are not hard numbers to use as to how much is removable of those through secondary treatment removal.

So the question is, you want to focus on what you think the problems are, and then control the source, treat it, and dilute it, so that you can provide acceptable concentrations in the environment, to produce the minimum adverse effect, or possibly, a beneficial effect—which, of course, would be better.

If you put nutrients in, in too high a concentration, they produce an excess enrichment you do not want. If you put them in a low concentration—in the Mediterranean, for example, this is a key problem. An island has been dammed, and nutrient cost to the Mediterranean has been reduced.

Why should everyone want to build phosphorus removal plants? That is not germane, but they have got PCB, DDT, and other kinds of problems, and those will not be solved by secondary treatment. You have got to do something else, and that is why waste disposal is a combination of source control, treatment to reduce the concentrations in a land-based system, and a proper dispersion system, for location

and dilution, so that you minimize the concentration of waste in the environment, so the effects are minimum, or beneficial.

Mr. OBERSTAR. Well, Professor, in your judgment, what are the key elements of discharge that secondary treatment does not reach?

You have cited a couple—PCB, DDT. Are there other elements, and how do you remove those elements if you do not have secondary treatment? What other means of treatment do you recommend?

Dr. PEARSON. Well, today, the technology is such that there is no known effective way of removing DDT and PCB, other than maybe by some sort of adsorption, granular-activated carbon, or something like that.

But that just has not been at least economically feasible. But the way to reduce those substances is by source control, and that is the principal way.

The next step is that we are going to have to look at treatment process—and this is debatable even among engineers, which I represent—we ought to be giving more concern to designing process to removing microparticles which have these materials attached to them—not just removing gross-suspended solids. That is a lumpier kind of thing.

We should be concerned about the fractions of the materials that are of concern. And someday, we are going to have to address removing DDT and PCB, and maybe other exotic organics.

Mr. OBERSTAR. You are talking, then, about industrial pretreatment, which is a matter that this committee has addressed.

Dr. PEARSON. I did not understand your question.

Mr. OBERSTAR. I just made an observation. I said you are talking essentially about industrial pretreatment, which is a matter this committee has already addressed in the legislation that has become law.

Dr. PEARSON. That is where those materials should be handled, where they are relatively concentrated, at the source, by pretreatment or source control, yes; not after dilution in wastewater.

Mr. OBERSTAR. Thank you, Mr. Chairman.

[Whereupon, the Chairman assumed the Chair.]

The CHAIRMAN. Any other questions of Dr. Pearson?

[No response.]

The CHAIRMAN. I want to thank you, Dr. Pearson, for your responses here. If you will stay with us, I am sure there will be additional questions. Miss Kovalic?

Ms. KOVALIC. Thank you, Mr. Chairman.

Dr. Pearson, could you describe for us the relative characteristics of those marine environments that should be able to accept municipal wastewaters with something other than secondary treatment?

Dr. PEARSON. Well, many waters can accept wastewaters other than secondary treatment. What you simply need—or, let me put it the other way. You ought to be most concerned about where you put the waste. The first consideration is where in the environment are the characteristics most suitable for the statement you made, minimizing the effect.

Now, that is not just because of the hydrologic or hydrographic characteristic, but also where are the ecological values the least.

In other words, not put it where it is important in fishery or where it has the most obvious adverse effect; put it where it would have potentially the least effect. That is one thing.

Then, second, the conditions of, say, currents and water flow with which you have to dilute the waste. Remember, it has been said—some people advocate dilution is the solution to pollution. I am not advocating that. I am saying that whatever you do with waste treatment, you have got to ultimately dilute what you get into the environment. And you want to do that in the most effective way. So that, you want to put the waste in its most dilute form, in other words, the lowest concentration, which means mixing the waste stream, whatever it has, with the greatest flux of diluting water.

Now, this is also true in air pollution, you know. You put material in the air, and if you have high air flow, by dilution, you reduce effects. The same applies in waste.

So that the main feature, apart from the ecology in the area, which affects the site selection, is, of course, the physical and chemical aspects of the water environment. And you want a place where you have a lot of dilution. It does not necessarily have to be deep, like deep California, but you want a place where you have got a lot of water flow in which the mix, the residual waste, will reduce the concentration in the environment.

Ms. KOVALIC. In your opinion, do we know enough scientifically to be able to relate the marine conditions and the outfall diffuser design and whatever type of onshore treatment we would need in order to achieve what you are just describing?

Dr. PEARSON. Well, I think I can answer that, without any question, based on one California experience. Most of these outfalls that have been studied were designed and built, say, 10 to 20 years ago or more, by engineers that did not have a lot of scientific information.

But we had—they had—I participated in some of these—we had a pretty good perception of what the problems were and how to go at them. And the very fact that we have been able, through the southern California project, to study and show that there are relatively minimal effects—there are still some effects, but they are not resolved by secondary treatment; unrelated to secondary treatment.

The point I am making is we know enough about the problems to make a sensible design today. It is not going to ask the scientists' last word concern, but it is going to do a good job of protecting the environment. And we know how to manipulate those terms in that equation, when you talk about specific pollutants, that nobody can use secondary treatment as a key parameter in coming up with what is needed to predict concentrations in the environment. That is not a sensible approach.

Ms. KOVALIC. Well, do you think we can get the same effect on the marine environment by extending or deepening or redesigning an outfall as we would be able to get by adding biological or chemical processes and removing more suspended solids?

Dr. PEARSON. Well, again, this depends on what kind of problems might be associated with the water of concern. But if you are talking about those things associated with secondary treatment, yes, there is no question.

But you see, secondary treatment does nothing with PCB's or DDT's of any significant magnitude. It doesn't even do a good job of removing the trace metals that we are concerned about. It does not do anything about some of the other exotic organics that we have even dis-

covered in the southern California project, the chlorinated benzenes and other toxicants.

So my answer is, secondary treatment does not deal with the problems that are foremost in the minds of those who know something about the business and are trying to provide some sensible leadership in how to design systems.

Ms. KOVALIC. Can you describe some reasonable alternatives, say, between primary treatment and full secondary treatment, that could be cost effective and also could achieve some of the impacts you have described?

Dr. PEARSON. Well, I do not know whether I should mention this, because this does not fly very well in the United States. But let me just tell you about the problem in Italy.

The problem in Italy around the area from Trieste to Venice, in that whole Po River, 100-kilometer stretch, is essentially one of health hazards, associated with that they grow a lot of mussels, you know, in the coastal nearwaters, and people eat them; and second, it is very shallow waters. Say, it is down to maybe a kilometer or two; the depth is maybe 5 meters—some places less, some places 10 meters. So it is very shallow.

OK. The approach the Italians were sold—by people that presumably were to know—was build secondary treatment, and they built some of them. They found out that after building secondary treatment, they had more of a problem than they had before.

First of all, they concentrated all the waste at one point, and then they gave it secondary treatment. Well, without commenting on Italians, they are not what I would say the world's leaders in operating wastewater treatment plants, so that it suffered a little bit from operation. But, by providing secondary treatment, they put the waste essentially on the beach—no dilution—so it was essentially 100 percent right onshore, because it was, say, maybe a 5- or 10-meter pipe on the beach.

Correspondingly, that water was only partially treated, was highly enriched, because secondary treatment takes and transforms, say, nitrogen and phosphorus compounds that are bound in organic form to a mineralized, at least in part. So that it is more readily available as a nutrient after biological treatment than before.

So you put a highly nutrient-available waste on the beach and what happens? You get the most pea soup kind of a coastal zone you can imagine. In addition, secondary treatment does not do anything in taking out the disease organisms.

So anybody that knows anything about Italy, they have had a lot of problems along the Mediterranean, that destroyed their beaches. Nobody likes to swim in that putrified, shallow water.

Moreover, if you eat mussels out of there, you have got a hazard, because there is not much protection in reducing disease over there. In that part of the world, disease is not an insignificant problem, because they have outbreaks rather commonly. If you have traveled there, you may have had some experience with a mild form.

So this is one place where they have a lot of negative experience. How have they approached it? One year, one young engineer, who has a very good perception of the problem, has built in the last few years more than 20 dispersion systems that take the waste, not after second-

any treatment, but take the waste without treatment at all, other than crude screening, and disperse it out through a well-designed disperser, say, 1, 2, 3 kilometers offshore. The disperser—and most of these are relatively small systems—1 meter in size, but the dilution structures have holes in some cases as small as 2 centimeters in diameter, and the jet velocity is as high as 6 or 7 meters per second, 20 feet per second or more.

In other words, the sewage shoots out like a high velocity gun. It mixes the waste well with the shallow water. It reduces the concentration of everything that is in the waste, and correspondingly, since it is quite a ways offshore, it is not this shallow, 2, 3, 5 meters. It is out in the deeper water so that they get enough dilution so that they have been able to minimize the problem by just the discharge of untreated sewage, screened crudely, put in through the shallow water at offshore, with just a mixing system, by just using the dilution aspect of that expression. They did not take out any waste at all, and they relied, in this case, only on the dilution concept.

Now, I do not want to say that is the total solution, because the combination that is appropriate is some form of treatment that is needed, plus the proper dilution.

Ms. KOVALIC. You have given us this morning, I think, a very good description of some of the experiences of the European countries.

I am wondering, can we bring it a little bit closer to home—and I have just one more question. Can you compare for us some of the characteristics of the east coast and the west coast of the United States, according to factors such as the sensitivity of the marine life, the depth of the waters, and the kind of dilution and dispersion that would be required if an ocean outfall were to be constructed on either coast?

Dr. PEARSON. Well, I—how much time do I have to respond to that question?

Ms. KOVALIC. It is up to the chairman.

Dr. PEARSON. Well, first let me say, Los Angeles City, Hyperion, built back in the fifties, a high rate activated sludge treatment plant, a secondary plant such as is now required, and they put the effluent in Santa Monica Bay, through a 1-mile pipe, to my recollection. And it lasted 7 years before the conditions were so bad that there was actually a cease and desist order that you could not build in Los Angeles City because the bacterial concentration was high, but the principal problem was oil and grease on the beach. And the concern about this was mostly the housewives, because their children came back from the beach with tar on their feet, and they took a rather dim view of it.

They were not deeply concerned about the bacterial count, but the beaches were quarantined, because that was the legal mechanism to force a reevaluation.

Now, that was in the early fifties. The plant, I think, was built—I do not remember the numbers—say, 1949, 1950—you can correct the numbers; I cannot recall that well—but something like 6 or 7 years later, after building that plant which, as I recall, cost some \$40 million, the conditions were so bad on Santa Monica Bay that they had to go back and redesign the system.

And what did they do? They reduced the level of treatment, essentially, mostly to primary. They still have a fraction flow between secondary. But they went back to just primary treatment and built a

5-mile outfall with a good dispersion system which, as far as I know, is still working very well, and our studies show that it does.

So I am just saying the city of Los Angeles went through this themselves, and it seems to me we ought to have learned something about that and the problem there. And I was a consultant on that project, as well. The problem was from a legal standpoint; it was bacteria on the beach, but the real problem was oil and grease on the beach.

[Whereupn, Mr. Roberts assumed the Chair.]

Mr. ROBERTS. Thank you, Dr. Pearson.

We are pleased now to have Prof. John Isaacs, who is currently professor of oceanography at Scripps Institution of Oceanography and director of the statewide Institute of Marine Resources, University of California.

He is a member of the National Academy of Sciences, the National Academy of Engineering, and the World and American Academies of Arts and Sciences. He has worked with the State Department, the Ocean Affairs Advisory Committee, and he is a past president of the Pacific division of the Association for the Advancement of Science.

He has a long list of credits, which I will not attempt to read. Please proceed.

TESTIMONY OF PROF. JOHN D. ISAACS, DIRECTOR, INSTITUTE OF MARINE RESOURCES, UNIVERSITY OF CALIFORNIA, SAN DIEGO

Dr. ISAACS. Thank you, Mr. Chairman. Another decrepit member of the faculty of the University of California rises to these hearings.

As I understand my role in these hearings, it was to lend a broad perspective to the nature of marine trophic systems, particularly contrasting with the commonly accepted view, that in rivers and lakes, and also particularly as the characteristics of them relate to waste water effects in the open sea.

Mr. Chairman, members of the Subcommittee on Water Resources, my name is John D. Isaacs. I am a professor of oceanography in the University of California, at Scripps Institution of Oceanography and director of the statewide Institute of Marine Resources. In this capacity I also administer the California Sea Grant College program, the Food Chain Research Group, and other components of the institute.

I continue to carry out personal research on a variety of marine oriented scientific and technical matters. These interests and research projects include those in the areas of physical oceanography, climatology, resources, marine biology, pollution, marine microbiology, trophic systems, marine engineering of various sorts, and a number of others, even social scientific, as are indicated by a representative list of publications which has been supplied to the subcommittee. In addition, I can make a complete list available should the subcommittee wish.

I am a graduate of the University of California at Berkeley, and have been a member of the staff and faculty of the university for about 34 years. I have been elected to membership in the three academies—the National Academy of Science, the National Academy of Engineering, and the American Academy of Arts and Sciences.

However, my beginning interests in marine matters stemmed from nonacademic experience. My early years as a merchant seaman, the owner and operator of a deep sea fishing vessel off the Pacific coast, and

as an engineer in charge of naval base construction, have often guided me toward the applied.

I appear at the invitation of the subcommittee. My statement briefly sketches an overall perspective of the biological economy of the sea, contrasting it to the terrestrial and freshwater systems, pointing out from this contrast the serious ways in which the nature of the sea is commonly misunderstood, and commenting on the faulty perception of the system apparent in the regulations of the Environmental Protection Agency in their marine discharge policy and those misperceptions of the present proposed modification that is the subject of these hearings.

In a few minutes I will try to indicate the broader picture of how the forms and nature of the living systems of the sea have come to be, and particularly of the ways in which their sharp contrasts with the living systems of land have arisen and how these differences widely mislead us in our struggle to understand the impact of man's rapid emergence as a geophysical, geochemical, and biological force.

I will point out examples of these marine versus terrestrial contrasts and attempt to indicate some of the ways in which they often drive our research, our concerns, and our social and legal actions into irresponsible and unrewarding directions—directions that can be not only impressively expensive or even impoverishing but which may fail to profit from potential benefits of man's work.

The usual picture of the nature of the web of life of the sea is a more complex visualization of the trophic pyramid that is commonly thought to model the food pathways on land. In this imaginary textbook picture, plants initiate the cycle, and various herbivores, primary carnivores, secondary carnivores, are each born into their allotted niche in the pyramid, to constitute a vast, delicately balanced and tottering structure—a house of cards—ready to collapse into lifeless chaos with the slightest jiggling by the profane hand of man.

Regardless of the possible veracity of this picture in land, lake, and perhaps other special delicate or limited systems, it is the misapplication of this idealization to the living systems of the open sea that has misled us into an hysterical “the planet is dying and the sea is dead” syndrome and into irrational proposals and actions.

Actually, almost all of the creatures of the open sea are born into a highly variable and stochastic system, in which they have little assurance of the nature of their prey, predators, associates, or competitors during their span of existence. They find repast in anything grossly accessible to their mode of feeding, and are eaten by anything to which they are available. Individually and collectively as populations, they are opportunistic, unspecialized, and resilient.

Yet the hypothesis of the ordered pyramid of life persists. To paraphrase Niccolò Machiavelli, “An hypothesis is always more believable than the truth, for it has been tailored to resemble our ideas of truth whereas the truth is just its own clumsy self. Ergo, never discover the truth when an hypothesis will do.”

The terrestrial, marine, and freshwater systems have developed in adherence to the same great natural laws of physical, chemical, and biological evolution; in consequence of the same initial bequest of cosmic matter; and in response to the same broad episodes of solar and planetary evolution. Yet in the present stages of development, these

systems usually dramatically differ, and seldom coincide in their responses and vulnerability to the activities of man. The creatures of the sea are born, live, breathe, feed, excrete, move, grow, mate, reproduce, and die within a single interconnected medium. In land animals, however, many of these functions are largely separate between and within the three media of air, water, and soil that land creatures utilize. It is not in the terrestrial experience continuously to inhale the young, eggs, sperm, food, and excreta of all of our fellow creatures, as do essentially all marine organisms. Although it may seem repulsive to us, it, nevertheless, is the way of marine life.

The cycle of life in the sea, like that of the land, is fueled by the sun's luminous energy acting on the pigments of green plants. Of every 10,000 photons of light reaching Earth only some 5 enter into the net production of basic organic material. Perhaps 3 of these 10,000 photons contribute to the growth of land plants and 2 to the growth of the single-celled green plants of the sea, the phytoplankton.

It is at this first stage that the fundamental differences between the terrestrial and the marine organisms and life systems are initiated. The primary production of organic material on land is mainly conducted by large multicellular plants immersed in a light gas and attached and concentrated on solid surfaces, whereas the marine food material is first elaborated by microscopic cells, singly or in loose aggregations, which are dispersed widely in a dense, circulating, and liquid medium. Only along some rocky coasts, where large marine plants are conspicuous does the sea produce some relatively large herbivores in a single trophic step.

At every subsequent step in the two living game plans these initial differences are further complicated. I will have time to point out and sketch only a few examples of these differences, but my emphasis, of course, is that these differences must be recognized if we are not to be tragically misled in our attempts to deal with mankind's needs from the sea and man's effects in the oftentimes painful process of his accommodation on this planet.

The initial input of food in the form of microscopic dispersed particles imposes restrictions that influence the nature of oceanic life throughout its entire development. This condition has not only encouraged such developments as eyes in near microscopic forms and filters of a bewildering variety, but it has urged all creatures excepting the terrestrial expatriates—marine mammals and birds (and some sharks)—to produce their young in immature larval forms so that they have access to the much more abundant fine particulate food at the commencement and terminus of the trophic web. Most of these larval forms pass through a number of complex and often grotesque stages and suffer almost total mortality before some few rejoin the adult stocks. The results of this ubiquitous tactic of marine organisms are many and I will mention a few. First, reproduction, which imposes an inescapable material burden on all adult organisms and which may expend 50 percent or more of their potential growth, is subtracted from the population biomass of almost all marine creatures. The remnants of the original material of the reproductive products which persist in the developing adult are infinitesimal. In the marine realm essentially all of this material is thus thrown downward in the food web to the more primitive particulate and detrital feeders, and is one of the strong homog-

enizing influences in the marine food web, one that drives marine systems even more strongly toward particulate and detrital feeding. In sharp contrast, in the macroscopic land food web large herbivores feed on large plants, reproductive products are added to the population biomass, and the young soon partake of the adult food and are early susceptible to the adult predators and parasites.

Parenthetically, would we not find it a peculiar world if each wolf produced 1 million tiny wolf eggs dispersed widely in the winds to hatch into virtually unrecognizable wolf larvae, metamorphosing and growing in innumerable stages, early preyed upon by spiders, birds, and earthworms? And imagine the shepherd, dealing with a flock that not only produced 100 million barely visible young sheep larvae, but which also consumed young wolves in their grazing. It is just such almost unimaginable differences as these that sharply contrast the living system of the land and sea and that foster widespread misconceptions of the sea.

Implications of this difference in the two reproductive game plans are important, and some particularly so, in respect both to our employment of the oceans as a source of food and to our dealings with pollution of the marine environment.

For example, one class of usually worrisome contaminants is mutagens, those chemical agents that produce genetic changes. Since most mutations are undesirable, the creatures of the terrestrial system, with their limited number of progeny, are particularly vulnerable. However, for creatures that each produce a half million to one-half billion young as with most of the creatures of the sea, genetic defects appear to be naturally common. When marine fishes first were introduced into the Salton Sea of California, over 30 percent of their progeny were grossly defective with blind, even jawless adults being abundant. As soon as competition and predation developed in that sea, however, such defective adults disappeared. Similar conclusions can be drawn from as absence of genetic defects in the fishes of Bikini Atoll, subjected to millions of megacuries of highly mutagenic radioactive material in the mid-decade of this century. It is important to note that defective marine creatures can exist only where the environment is broadly out of balance, for example, where a selective fishery on a major predator has reduced predation. Otherwise, defective individuals are rapidly eliminated. This is a particularly instructive case, with their limited number of progeny, are particularly vulnerable, of some trace substances, as they are slower growing than the average. Thus the abnormal survival of a normal incidence of defective marine fish may be falsely interpreted as a problem of pollution, whereas in truth it may be the result of a selective fishery on quite a different species.

I will mention one more important case that ensues from the marine reproductive game plan. The organic pathways of the sea are largely conducted by immature and growing individuals who suffer immense mortality in this role. This is quite unlike the land, where young are a comparatively minor component of the biomass, mortality is low and adults dominate. This preponderance of growing individuals sets an important limit on the single step concentration factors for trace substances and contaminants that pass through the marine food web in ingested food. The effect, which is inadequately recognized,

can be stated as follows: a trace substance in food that is taken up by an organism is "diluted" by the new tissue that a growing organism is accumulating from the food. Thus, for example, if one quarter of the food is converted into new tissue, the upper limit of the single step concentration factor for such a trace substance in the organism is four. In nongrowing organisms such as adult land animals there exists no limit from this effect, the concentration factors can be tens or hundreds of thousands. It is this effect that undoubtedly has in part been responsible for the failure to demonstrate serious bioaccumulation of trace contaminants in marine creatures except in the nongrowing adult marine birds and mammals, such as gulls, seals and sea lions, which follow the terrestrial plan to a degree. This is not to say that these forms should not be protected, of course.

It is quite likely that this effect also has been responsible for the fact that fishes of the Mediterranean display somewhat higher levels of a number of trace substances than their Atlantic and Pacific counterparts, for the fishes of the Mediterranean are undoubtedly slower growing than the former, for the Mediterranean is a particularly unproductive and starving sea. It is also this effect that must be carefully considered in any interpretation of abnormalities in marine forms associated with elevated levels of trace substances in their tissue. The facts may be that the elevated levels are merely the result of slow growth due to undernourishment from impaired activity.

It is a fact that the seas of this planet hold only about one-tenth of the number of species of creatures that inhabit the land environment. *Prima facie* conclusions from this fact are that the sea holds fewer environmental niches, and that there are fewer specialists and more generalists and opportunists in the marine than in the land system. Another conclusion is that the trophic system of the sea cannot be the delicately balanced, structured trophic pyramid that is envisaged and idealized. Why should there be comparatively fewer species in the sea? I have discussed two homogenizing effects, the microscopic input of food and the wide dispersal of reproductive products (and detritus) which make it difficult for specialists to develop, particularly in the early stages of the food web, and which also makes most creatures similar as far as trace element composition is concerned.

As a measure of the comparative degrees of specialization possible in the two realms, we might contrast the 8,000 or so species of free-living copepods (a broad general link in the oceanic food web) with their terrestrial counterpart, the 800,000 or probably, 1 million species of land insects. As a result of these several effects, and as I said earlier, most creatures born into the sea have little assurance of the nature of their prey, predators, competitors, or associates. They are forced to be opportunistic.

I will have time to touch on only two other contrasts of the land and sea, the chemistry and the stability.

The sea has ever been a sink for the chemical materials leached from the land. Thus, it should be no surprise that the land and sea creatures differ sharply in their chemical needs, deficiencies, and susceptibilities. By definition, in a manner of speaking, if land animals find it necessary to concentrate some trace material from terrestrial sources, it is unlikely that sea creatures will find the material in abundance, for it has been leached from the land. Iodine, calcium, and salt

are examples. On the other hand, those trace materials the sea creatures must concentrate, such as zinc, copper, iron, and silica, are likely abundant on land, for the materials have been precipitated from seawater and incorporated again into the landmasses. Thus, both the chemical evolution of the sea and the biochemical evolution of its creatures cause almost totally opposed effects for most inorganic chemical trace substances introduced into the sea.

It is from the action of these dual principles that the bones of sheep, remote from nuclear contamination by almost half the circumference of the planet, contain a higher concentration of radioactive strontium than do the bones of Bikini fish, where millions of megacuries of fission products have been injected over the last two decades!

The penultimate point that I must make concerns the circulation, the chemistry, and the stability of the oceans, and the distribution of major plant nutrients, those materials—phosphate and nitrate—that are essential to all plant growth. On land these substances are taken up by plants and regenerated (or in some cases manufactured) from debris in the soil where they are readily available for recycling into the food web. In humid jungles, for example, the free nutrients in the soil are almost nonexistent, so rapid is the uptake by the plants. In the sea the same regenerative processes take place but much of it so far below the lighted levels of the sea, that only extraordinary conditions or events, such as upwelling, can elevate or mix the essential nutrients into the near surface layers where they can again be employed by plants to reinitiate the cycle of life. It is the peculiar nutrient cycle of the sea, and the sea's circulation and stability, that restrict highly productive regions of the oceans to less than 20 percent of its area. These factors condemn the oceans to a total organic production that is probably less than that of land, despite their far greater expanse, for most of it is on a starvation diet. Blue, the color of oceanic deserts, dominates the sea, even in relatively productive regions such as the Pacific coast.

Many countries bordering on the deep blue sea are planning extremely expensive and highly advanced municipal waste treatment plants, ostensibly to avoid "polluting" the sea with organic material and nutrients. In my mind, such plans reflect the serious misunderstanding of science and the misguidance of social action by a lack of appreciation of the nature of marine biological systems. They neglect these facts: that a major part of the adaptation and activity of the creatures of the sea is directed to the conversion of waste particulates into new organisms; that most of the sea is starving and particularly deficient in just those sorts of materials that are introduced by domestic waste; that seawater is a toxic material to most land organisms and highly inimical to their survival (apparently including wastewater pathogens); that the many parts of the sea are now even denied the millions of tons of organic material that once annually flowed from rivers (for the natural flows of these materials are now stopped by dams); that there is no evidence that the marine discharge of secondary effluent improves anything, and reasons to believe it may be more disturbing than any present practice; that the net changes engendered in the marine environment by present best primary discharge are an enrichment; that to expend vast sums of money for

the construction of advanced treatment plants for domestic waste to prevent feeding a starving sea may well be a wholly irresponsible act. Witness that the doubling of fisheries production in the North Sea over the last two decades is reluctantly being attributed to the input of domestic waste into that system.

I must, of course, immediately modify this statement. There must be adequate source control of chemical pollutants. It is insanity to introduce into the sea such levels of organic mercury or DDT as have been discharged into Minemata Bay in Japan and Whites Point in California in the past. Also, removal of floatable materials and other advanced primary treatment must be exercised, and properly designed offshore discharges must be used. There also must be continuous alertness and monitoring for important pollutants such as PCB or mutagenic compounds and mitotic poisons, like dioxin. But to urge devotion of immense amounts of precious capital for sophisticated treatment at the secondary, tertiary, or quaternary level, perhaps suitable for delicate lake or river environments, to avoid feeding the open sea, totally disregards, I believe, the true nature of the sea.

Indeed, to repeat, it is not clear that secondary treatment of domestic waste is a panacea for anything. In secondary effluent, trace metals and plant nutrients, are introduced in highly oxidized and highly available form. The toxicity of metals is closely related to their valence state, and it makes no sense at all to reduce the metal contents of a discharge by 60 percent or so at great difficulty and expense, only to increase the toxicity of these metals by factors of thousands or more. Chromium and mercury are cases in point, where the usual valence states are essentially nontoxic but the more oxidized states are violent poisons. The same applies to the plant nutrients, which in primary treated sewage are partly tied up in organic food and only slowly available after passage through the food web. In secondary effluent, these nutrients are in the raw form and rapidly stimulatory to plant growth. On land, one pays a high premium for "natural" fertilizers where the trace metals and nutrients are in organic form and only slowly released to the plants after decay in the soil. However, the chemical fertilizers, ammonium phosphate, for example, are far cheaper but far more difficult and dangerous to employ. It seems a strange aberration of logic to contemplate expensive steps that take a premium grade natural fertilizer and food, and degrade it into brash and toxic chemicals before discharge into the sea.

I have spoken at length with planners in other countries on these matters. Their ultimate point seems to be that they want to copy us! They want the best technology regardless of whether it is the right technology. Like the March Hare, in *Alice in Wonderland*, who, after having buttered the works of his pocket watch, could think of nothing better to say than: "It was the best butter, you know."

More generally, I believe that it is the responsibility of scientists objectively and openmindedly to investigate and understand; and of public servants to weigh the total research, knowledge, and understanding and to act on it with insight and perspective without regard for the hysteria of the movement. We have yet to learn how to support scientific research dealing with man's accommodation to this planet, and to take social action without first generating a popular hysteria that clouds the vision of scientists and engenders acts and regulations that

most often have no basis in research understanding nor even a basis in good judgment and probability.

There is a vast fund of important research results and understanding of the sea. This fund is a major resource. The responsible scientist and the responsible civil authority will act freshly on this knowledge, rather than blindly follow the "planet is dying and the oceans are dead" syndrome of hysterical actions.

Yet, in the United States, great sums of money have been expended in marine research, but to believe that the majority of regulatory actions of U.S. authorities on a wide range of marine problems are a rational result of the research findings, is a delusion.

This is truly a worldwide tragedy. No other country can conceivably duplicate the extensive research of the United States. A natural result is for other countries to conclude that our acts are the result of our understanding, and to copy them. Perhaps, we can afford this sort of irrational expenditure, but for some other countries it can only compound their bitter struggles.

With my conviction that the gulf that cleaves action and understanding is a most tragic syndrome of our times, it was with deepening sadness that I reviewed the EPA proposed modifications under consideration. Although the document does not reflect a bare suspicion that the open sea may have different characteristics than rivers and lakes, it directly or implicitly repeats the same old myths of the bioaccumulation of trace metals, the delicate balance of the marine environment, the all-healing properties of secondary sewage treatment, and many of the other clichés and misperceptions that already have led us to a serious estrangement from reality.

There is an abundance of similar cases, each somewhat different but each difficult or impossible to approach because the problem, if in fact there is one, has been defined too narrowly or erroneously or capriciously. Indeed, once these definitions have been recorded in the pristine and persistent tablets of law or policy, the enforcing or regulatory agency may specifically constrain any research that questions the validity of the supposed premises under which the law was established. The Marine Mammals Act, as administered, in effect eliminates the possibility of meaningful inquiries on the tuna-porpoise problem, just as the policy on domestic sewage effluent discharged into the open sea largely precludes research into its actual effects (for this also would question the presumptions of the law) despite the fact that these inputs appear mainly to be beneficial, contrary to the proclamations of Cousteau and Heyerdahl.

This is the most ominous cut of all, and many of the great regulatory and enforcement agencies in the United States are beginning to adopt the pose of the medieval churches, with regard not for what is true or right, but rather for what defends their notions of the intent of regulatory laws or their established policies and for what supports their own delusions of power, omniscience, and infallibility! The beleaguered scientist with evidence of the fallibility of these agencies, or the triviality of a program that they regulate, or of the underlying faults in their regulations can only recant his findings (if he wants any more research support) and content himself with the muttered aside: *Eppur si muove* ("nevertheless it moves")—as did Galileo, following his confrontation with the awesome forces of the hierarchy of his times.

One of the reasons for these excesses is that problems are our new frontier. We have come to value the problems more than the solutions. As Meg Greenfield recently pointed out, we tend to "colonize" them greeting each new problem, real or otherwise, as new and precious lands for settlement and a joyous, happy, and profitable existence. Shortly, such multitudes of research scientists, politicians, agencies, administrators and subsidized industries have joyously thronged to and colonized the problem that we daren't penetrate it very deeply lest it sink. In fact, much effort is spent in cultivation and refurbishment of the problem so that it continues to appear fresh, important, and worthy.

I submit that humankind will encounter a sufficiency of problems on our stumbling path toward an adjustment with this planet. We cannot afford to do other than dismiss or solve those we can and move onto newer lands. What that requires is the vision to perceive the nature of these new continents across new seas so that the colonials can be moved on. As Whitehead has said :

Here we are with our finite beings and physical senses in the presence of a universe whose possibilities are infinite, and even though we may not apprehend them, those infinite possibilities are actualities.

With few exceptions—and the proposed policy modification before you is not an exception—I truly see little that evokes joy whenever I approach the verge of that deep and unbridged gulf that now cleaves action from understanding.

It was mainly the challenge of the sea that lifted medieval European man out of the dark ages. His explorations of the oceans of this planet, his discoveries of continents, his development of navigational instruments and ships led to new confidence that he could surpass the accomplishments of the ancients and overcome the inadequacies of his institutions and the darkness of his times.

The sea again challenges our sciences and our institutions and again possesses the potential of leading us into a new and future world.

Surely we must strive to perceive that new and future world within the infinite possibilities of which Whitehead is so confident, lest ultimately, like Stevenson's Villon, we be found still doctoring toothache on the Judgment Day.

I have available to the subcommittee if you wish, a Scientific American offprint on "The Nature of Oceanic Life" that I published several years ago. I have used some extracts from this and others of my publications in the foregoing statement.

I thank you for your interest and for the privilege of presenting my thoughts to you on this important issue.

[The following was received for the record:]

THE NATURE OF OCEANIC LIFE

The conditions of the marine environment have given rise to a food web in which the dominant primary production of organic matter is carried out by microscopic plants

by John D. Isaacs

I plan to take the reader on a brief tour of marine life from the surface layers of the open sea, down through the intermediate layers to the deep-sea floor, and from there to the living communities on continental shelves and coral reefs. Like Dante, I shall be able to record only a scattered sampling of the races and inhabitants of each region and to point out only the general dominant factors that typify each domain; in particular I shall review some of the conditions, principles and interactions that appear to have molded the forms of life in the sea and to have established their range and compass.

The organisms of the sea are born, live, breathe, feed, excrete, move, grow, mate, reproduce and die within a single interconnected medium. Thus interactions among the marine organisms and interactions of the organisms with the chemical and physical processes of the sea range across the entire spectrum from simple, adamant constraints to complex effects of many subtle interactions.

Far more, of course, is known about the life of the sea than I shall be able even to suggest, and there are yet to be achieved great steps in our knowledge of the living entities of the sea. I shall mention some of these possibilities in my concluding remarks.

A general discussion of a living system should consider the ways in which plants

elaborate basic organic material from inorganic substances and the successive and often highly intricate steps by which organisms then return this material to the inorganic reservoir. The discussion should also show the forms of life by which such processes are conducted. I shall briefly trace these processes through the regions I have indicated, returning later to a more detailed discussion of the living forms and their constraints.

Some organic material is carried to the sea by rivers, and some is manufactured in shallow water by attached plants. More than 90 percent of the basic organic material that fuels and builds the life in the sea, however, is synthesized within the lighted surface layers of open water by the many varieties of phytoplankton. These sunny pastures of plant cells are grazed by the herbivorous zooplankton (small planktonic animals) and by some small fishes. These in turn are prey to various carnivorous creatures, large and small, who have their predators also.

The debris from the activities in the surface layers settles into the dimly lighted and unlighted midlayers of the sea, the twilight mesopelagic zone and the midnight bathypelagic zone, to serve as one source of food for their strange inhabitants. This process depletes the

surface layers of some food and particularly of the vital plant nutrients, or fertilizers, that become trapped below the surface layers, where they are unavailable to the plants. Food and nutrients are also actively carried downward from the surface by vertically migrating animals.

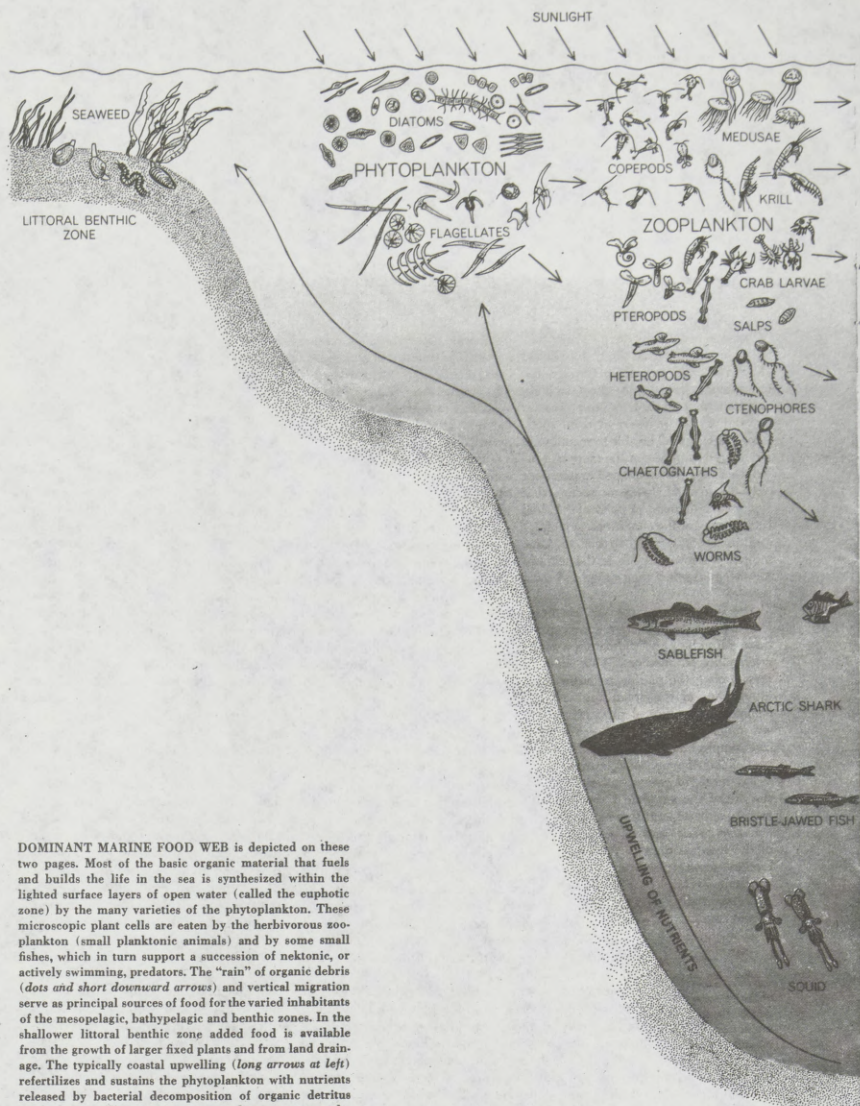
The depleted remnants of this constant "rain" of detritus continue to the sea floor and support those animals that live just above the bottom (epibenthic animals), on the bottom (benthic animals) and burrowed into the bottom. Here filter-feeding and burrowing (deposit-feeding) animals and bacteria rework the remaining refractory particles. The more active animals also find repast in mid-water creatures and in the occasional falls of carcasses and other larger debris. Except in unusual small areas there is an abundance of oxygen in the deep water, and the solid bottom presents advantages that allow the support of a denser population of larger creatures than can exist in deep mid-water.

In shallower water such as banks, atolls, continental shelves and shallow seas conditions associated with a solid bottom and other regional modifications of the general regime enable rich populations to develop. Such areas constitute about 7 percent of the total area of the ocean. In some of these regions added food results from the growth of large fixed plants and from land drainage.

With the above bare recitation for general orientation, I shall now discuss these matters in more detail.

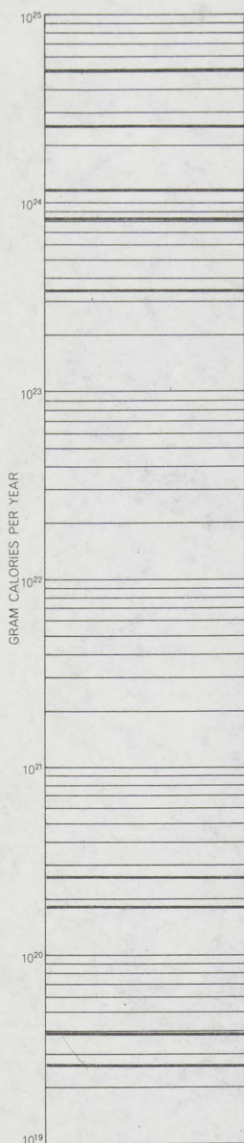
The cycle of life in the sea, like that on land, is fueled by the sun's visible light acting on green plants. Of every million photons of sunlight reaching the earth's surface, some 90 enter into the net production of basic food. Perhaps 50 of the 90 contribute to the growth of

NEW EVIDENCE that an abundance of large active fishes inhabit the deep-sea floor was obtained recently by the author and his colleagues in the form of photographs such as the one on the opposite page. The photograph was made by a camera hovering over a five-gallon bait can at a depth of 1,400 meters off Lower California. The diagonal of the bait can measures a foot. The larger fish are mostly rat-tailed grenadiers and sablefish. The fact that large numbers of such fish are attracted almost immediately to the bait suggests that two rather independent branches of the marine food web coexist in support of the deep-bottom creatures by dead material: the rain of fine detritus, which supports a variety of attached filter-feeding and burrowing organisms, and rare, widely separated falls of large food fragments, which support active creatures adapted to the discovery and utilization of such food.



DOMINANT MARINE FOOD WEB is depicted on these two pages. Most of the basic organic material that fuels and builds the life in the sea is synthesized within the lighted surface layers of open water (called the euphotic zone) by the many varieties of the phytoplankton. These microscopic plant cells are eaten by the herbivorous zooplankton (small planktonic animals) and by some small fishes, which in turn support a succession of nektonic, or actively swimming, predators. The "rain" of organic debris (dots and short downward arrows) and vertical migration serve as principal sources of food for the varied inhabitants of the mesopelagic, bathypelagic and benthic zones. In the shallower littoral benthic zone added food is available from the growth of larger fixed plants and from land drainage. The typically coastal upwelling (long arrows at left) refertilizes and sustains the phytoplankton with nutrients released by bacterial decomposition of organic detritus on the bottom. The organisms are not drawn to same scale.





land plants and about 40 to the growth of the single-celled green plants of the sea, the phytoplankton [see illustration at left]. It is this minute fraction of the sun's radiant energy that supplies the living organisms of this planet not only with their food but also with a breathable atmosphere.

The terrestrial and marine plants and animals arose from the same sources, through similar evolutionary sequences and by the action of the same natural laws. Yet these two living systems differ greatly at the stage in which we now view them. Were we to imagine a terrestrial food web that had developed in a form limited to that of the open sea, we would envision the land populated predominantly by short-lived simple plant cells grazed by small insects, worms and snails, which in turn would support a sparse predaceous population of larger insects, birds, frogs and lizards. The population of still larger carnivores would be a small fraction of the populations of large creatures that the existing land food web can nurture, because organisms in each of these steps pass on not more than 15 percent of the organic substance.

In some important respects this imaginary condition is not unlike that of the dominant food web of the sea, where almost all marine life is sustained by microscopic plants and near-microscopic herbivores and carnivores, which pass on only a greatly diminished supply of food to sustain the larger, more active and more complex creatures. In other respects the analogy is substantially inaccurate, because the primary marine food production is carried out by cells dispersed widely in a dense fluid medium.

This fact of an initial dispersal imposes a set of profound general conditions on all forms of life in the sea. For comparison, the concentration of plant food in a moderately rich grassland is of the order of a thousandth of the volume of the gross space it occupies and of the order of half of the mass of the air in which it is immersed. In moderately rich areas of the sea, on the other hand, food

is hundreds of times more dilute in volume and hundreds of thousands of times more dilute in relative mass. To crop this meager broth a blind herbivore or a simple pore in a filtering structure would need to process a weight of water hundreds of thousands of times the weight of the cell it eventually captures. In even the densest concentrations the factor exceeds several thousands, and with each further step in the food web dilution increases. Thus from the beginnings of the marine food web we see many adaptations accommodating to this dilution: eyes in microscopic herbivorous animals, filters of exquisite design, mechanisms and behavior for discovering local concentrations, complex search gear and, on the bottom, attachments to elicit the aid of moving water in carrying out the task of filtration. All these adaptations stem from the conditions that limit plant life in the open sea to microscopic dimensions.

It is in the sunlit near-surface of the open sea that the unique nature of the dominant system of marine life is irrevocably molded. The near-surface, or mixed, layer of the sea varies in thickness from tens of feet to hundreds depending on the nature of the general circulation, mixing by winds and heating [see "The Atmosphere and the Ocean," by R. W. Stewart; SCIENTIFIC AMERICAN, September, 1969]. Here the basic food production of the sea is accomplished by single-celled plants. One common group of small phytoplankton are the coccolithophores, with calcareous plates, a swimming ability and often an oil droplet for food storage and buoyancy. The larger microscopic phytoplankton are composed of many species belonging to several groups: naked algal cells, diatoms with complex shells of silica and actively swimming and rotating flagellates. Very small forms of many groups are also abundant and collectively are called nanoplankton.

The species composition of the phytoplankton is everywhere complex and varies from place to place, season to season and year to year. The various regions of the ocean are typified, however, by

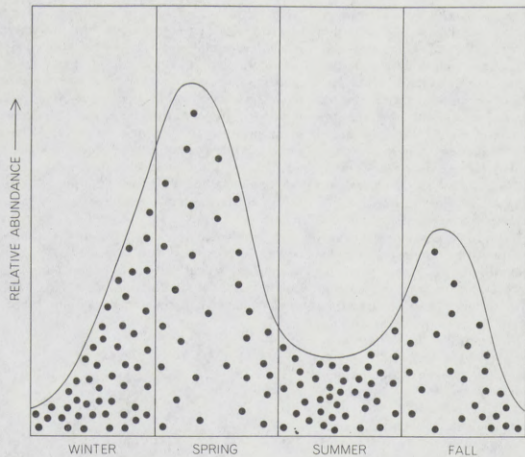
PRODUCTIVITY of the land and the sea are compared in terms of the net amount of energy that is converted from sunlight to organic matter by the green cells of land and sea plants. Colored lines denote total energy reaching the earth's upper atmosphere (a), total energy reaching earth's surface (b), total energy usable for photosynthesis (c), total energy usable for photosynthesis at sea (d), total energy usable for photosynthesis on land (e), net energy used for photosynthesis on land (f), net energy used for photosynthesis at sea (g), net energy used by land herbivores (h) and net energy used by sea herbivores (i). Although more sunlight falls on the sea than on the land (by virtue of the sea's larger surface area), the total land area is estimated to outproduce the total sea area by 25 to 50 percent. This is primarily due to low nutrient concentrations in the euphotic zone and high metabolism in marine plants. The data are from Walter R. Schmitt of Scripps Institution of Oceanography.

dominant major groups and particular species. Seasonal effects are often strong, with dense blooms of phytoplankton occurring when high levels of plant nutrients suddenly become usable or available, such as in high latitudes in spring or along coasts at the onset of upwelling. The concentration of phytoplankton varies on all dimensional scales, even down to small patches.

It is not immediately obvious why the dominant primary production of organic matter in the sea is carried out by microscopic single-celled plants instead of free-floating higher plants or other intermediate plant forms. The question arises: Why are there no pelagic "trees" in the ocean? One can easily compute the advantages such a tree would enjoy, with its canopy near the surface in the lighted levels and its trunk and roots extending down to the nutrient-rich waters under the mixed layer. The answer to this fundamental question probably has several parts. The evolution of plants in the pelagic realm favored smallness rather than expansion because the mixed layer in which these plants live is quite homogeneous; hence small incremental extensions from a plant cell cannot aid it in bridging to richer sources in order to satisfy its several needs.

On land, light is immediately above the soil and nutrients are immediately below; thus any extension is of immediate benefit, and the development of single cells into higher erect plants is able to follow in a stepwise evolutionary sequence. At sea the same richer sources exist but are so far apart that only a very large ready-made plant could act as a bridge between them. Although such plants could develop in some other environment and then adapt to the pelagic conditions, this has not come about. It is difficult to see how such a plant would propagate anyway; certainly it could not propagate in the open sea, because the young plants there would be at a severe disadvantage. In the sea small-scale differential motions of water are rapidly damped out, and any free-floating plant must often depend on molecular diffusion in the water for the uptake of nutrients and excretion of wastes. Smallness and self-motion are then advantageous, and a gross structure of cells cannot exchange nutrients or wastes as well as the same cells can separately or in open aggregations.

In addition the large-scale circulation of the ocean continuously sweeps the pelagic plants out of the region to which they are best adapted. It is essential that some individuals be returned to renew



SPECIES COMPOSITION AND ABUNDANCE of the phytoplankton varies from season to season, particularly at high latitudes. During the winter the turbulence caused by storms replenishes the supply of nutrients in the surface layers. During this period flagellates (black dots) tend to dominate. In early spring the increase in the amount of sunlight reaching the surface stimulates plant growth, and diatoms (colored dots) are stimulated to grow. Later in spring grazing by zooplankton and a decrease in the supply of nutrients caused by calmer weather result in a general reduction in the phytoplankton population, which reaches a secondary minimum in midsummer, during which time flagellates again dominate. The increased mixing caused by early autumn storms causes a rise in the supply of nutrients and a corresponding minor surge in the population of diatoms. The decreasing sunlight of late fall and grazing by zooplankton again reduce the general level of the plant population.

the populations. More mechanisms for this essential return exist for single-celled plants than exist for large plants, or even for any conventional spores, seeds or juveniles. Any of these can be carried by oceanic gyres or diffused by large-scale motions of surface eddies and periodic counterflow, but single-celled plants can also ride submerged counter-currents while temporarily feeding on food particles or perhaps on dissolved organic material. Other mechanisms of distribution undoubtedly are also occasionally important. For example, living marine plant cells are carried by storm-borne spray, in bird feathers and by well-fed fish and birds in their undigested food.

No large plant has solved the many problems of development, dispersal and reproduction. There are no pelagic trees, and these several factors in concert therefore restrict the open sea in a profound way. They confine it to an initial food web composed of microscopic forms, whereas larger plants live attached only to shallow bottoms (which

comprise some 2 percent of the ocean area). Attached plants, unlike free-floating plants, are not subject to the aforementioned limitations. For attached plants all degrees of water motion enhance the exchange of nutrients and wastes. Moreover, their normal population does not drift, much of their reproduction is by budding, and their spores are adapted for rapid development and settlement. Larger plants too are sometimes found in nonreproducing terminal accumulations of drifting shore plants in a few special convergent deep-sea areas such as the Sargasso Sea.

Although species of phytoplankton will populate only regions with conditions to which they are adapted, factors other than temperature, nutrients and light levels undoubtedly are important in determining the species composition of phytoplankton populations. Little is understood of the mechanisms that give rise to an abundance of particular species under certain conditions. Grazing herbivores may consume only a part of

the size range of cells, allowing certain sizes and types to dominate temporarily. Little is understood of the mechanisms that give rise to an abundance of particular species under certain conditions. Chemical by-products of certain species probably exclude certain other species. Often details of individual cell behavior are probably also important in the introduction and success of a species in a particular area. In some cases we can glimpse what these mechanisms are.

For example, both the larger diatoms and the larger flagellates can move at appreciable velocities through the water. The diatoms commonly sink downward, whereas the flagellates actively swim upward toward light. These are probably patterns of behavior primarily for increasing exchange, but the interaction of such unidirectional motions with random turbulence or systematic convective motion is not simple, as it is with an inactive particle. Rather, we would expect diatoms to be statistically abundant in upward-moving water and to sink out of the near-surface layers when turbulence or upward convection is low.

Conversely, flagellates should be statistically more abundant in downwelling water and should concentrate near the surface in low turbulence and slow downward water motions. These effects seem to exist. Off some continental coasts in summer flagellates may eventually collect in high concentrations. As they begin to shade one another from the light, each individual struggles closer to the lighted surface, producing such a high density that large areas of the water are turned red or brown by their pigments. The concentration of flagellates in these "red tides" sometimes becomes too great for their own survival. Several species of flagellates also become highly toxic as they grow older. Thus they sometimes both produce and participate in a mass death of fish and invertebrates that has been known to give rise to such a high yield of hydrogen sulfide as to blacken the white houses of coastal cities.

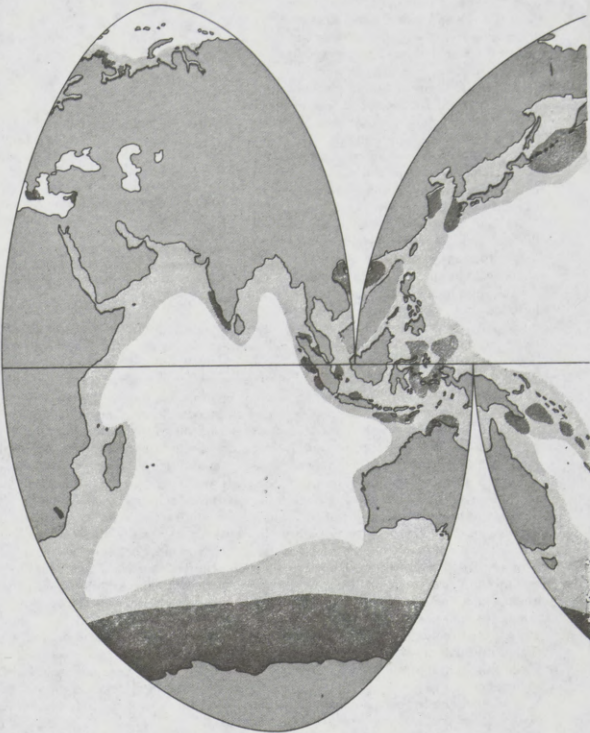
Large diatom cells, on the other hand, spend a disproportionately greater time in upward-moving regions of the water and an unlimited time in any region where the upward motion about equals their own downward motion. (The support of unidirectionally moving objects by contrary environmental motion is observed in other phenomena, such as the production of rain and hail.) Diatom cells are thus statistically abundant in upwelling water, and the distribution of diatoms probably is often a reflection of the turbulent-convective regime of the water. Sinking and the dependence of

the larger diatoms on upward convection and turbulence for support aids them in reaching upwelling regions, where nutrients are high; it helps to explain their dominance in such regions and such other features of their distribution as their high proportion in rich ocean regions and their frequent inverse occurrence with flagellates. Differences in adaptations to the physical and chemical conditions, and the release of chemical products, probably reinforce such relations.

In some areas, such as parts of the equatorial current system and shallow seas, where lateral and vertical circulation is rapid, the species composition of phytoplankton is perhaps more simply

a result of the inherent ability of the species to grow, survive and reproduce under the local conditions of temperature, light, nutrients, competitors and herbivores. Elsewhere second-order effects of the detailed cell behavior often dominate. Those details of behavior that give rise to concentrations on any dimensional scale are particularly important to all subsequent steps in the food chain.

All phytoplankton cells eventually settle from the surface layers. The depletion of nutrients and food from the surface layers takes place continuously through the loss of organic material, plant cells, molts, bodies of animals, fecal pellets and so forth, which release their content of chemical nutrients at



FAVORABLE CONDITIONS for the growth of phytoplankton occur wherever upwelling or mixing tends to bring subsurface nutrients up to the euphotic layer of the ocean. This map,

various depths through the action of bacteria and other organisms. The periodic downward migration of zooplankton further contributes to this loss.

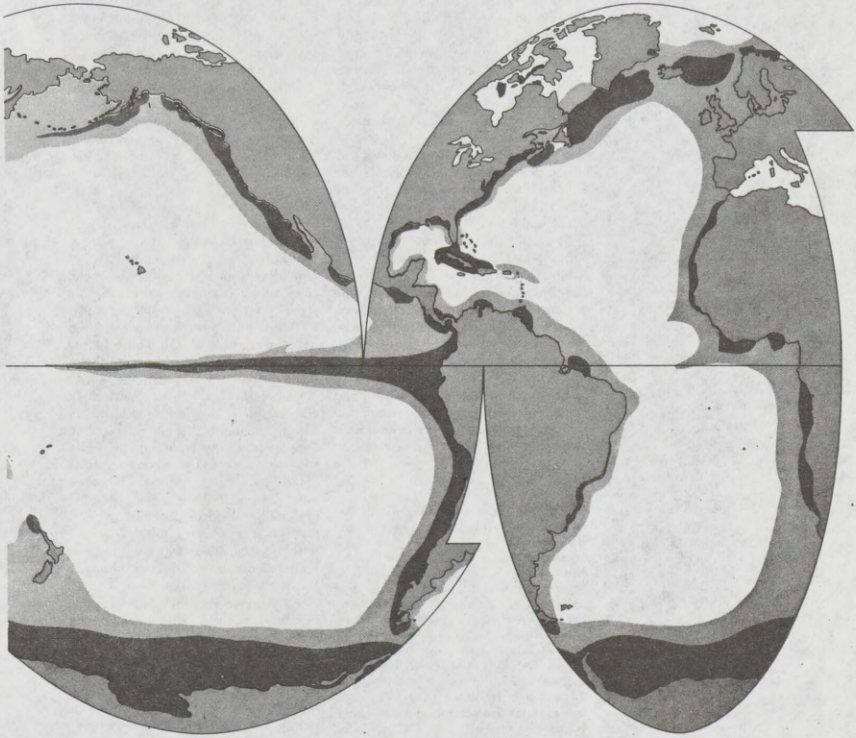
These nutrients are "trapped" below the level of light adequate to sustain photosynthesis, and therefore the water in which plants must grow generally contains very low concentrations of such vital substances. It is this condition that is principally responsible for the comparatively low total net productivity of the sea compared with that of the land. The regions where trapping is broken down or does not exist—where there is upwelling of nutrient-rich water along coasts, in parts of the equatorial regions, in the wakes of islands and banks and in high

latitudes, and where there is rapid recirculation of nutrients over shallow shelves and seas—locally bear the sea's richest fund of life.

The initial factors discussed so far have placed an inescapable stamp on the form of all life in the open sea, as irrevocably no doubt as the properties and distribution of hydrogen have dictated the form of the universe. These factors have limited the dominant form of life in the sea to an initial microscopic sequence that is relatively unproductive, is stimulated by upwelling and mixing and is otherwise altered in species composition and distribution by physical, chemical and biological processes on all dimensional scales. The same factors also

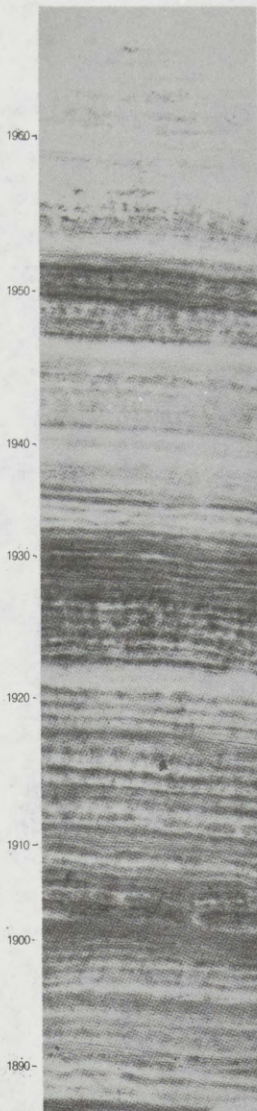
limit the populations of higher animals and have led to unexpectedly simple adaptations, such as the sinking of the larger diatoms as a tactic to solve the manifold problems of enhancing nutrient and waste exchange, finding nutrients, remaining in the surface waters and repopulating.

The grazing of the phytoplankton is principally conducted by the herbivorous members of the zooplankton, a heterogeneous group of small animals that carry out several steps in the food web as herbivores, carnivores and detrital (debris-eating) feeders. Among the important members of the zooplankton are the arthropods, animals with external



which is adapted from one compiled by the Norwegian oceanographer Harald U. Sverdrup, shows the global distribution of such

waters, in which the productivity of marine life would be expected to be very high (dark color) and moderately high (light color).



skeletons that belong to the same broad group as insects, crabs and shrimps. The planktonic arthropods include the abundant copepods, which are in a sense the marine equivalent of insects. Copepods are represented in the sea by some 10,000 or more species that act not only as herbivores, carnivores or detrital feeders but also as external or even internal parasites! Two or three thousand of these species live in the open sea. Other important arthropods are the shrimplike euphausiids, the strongest vertical migrators of the zooplankton. They compose the vast shoals of krill that occur in high latitudes and that constitute one of the principal foods of the baleen whales. The zooplankton also include the strange bristle-jawed chaetognaths, or arrow-worms, carnivores of mysterious origin and affinities known only in the marine environment. Widely distributed and abundant, the chaetognaths are represented by a surprisingly small number of species, perhaps fewer than 50. Larvae of many types, worms, medusae (jellyfish), ctenophores (comb jellies), gastropods (snails), pteropods and heteropods (other pelagic mollusks), salps, unpigmented flagellates and many others are also important components of this milieu, each with its own remarkably complex and often bizarre life history, behavior and form.

The larger zooplankton are mainly carnivores, and those of herbivorous habit are restricted to feeding on the larger plant cells. Much of the food supply, however, exists in the form of very small particles such as the nanoplankton, and these appear to be available almost solely to microscopic creatures. The immense distances between plant cells, many thousands of times their diameter, place a great premium on the development of feeding mechanisms that avoid the simple filtering of water

through fine pores. The power necessary to maintain a certain rate of flow through pores or nets increases inversely at an exponential rate with respect to the pore or mesh diameter, and the small planktonic herbivores, detrital feeders and carnivores show many adaptations to avoid this energy loss. Eyesight has developed in many minute animals to make possible selective capture. A variety of webs, bristles, rakes, combs, cilia and other structures are found, and they are often sticky. Stickiness allows the capture of food that is finer than the interspaces in the filtering structures, and it greatly reduces the expenditure of energy.

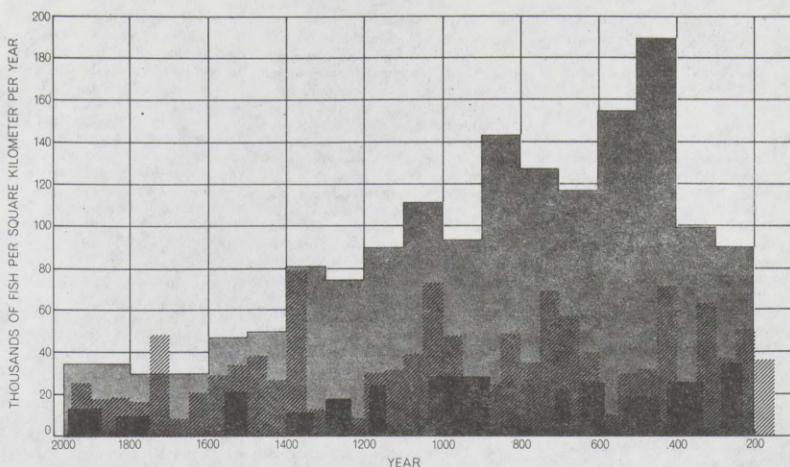
A few groups have developed extremely fine and apparently quite effective nets. One group that has accomplished this is the Larvacea. A larvacean produces and inhabits a complex external "house," much larger than its owner, that contains a system of very finely constructed nets through which the creature maintains a gentle flow [see illustration on page 12]. The Larvacea have apparently solved the problem of energy loss in filtering by having proportionately large nets, fine strong threads and a low rate of flow.

The composition of the zooplankton differs from place to place, day to night, season to season and year to year, yet most species are limited in distribution, and the members of the planktonic communities commonly show a rather stable representation of the modes of life.

The zooplankton are, of course, faced with the necessity of maintaining breeding assemblages and, like the phytoplankton, with the necessity of establishing a reinoculation of parent waters. In addition, their behavior must lead to a correspondence with their food and to the pattern of large-scale and small-scale spottiness already imposed on the marine realm by the phytoplankton. The swimming powers of the larger zooplankton are quite adequate for finding local small-scale patches of food. That this task is accomplished on a large scale is indirectly demonstrated by the observed correspondence between the quantities of zooplankton and the plant nutrients in the surface waters. How this large-scale task is accomplished is understood for some groups. For example, some zooplankton species have been shown to descend near the end of suitable conditions at the surface and to take temporary residence in a submerged countercurrent that returns them upstream.

There are many large and small puzzles

RARE SEDIMENTARY RECORD of the recent annual oceanographic, meteorological and biological history of part of a major oceanic system is revealed in this radiograph of a section of an ocean-bottom core obtained by Andrew Soutar of the Scripps Institution of Oceanography in the Santa Barbara Basin off the California coast. In some near-shore basins such as this one the absence of oxygen causes refractory parts of the organic debris to be left undecomposed and the sediment to remain undisturbed in the annual layers called varves. The dark layers are the densest and represent winter sedimentation. The lighter and less dense layers are composed mostly of diatoms and represent spring and summer sedimentation.



ESTIMATED FISH POPULATIONS in the Santa Barbara Basin over the past 1,800 years were obtained for three species by counting the average number of scales of each species in the varves of

the core shown on the opposite page. Minimum population estimates for fish one year old and older are given for Pacific sardines (grey), northern sardines (colored areas) and Pacific hake (hatched).

zles in the distribution of zooplankton. As an example, dense concentrations of phytoplankton are often associated with low populations of zooplankton. These are probably rapidly growing blooms that zooplankton have not yet invaded and grazed on, but it is not completely clear that this is so. Chemical repulsion may be involved.

The concentration of larger zooplankton and small fish in the surface layers is much greater at night than during the day, because of a group of strongly swimming members that share their time between the surface and the mesopelagic region. This behavior is probably primarily a tactic to enjoy the best of two worlds: to crop the richer food developing in the surface layers and to minimize mortality from predation by remaining always in the dark, like timid rabbits emerging from the thicket to graze the nighttime fields, although still in the presence of foxes and ferrets. Many small zooplankton organisms also make a daily migration of some vertical extent.

In addition to its primary purpose daily vertical migration undoubtedly serves the migrating organisms in a number of other ways. It enables the creatures to adjust their mean temperature, so that by spending the days in cooler water the amount of food used during

rest is reduced. Perhaps such processes as the rate of egg development are also controlled by these tactics. Many land animals employ hiding behavior for similar kinds of adjustment. Convincing arguments have also been presented to show that vertical migration serves to maintain a wide range of tolerance in the migrating species, so that they will be more successful under many more conditions than if they lived solely in the surface layers. This migration must also play an important part in the distribution of many species. Interaction of the daily migrants with the water motion produced by daily land-sea breeze alternation can hold the migrants offshore by a kind of "rectification" of the oscillating water motion. More generally, descent into the lower layers increases the influence of submerged countercurrents, thereby enhancing the opportunity to return upstream, to enter upwelling regions and hence to find high nutrient levels and associated high phytoplankton productivity.

Even minor details of behavior may strongly contribute to success. Migrants spend the day at a depth corresponding to relatively constant low light levels, where the movement of the water commonly is different from that at the surface. Most of the members rise some-

what even at the passage of a cloud shadow. Should they be carried under the shadow of an area rich in phytoplankton, they migrate to shallower depths, thereby often decreasing or even halting their drift with respect to this rich region to which they will ascend at night. Conversely, when the surface waters are clear and lean, they will migrate deeper and most often drift relatively faster.

We might simplistically view the distribution of zooplankton, and phytoplankton for that matter, as the consequence of a broad inoculation of the oceans with a spectrum of species, each with a certain adaptive range of tolerances and a certain variable range of feeding, reproducing and migrating behavior. At some places and at some times the behavior of a species, interacting even in detailed secondary ways with the variable conditions of the ocean and its other inhabitants, results in temporary, seasonal or persistent success.

There are a few exceptions to the microscopic dimensions of the herbivores in the pelagic food web. Among these the herrings and herring-like fishes are able to consume phytoplankton as a substantial component of their diet. Such an adaptation gives these fishes access to many times the food supply of the more

carnivorous groups. It is therefore no surprise that the partly herbivorous fishes comprise the bulk of the world's fisheries [see "The Food Resources of the Ocean," by S. J. Holt; *SCIENTIFIC AMERICAN*, September, 1969].

The principal food supplies of the pelagic populations are passed on in incremental steps and rapidly depleted quantity to the larger carnivorous zooplankton, then to small fishes and squids, and ultimately to the wide range of larger carnivores of the pelagic realm. In this region without refuge, either powerful static defenses, such as the stinging cells of the medusae and men-o'-war, or increasing size, acuity, alertness, speed and strength are the requirements for survival at each step. Streamlining of form here reaches a high point of development, and in tropical waters it is conspicuous even in small fishes, since the lower viscosity of the warmer waters will enable a highly streamlined small prey to escape a poorly streamlined predator, an effect that exists only for fishes of twice the length in cold, viscous, arctic or deep waters.

The pelagic region contains some of the largest and most superbly designed creatures ever to inhabit this earth: the exquisitely constructed pelagic tunas; the multicolored dolphins; the great flying fishes; the conversational porpoises; the shallow- and deep-feeding swordfishes and toothed whales, and the greatest carnivores of all, the baleen whales and some plankton-eating sharks, whose prey are entire schools of krill or small fishes. Seals and sea lions feed far into the pelagic realm. In concert with

these great predators, large carnivorous sharks await injured prey. Marine birds, some adapted to almost continuous pelagic life, consume surprising quantities of ocean food, diving, plunging, skimming and gulping in pursuit. Creatures of this region have developed such faculties as advanced sonar, unexplained senses of orientation and homing, and extreme olfactory sensitivity.

These larger creatures of the sea commonly move in schools, shoals and herds. In addition to meeting the needs of mating such grouping is advantageous in both defensive and predatory strategy, much like the cargo-ship convoy and submarine "wolf pack" of World War II. Both defensive and predatory assemblages are often complex. Small fishes of several species commonly school together. Diverse predators also form loosely cooperative groups, and many species of marine birds depend almost wholly on prey driven to the surface by submerged predators.

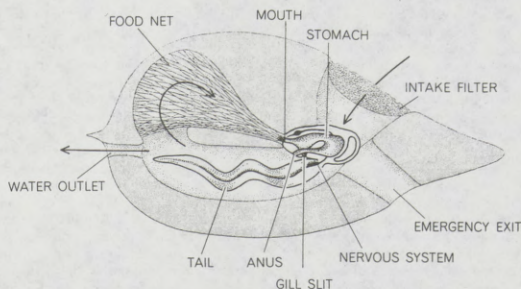
At night, schools of prey and predators are almost always spectacularly illuminated by bioluminescence produced by the microscopic and larger plankton. The reason for the ubiquitous production of light by the microorganisms of the sea remains obscure, and suggested explanations are controversial. It has been suggested that light is a kind of inadvertent by-product of life in transparent organisms. It has also been hypothesized that the emission of light on disturbance is advantageous to the plankton in making the predators of the plankton conspicuous to their predators! Unquestionably it does act this way. Indeed, some fisheries base the detection of their prey on

the bioluminescence that the fish excite. It is difficult, however, to defend the thesis that this effect was the direct factor in the original development of bioluminescence, since the effect was of no advantage to the individual microorganism that first developed it. Perhaps the luminescence of a microorganism also discourages attack by the light-avoiding zooplankton and is of initial survival benefit to the individual. As it then became general in the population, the effect of revealing plankton predators to their predators would also become important.

The fallout of organic material into the deep, dimly lighted mid-water supports a sparse population of fishes and invertebrates. Within the mesopelagic and bathypelagic zones are found some of the most curious and bizarre creatures of this earth. These range from the highly developed and powerfully predaceous intruders, toothed whales and swordfishes, at the climax of the food chain, to the remarkable squids, octopuses, euphausiids, lantern fishes, gulpers and anglerfishes that inhabit the bathypelagic region.

In the mesopelagic region, where some sunlight penetrates, fishes are often countershaded, that is, they are darker above and lighter below, as are surface fishes. Many of the creatures of this dimly lighted region participate in the daily migration, swimming to the upper layers at evening like bats emerging from their caves. At greater depths, over a half-mile or so, the common inhabitants are often darkly pigmented, weak-bodied and frequently adapted to unusual feeding techniques. Attraction of prey by luminescent lures or by mimicry of small prey, greatly extensible jaws and expandable abdomens are common. It is, however, a region of Lilliputian monsters, usually not more than six inches in length, with most larger fishes greatly reduced in musculature and weakly constructed.

There are some much larger, stronger and more active fishes and squids in this region, although they are not taken in trawls or seen from submersibles. Knowledge of their existence comes mainly from specimens found in the stomach of sperm whales and swordfish. They must be rare, however, since the slow, conservative creatures that are taken in trawls could hardly coexist with large numbers of active predators. Nevertheless, populations must be sufficiently large to attract the sperm whales and swordfish. There is evidence that the sperm whales possess highly developed long-range hunting sonar. They may lo-



LARVICIAN is representative of a group of small planktonic herbivores that has solved the problem of energy loss in filtering, apparently without utilizing "stickiness," by having proportionately large nets, strong fine threads and a low rate of water flow. The larvician (black) produces and inhabits a complex external "house" (color), much larger than its owner, which contains a system of nets through which the organism maintains a gentle flow. In almost all other groups simple filters are employed only to exclude large particles.

cate their prey over relatively great distances, perhaps miles, from just such an extremely sparse population of active bathypelagic animals.

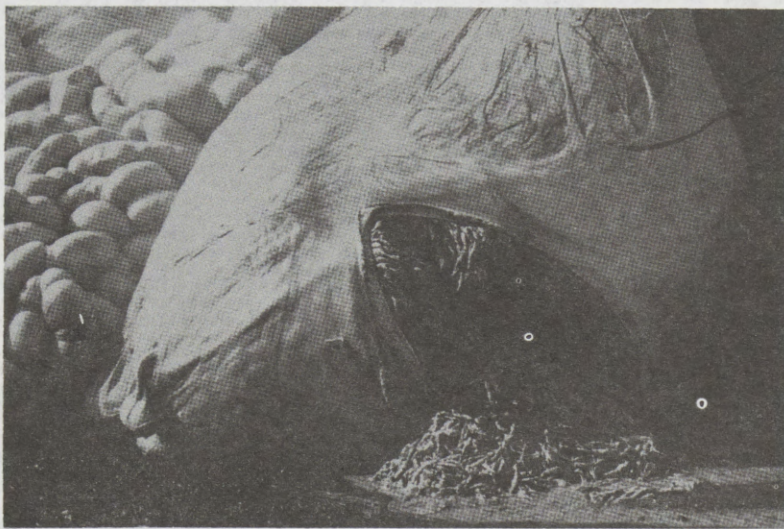
Although many near-surface organisms are luminescent, it is in the bathypelagic region that bioluminescence has reached a surprising level of development, with at least two-thirds of the species producing light. Were we truly marine-oriented, we would perhaps be more surprised by the almost complete absence of biological light in the land environment, with its few rare cases of fireflies, glowworms and luminous bacteria. Clearly bioluminescence can be valuable to higher organisms, and the creatures of the bathypelagic realm have developed light-producing organs and structures to a high degree. In many cases the organs have obvious functions. Some fishes, squids and euphausiids possess searchlights with reflector, lens and iris almost as complex as the eye. Others have complex patterns of small lights that may serve the functions of recognition, schooling control and even mimicry of a small group of luminous plank-

ton. Strong flashes may confuse predators by "target alteration" effects, or by producing residual images in the predators' vision. Some squids and shrimps are more direct and discharge luminous clouds to cover their escape. The luminous organs are arranged on some fishes so that they can be used to countershade their silhouettes against faint light coming from the surface. Luminous baits are well developed. Lights may also be used for locating a mate, a problem of this vast, sparsely populated domain that has been solved by some anglerfishes by the development of tiny males that live parasitically attached to their relatively huge mates.

It has been shown that the vertebrate eye has been adapted to detect objects in the lowest light level on the earth's surface—a moonless, overcast night under a dense forest canopy—but not lower. Light levels in the bathypelagic region can be much lower. This is most probably the primary difference that accounts for the absence of bioluminescence in higher land animals and the richness of its development in the ocean forms.

The densest populations of bathypelagic creatures lie below the most productive surface regions, except at high latitudes, where the dearth of winter food probably would exhaust the meager reserves of these creatures. All the bathypelagic populations are sparse, and in this region living creatures are less than one hundred-millionth of the water volume. Nevertheless, the zone is of immense dimensions and the total populations may be large. Some genera, such as the feeble, tiny bristle-jawed fishes, are probably the most numerous fishes in the world and constitute a gigantic total biomass. There are some 2,000 species of fishes and as many species of the larger invertebrates known to inhabit the bathypelagic zone, but only a few of these species appear to be widespread. The barriers to distribution in this widely interconnected mid-water region are not obvious.

The floor of the deep sea constitutes an environment quite unlike the mid-water and surface environments. Here are sites for the attachment of the larger



CHAMPION FILTER FEEDER of the world ocean in terms of volume is the blue whale, a mature specimen of which lies freshly butchered on the deck of a whaling vessel in this photograph. The whale's stomach has been cut open with a flensing knife to reveal its last meal: an immense quantity of euphausiids, or

krill, each measuring about three inches in length. The baleen whales are not plankton-filterers in the ordinary sense but rather are great carnivores that seek out and engulf entire schools of small fish or invertebrates. The photograph was made by Robert Clarke of the National Institute of Oceanography in Wormley, England.

invertebrates that filter detritus from the water. Among these animals are representatives of some of the earliest multicelled creatures to exist on the earth, glass sponges, sea lilies (crinoids)—once thought to have been long extinct—and lamp shells (brachiopods).

At one time it was also thought that the abyssal floor was sparsely inhabited and that the populations of the deep-ocean floor were supplied with food only by the slow, meager rain of terminal detrital food material that has passed through the surface and bathypelagic populations. Such refractory material requires further passage into filter feeders or through slow bacterial action in the sediment, followed by consumption by larger burrowing organisms, before it becomes available to active free-living animals. This remnant portion of the food web could support only a very small active population.

Recent exploration of the abyssal realm with a baited camera throws doubt on the view that this is the exclusive mechanism of food transfer to the deep bottom. Large numbers of active fishes and other creatures are attracted to the bait almost immediately [see *illustration on page 2*]. It is probably true that several rather independent branches of the food web coexist in support of the deep-bottom creatures: one the familiar rain of fine detritus, and the other the rare, widely separated falls of large food particles that are in excess of the local feeding capacity of the broadly diffuse bathypelagic population. Such falls would include dead whales, large sharks or other large fishes and fragments of these, the multitude of remnants that are left when predators attack a school of surface fish and now, undoubtedly, garbage from ships and kills from underwater explosions. These sources result in an influx of high-grade food to the sea floor, and we would expect to find a population of active creatures adapted to its prompt discovery and utilization. The baited cameras have demonstrated that this is so.

Other sources of food materials are braided into these two extremes of the abyssal food web. There is the rather subtle downward diffusion of living and dead food that results initially from the daily vertical migration of small fish and zooplankton near the surface. This migration appears to impress a sympathetic daily migration on the mid-water populations down to great depths, far below the levels that light penetrates. Not only may such vertical migration bring feeble bathypelagic creatures near the bottom but also it accelerates in itself the flux of

dead food material to the bottom of the deep sea.

There must also be some unassignable flux of food to the abyssal population resulting from the return of juveniles to their habitat. The larvae and young of many abyssal creatures develop at much shallower levels. To the extent that the biomass of juveniles returning to the deep regions exceeds the biomass of spawn released from it, this process, which might be called "Faginism," constitutes an input of food.

Benthic animals are much more abundant in the shallower waters off continents, particularly offshore from large rivers. Here there is often not only a richer near-surface production and a less hazardous journey of food to the sea floor but also a considerable input of food conveyed by rivers to the bottom. The deep slopes of river sediment wedges are typified by a comparatively rich population of burrowing and filtering animals that utilize this fine organic material. All the great rivers of the world save one, the Congo, have built sedimentary wedges along broad reaches of their coast, and in many instances these wedges extend into deep water. The shallow regions of such wedges are highly productive of active and often valuable marine organisms. At all depths the wedges bear larger populations than are common at similar depths elsewhere. Thus one wonders what inhabits the fan of the Congo. That great river, because of a strange invasion of a submarine canyon into its mouth, has built no wedge but rather is depositing a vast alluvial fan in the two-mile depths of the Angola Basin. This great deep region of the sea floor may harbor an unexplored population that is wholly unique.

In itself the pressure of the water at great depths appears to constitute no insurmountable barrier to water-breathing animal life. The depth limitations of many creatures are the associated conditions of low temperature, darkness, sparse food and so on. It should perhaps come as no surprise, therefore, that some of the fishes of high latitudes, which are of course adapted to cold dark waters, extend far into the deep cold waters in much more southern latitudes. Off the coast of Lower California, in water 1,200 to 6,000 feet deep, baited cameras have found an abundance of several species of fishes that are known at the near surface only far to the north. These include giant arctic sharks, sablefish and others. It appears that some of the fishes that have been called arctic species are actually fishes of the dark cold waters of the seas,

which only "outcrop" in the Arctic, where cold water is at the surface.

I have discussed several of the benthic and epibenthic environments without pointing out some of the unique features the presence of a solid interface entails. The bottom is much more variable than the mid-water zone is. There are as a result more environmental niches for an organism to occupy, and hence we see organisms that are of a wider range of form and habit. Adaptations develop for hiding and ambush, for mimicry and controlled patterns. Nests and burrows can be built, lairs occupied and defended and booby traps set.

Aside from the wide range of form and function the benthic environment elicits from its inhabitants, there are more fundamental conditions that influence the nature and form of life there. For example, the dispersed food material settling from the upper layers becomes much concentrated against the sea floor. Indeed, it may become further concentrated by lateral currents moving it into depressions or the troughs of ripples.

In the mid-water environment most creatures must move by their own energies to seek food, using their own food stores for this motion. On the bottom, however, substantial water currents are present at all depths, and creatures can await the passage of their food. Although this saving only amounts to an added effectiveness for predators, it is of critical importance to those organisms that filter water for the fine food material it contains, and it is against the bottom interface that a major bypass to the microscopic steps of the dominant food web is achieved. Here large organisms can grow by consuming microscopic or even submicroscopic food particles. Clams, scallops, mussels, tube worms, barnacles and a host of other creatures that inhabit this zone have developed a wide range of extremely effective filtering mechanisms. In one step, aided by their attachment, the constant currents and the concentration of detritus against the interface, they perform the feat, most unusual in the sea, of growing large organisms directly from microscopic food.

Although the benthic environment enables the creatures of the sea to develop a major branch of the food web that is emancipated from successive microscopic steps, this makes little difference to the food economy of the sea. The sea is quite content with a large population of tiny organisms. From man's standpoint, however, the shallow benthic environment is an unusually effective producer of large creatures for his

food, and he widely utilizes these resources.

Man may not have created an ideal environment for himself, but of all the environments of the sea it is difficult to conceive of one better for its inhabitants than the one marine creatures have created almost exclusively for themselves: the coral islands and coral reefs. In these exquisite, immense and well-nigh unbelievable structures form and adaptation reach a zenith.

An adequate description of the coral reef and coral atoll structure, environments and living communities is beyond the scope of this article. The general history and structure of atolls is well known, not only because of an inherent fascination with the magic and beauty of coral islands but also because of the wide admiration and publicity given to the prescient deductions on the origin of atolls by Charles Darwin, who foresaw much of what modern exploration has affirmed.

From their slowly sinking foundations of ancient volcanic mountains, the creatures of the coral shoals have erected the greatest organic structures that exist. Even the smallest atoll far surpasses any of man's greatest building feats, and a large atoll structure in actual mass approaches the total of all man's building that now exists.

These are living monuments to the success of an extremely intricate but balanced society of fish, invertebrates and plants, capitalizing on the basic advantages of benthic populations already discussed. Here, however, each of the reef structures acts almost like a single great isolated and complex benthic organism that has extended itself from the deep poor waters to the sunlit richer surface. The trapping of the advected food from the surface currents enriches the entire community. Attached plants further add to the economy, and there is considerable direct consumption of plant life by large invertebrates and fish. Some of the creatures and relationships that have developed in this environment are among the most highly adapted found on the earth. For example, a number of the important reef-building animals, the corals, the great tridacna clams and others not only feed but also harbor within their tissues dense populations of single-celled green plants. These plants photosynthesize food that is then directly available within the bodies of the animals; the plants in turn depend on the animal waste products within the body fluids, with which they are bathed, to derive their basic nutrients. Thus within the small environment of these plant-animal

composites both the entire laborious nutrient cycle and the microscopic food web of the sea appear to be substantially bypassed.

There is much unknown and much to be discovered in the structure and ecology of coral atolls. Besides the task of unraveling the complex relationships of its inhabitants there are many questions such as: Why have many potential atolls never initiated effective growth and remained submerged almost a mile below the surface? Why have others lost the race with submergence in recent times and now become shallowly submerged, dying banks? Can the nature of the circulation of the ancient ocean be deduced from the distribution of successful and unsuccessful atolls? Is there circulation within the coral limestone structure that adds to the nutrient supply, and is this related to the curious development of coral knolls, or coral heads, within the lagoons? Finally, what is the potential of cultivation within these vast, shallow-water bodies of the deep open sea?

There is, of course, much to learn about all marine life: the basic processes of the food web, productivity, populations, distributions and the mechanisms of reinoculation, and the effects of intervention into these processes, such as pollution, artificial upwelling, transplantation, cultivation and fisheries. To learn of these processes and effects we must understand the nature not only of strong simple actions but also of weak complex interactions, since the forms of life or the success of a species may be determined by extremely small second- and third-order effects. In natural affairs, unlike human codes, *de minimis curat lex*—the law is concerned with trivial!

Little is understood of the manner in which speciation (that is, the evolution of new species) occurs in the broadly intercommunicating pelagic environment with so few obvious barriers. Important yet unexpected environmental niches may exist in which temporary isolation may enable a new pelagic species to evolve. For example, the top few millimeters of the open sea have recently been shown to constitute a demanding environment with unique inhabitants. Further knowledge of such microcosms may well yield insight into speciation.

As it has in the past, further exploration of the abyssal realm will undoubtedly reveal undescribed creatures including members of groups thought long extinct, as well as commercially valuable populations. As we learn more of the conditions that control the distribution of species of pelagic organisms, we shall

become increasingly competent to read the pages of the earth's marine-biological, oceanographic and meteorological history that are recorded in the sediments by organic remains. We shall know more of primordial history, the early production of a breathable atmosphere and petroleum production. Some of these deposits of sediment cover even the period of man's recorded history with a fine time resolution. From such great records we should eventually be able to increase greatly our understanding of the range and interrelations of weather, ocean conditions and biology for sophisticated and enlightened guidance of a broad spectrum of man's activities extending from meteorology and hydrology to oceanography and fisheries.

Learning and guidance of a more specific nature can also be of great practical importance. The diving physiology of marine mammals throws much light on the same physiological processes in land animals in oxygen stress (during birth, for example). The higher flowering plants that inhabit the marine salt marshes are able to tolerate salt at high concentration, desalinating seawater with the sun's energy. Perhaps the tiny molecule of DNA that commands this process is the most precious of marine-life resources for man's uses. Bred into existing crop plants, it may bring salt-water agriculture to reality and nullify the creeping scourge of salinization of agricultural soils.

Routine upstream reinoculation of preferred species of phytoplankton and zooplankton might stabilize some pelagic marine populations at high effectiveness. Transplanted marine plants and animals may also animate the dead saline lakes of continental interiors, as they have the Salton Sea of California.

The possible benefits of broad marine-biological understanding are endless. Man's aesthetic, adventurous, recreational and practical proclivities can be richly served. Most important, undoubtedly, is the intellectual promise: to learn how to approach and understand a complex system of strongly interacting biological, physical and chemical entities that is vastly more than the sum of its parts, and thus how better to understand complex man and his interactions with his complex planet, and to explore with intelligence and open eyes a huge portion of this earth, which continuously teaches that when understanding and insight are sought for their own sake, the rewards are more substantial and enduring than when they are sought for more limited goals.

The Author

JOHN D. ISAACS is professor of oceanography and director of marine life research at the Scripps Institution of Oceanography. The titles reflect only a portion of his interests; his others include the mechanism of the heating of the earth's interior, the construction of harbors by atomic explosions and the disposal of radioactive wastes at sea. He was also a member of the group that suggested tethering a satellite to the earth by a cable, which would be attached near the Equator so that energy from the turning of the earth would drive loads up the cable to the satellite; the installation could be used to maintain an observatory or fuel spacecraft or even to support very tall structures on the earth's surface. Isaacs came to oceanography in a roundabout way. He went to college to study engineering but became bored and dropped out. Thereafter he worked as a

logger, a fire lookout, a merchant seaman and a commercial fisherman. He returned to college in 1944 and obtained his bachelor's degree in engineering (from the University of California at Berkeley) at the age of 32. He has been at Scripps since 1948.

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Professor ISAACS. I thank you for the opportunity to address you.

Mr. ROBERTS. The Chair will open the questioning with our resident scientist, Mr. McCormack, from Washington.

Mr. McCORMACK. Thank you, Mr. Chairman.

Professor Isaacs, I want to congratulate you on your statement. I wish somehow there were some manner in which the general public and the press and the Members of Congress in general would have an opportunity to hear and understand what you are saying.

I must commend you on expressing it so well, when you comment that the rest of the world looks upon our acts as a result of understanding. I assure you that I share your frustration, not only with respect to the question immediately before this committee, but also with respect to our present energy policy, at least as expressed by the press.

However, may I ask one general question that flows from what I would describe as a strong condemnation of our present policies and the regulations that have been proposed by EPA.

That is, can you be somewhat specific as to what you would recommend as a program for handling municipal waste, especially in coastal areas or, even more specifically, in coastal areas with deep water?

What I am trying to do is give you an opportunity to propose what would be almost an ideal situation. I would like to ask if you would try to describe what you would recommend in this instance.

Professor ISAACS. "The Utopia of Domestic Waste," by Isaacs; is that it?

Mr. McCORMACK. Yes; that is what I am getting at.

Professor ISAACS. Well, of course, I would defer to Dr. Pearson for more complete knowledge on this. Clearly, I think that source control is a *sine qua non*—floatables, coarse particles, all that sort of removal—certainly, as much particle removal as is feasible; highly developed, well-developed discharge structures, well offshore and below the thermocline, so that the wastes are actually trapped subthermocline, and probably high-velocity outflow jet ports, as another one.

I would certainly think it absolutely essential to set up a continuing and thoughtful program monitoring for really serious chemical material, such as mutagenic compounds.

Then I would consider a monitoring system, looking at not sensitive organisms as much as organisms that tend to display the presence of materials and fine particles, such as mussels which constitute a very effective analytical device to give a sample of what actually is the interreaction of this material with the ocean and its influence on at least these kinds of invertebrates.

Mr. McCORMACK. I have two questions that flow from that. I take it, then, that you would not recommend any specific action with respect to disinfection, or the killing of bacteria such as coliform bacteria?

Professor ISAACS. Well, I really ought to defer that question, too. But it seems clear from a great number of reports, and very excellent ones, from England, of which Dr. Pearson could remind me, that essentially zero cases of any kind of pathogenic infection have ever been traced to sewage disposal in the sea, except in the most primitive conditions, such as at—well, I will not mention the Italian city, but where raw mussels were sold on the market after essentially being anchored in a sewer outfall.

Mr. McCORMACK. Let me ask one more question, then. I think I understood you to say that you would discharge below the thermocline. Is that what you said, sir?

Professor ISAACS. I would discharge thermocline; yes.

Mr. McCORMACK. Well, now, would this imply that the material would get back in—there would be no upwelling under these conditions, would there?

Professor ISAACS. Well, sewage, of course, is essentially freshwater, and it enters seawater, rises up, comes to a density balance at some height above the bottom, but below the surface, and then spreads out. One of the advantages of this, of course, except under the most unusual circumstances, that diluted sewage can never partake again in the initial dilution. It is always somewhere else, because it is separated vertically from any source water. And that is a great advantage.

The other advantage is, of course, that the material, which is bio-stimulatory, is more diluted before it gets into the surface waters, where it supports phytoplankton.

Mr. McCORMACK. In other words, you say it would enter the food chain because it is less dense, being freshwater, it would automatically upwell—

Professor ISAACS. That is right.

Mr. McCORMACK [continuing]. And under those conditions, it would get into the food chain.

Professor ISAACS. Sure. It automatically upwells. It is very light, buoyant.

Mr. McCORMACK. Thank you.

Thank you, Mr. Chairman.

Mr. ROBERTS. I thank the gentleman from Washington.

The Chair would like to announce that we anticipate a vote soon and I would ask the gentleman from Washington to please take the Chair until that time and then recess for approximately 1 hour.

[Whereupon, Mr. McCormack assumed the Chair.]

Mr. McCORMACK. Mr. Clausen?

Mr. CLAUSEN. The sum and substance of your comment, Dr. Isaacs, seems to center around what appears to be a misnomer in the eyes of a lot of people.

You are really saying that as a result of a lot of the treatment work that we have today, they are starving the ocean of the valuable nutrients to sustain fish and marine life. Is this what you are saying?

Professor ISAACS. Yes. Essentially, all man does is take things out of the ocean, and unlike any other member of the marine food web, he does not put back in the things that can regenerate that life again, if he really restricts his inputs from domestic sources.

But in addition to this, as I have pointed out, and in the eastern Mediterranean, this is going to be particularly serious, even the great inputs from the rivers, the natural inputs of millions of tons of organic material and nutrients from the Nile are no longer going in.

The Mediterranean is already a starved ocean, and a very profoundly starved ocean. All of man's acts now are going to exacerbate that starvation.

Mr. CLAUSEN. What would you recommend, then, to reverse that trend, knowing what you know about man's actions at this point.

Professor ISAACS. I would undertake to set up systems in which I

would recycle as much organic material into the ocean, at least as much as was naturally introduced. Certainly, man should put back in those degraded organics and nutrients at least at the level at which he takes them out. Also, since the ocean in general is a starving ocean, and even in relatively rich places like California, the productivity is far below the potential—only in very rare places does it approach the potential productivity of the ocean—I cannot conceive that a double or tripling of the input can have any other than a beneficial effect.

In general, we fail to appreciate how the ocean operates. And there is no place more apparent, I think, than in the proposal for secondary treatment. Somebody has said secondary treatment is just an expensive way to pump oxygen into the ocean, and to a certain degree that is true.

But it has other implications, and one of them is that the oxidation state of metals, very often changes their toxicity by immense factors. Merely to compare, then, some 60-percent removal of some metals as they may be removed along with some particulates by secondary treatment and neglect the possible oxidation state and vastly increased toxicity of these metals, is a little idiotic.

It is not really known what the oxidation state and toxicity of metals in secondary discharge will be. This is certainly something that should be known, and we should certainly look at it.

But the bare assumption that the toxicity of metals in various kinds of treatment is only measured by their gross mass emission is naive, indeed.

You can, for example, eat mercurous mercury by the gram and in fact, in the last century, it was used as a medicine. But mercuric mercury, no; a very small fraction of a gram will kill you. Chromium seems to be totally innocuous in seawater at the third valent state. Creatures can live in a sediment made out of nothing but dichromium trioxide.

But the hexavalent state of it affects organisms at parts per billion. The toxicity has gone from nothing via the oxidation state to extreme toxicity.

So no one knows what we have done with the metals—in secondary treatment at least—I do not think it is considered in this whole effort to oxidize everything before it is introduced into the ocean.

Mr. CLAUSEN. Then, if I read you, you are suggesting that there has to be some form of recycling to in effect restore to the ocean body of water the nutrients that are being deprived as a result of men's acts.

Professor ISAACS. The "has to be" caught me there a bit I think we can get along without it. It is just foolish not to take advantage of this natural process, to enrich our potential food source.

Mr. CLAUSEN. In other words, there is no reason for us to undo what has been done, but you would tend to downplay all the emphasis on secondary treatment as a product or an improvement to the environment, and the improvement of health conditions?

Professor ISAACS. Well, the assumption throughout these regulations or proposed modifications of the regulations, is just to assert that, without any examination, the secondary treatment solves all these problems. There is no data to support that. It is merely an assertion. But it is not up to argument or examination, apparently, the way the regulations are written.

Does it solve anything, or doesn't it solve anything—that is not questioned in these regulations. It is asserted that it does solve them, and that is all with no examination.

Mr. CLAUSEN. In other words, you are challenging EPA——

Professor ISAACS. I am challenging that assertion, yes.

Mr. CLAUSEN. You are challenging the EPA's regulations that they are planning to promulgate on what it does?

Professor ISAACS. I am challenging that the investigation has not been made as to whether this is a good idea or not, and I bring up one example of it; oxidation states of metals.

Mr. CLAUSEN. Thank you.

Mr. McCORMACK. Thank you, Mr. Clausen.

Mr. Anderson?

Mr. ANDERSON. Thank you, Mr. Chairman.

Professor ISAACS. I want to be a little more specific on the Los Angeles area. Now, in Los Angeles, we have a rather good primary treatment facility, and we have the Hyperian outfall that goes out 5, 6 miles into what is, I understand, a submarine channel. And we are trying to get a waiver so that we do not have to build an expensive secondary treatment facility there.

We have the primary control, we have source control, which can be improved, control of toxics, and so on. If we were to force Los Angeles to spend, let us say, \$300 million to build a secondary treatment plant and take these various things out of the system, what would we gain and what would we lose? I think you have made a study of the Los Angeles plant, haven't you?

Professor ISAACS. Yes; while I again would defer to Dr. Pearson on this one, from my opinion, and with the caveat we do not really know what secondary effluent will do, because we really do not even know what its metal contents are, I would say what would happen—providing there is no increased toxicity by introducing secondary treatment—is that the areas of the bottom that are now affected, that have somewhat different fauna, animals, living in it than live in unaffected areas, would shrink. The total biomass of animals living on the bottom would decrease, and the situation would return more to what is called "normal."

Mr. ANDERSON. Now, as I understand it, there is more fish life down there as a result of the sewage outfall, out that 5-, 7-mile area, that would not be there if the Hyperian plant did not go out that far; isn't that right?

Professor ISAACS. Sure, that is right.

Mr. ANDERSON. So we would lose a certain amount of our organic life that helps develop the fish life and everything else in that area.

Professor ISAACS. Surely. As far as the invertebrates living on the bottom, they are of a somewhat different nature; the diversity is somewhat lower. As far as the fish are concerned, they are in considerable abundance, of course, all the way along that part of the coast.

Yes; the total productivity would decrease. And then, of course, there is some more dispersed productivity, due to the fact that the nutrients, the phosphorus, and nitrogen that are put into the environment, and that of course supports, in a very broad way, additional phytoplankton.

Mr. ANDERSON. So that, if through a system of better source control, we make sure that we do not have the toxics and the metals go in, we would be foolish, then, to force them to spend that \$300 million to build a secondary plant. I think you mentioned awhile ago, in reference to the North Sea situation, that it would be irresponsible.

Professor ISAACS. I do not know whether it would be foolish or not, but it would be irresponsible.

Mr. ANDERSON. Thank you, Mr. Chairman.

Mr. McCORMACK. Thank you, Mr. Anderson.

Mr. Oberstar?

Mr. OBERSTAR. Yes; I would like to follow up on the question that my colleague from California raised, and the line of thinking there.

There must be some point at which the ocean life is not able to consume all the new growth generated by the discharge of nutrients and other materials into the ocean, a point at which we have to limit the discharge.

Now, I know, in my own State of Minnesota, that the lakes in the southern part of the State are more plentiful in fish production than the glaciated lakes in the northern part of the State, producing several more pounds per acre of fish than do the northern, glaciated, unpolluted—or relatively unpolluted—lakes.

What is that point? Have you conducted studies to indicate just how much dispersion is possible and what concentrations and which areas, and do you have enough historical information to indicate what was the condition of those waters before man began having an impact on them and the fish life that is generated there?

Professor ISAACS. That is a complicated question. I really do not know much about lakes, I am sorry, except that I like to fish in them.

There are a few places in the ocean where naturally, the input of nutrients is so high that you do indeed overstimulate them. That is called eutrophication, in general.

There is a place off the African coast in which there occurred periodic eutrophication with mass death. I believe there were some places just reported last year in the Atlantic, along the seaboard, where oxygen fell to very low levels. Whether that is a natural event or not, I do not know.

But there are a few places in the world where, under natural conditions, the ocean fertilizes itself to such a degree that there are mass collapses of entire systems.

In the rather remote past, where southern California was not so greatly different than it is now, there were many such events, with mass deaths and the production of the great fossil beds of the Monterey shales, with layers of just solid fish.

So under those circumstances of the Miocene, this was a common occurrence, to have essentially everything periodically wiped out in the southern California waters and fall down on the bottom in great layers.

We have been looking into some sediments in the Santa Barbara Basin which are laid down in such a way that one can examine what was going on each year, way into the remote past. It is possible to go back 6,000 or 7,000 years and examine yearly what went on.

It appears from that that the California current is not as productive in the last 400 years as it was in the previous 1,200. And this is a curious case.

Mr. OBERSTAR. Productive in what sense?

Professor ISAACS. Productive in terms of fish, and productive in terms of phytoplankton, and I have a number of articles on that.

But it is a curious fact, that productivity of the California current has been pretty steady over the last 400 years, but it appears that it was considerably higher before that. We do not quite understand what made that happen.

But of course, the big inputs of nutrients in the California current depend on a process called upwelling, and this is a slave of the meteorological situation.

It is possible for an upfall to put in increments of that, but the general level of productivity is controlled by large-scale meteorology, rather than any of man's acts.

Mr. OBERSTAR. Well, are you suggesting, then, that such currents and such natural oceanic phenomenon should be supplemented by discharges from land-based treatment plants?

Professor ISAACS. They are supplemented by discharges. This is cycled and recycled, so the input, of course, is continuously to enrich the ocean over very, very large areas, of course.

I am sure it is possible to introduce nutrients from waste discharge in such a way that one might produce a plankton bloom, not as it is possible in eutrophic lakes, where everything collapses, but if the bloom is very rich, then, perhaps, it may be objectionable from an esthetic standpoint.

But this does not produce those kinds of organisms that frequently develop in lakes—the blue-green algae for example, which are so difficult. Those exist in the ocean, but exist in quite a different form, in small, spotty, aggregations. In these there never develop those great layers of blue-green algae that cut off the light and oxygen to everything below, as in lakes or ponds.

So the possibilities of making southern California eutrophic, in the sense of a sensitive lake, I think are miniscule.

It has happened in the past naturally. It may happen in the future again.

Mr. OBERSTAR. There must be some treatment, however—I do not think you mean to minimize the concern—treatment of microorganisms that carry disease.

Professor ISAACS. Oh, well, the secondary treatment, of course, makes these nutrients much more available, because it puts them in organic form. The primary treatment leaves much of these nutrients—which was mainly, incidentally, in the Pacific limited by nitrogen, not phosphorus—it puts them in a form in which they are very slowly available. It is a difference between giving your crop a shot of ammonium nitrate versus giving it a shot of organic fertilizer.

Dr. CRAVEN. You missed his question. He was asking about pathogens.

Professor ISAACS. Oh, pathogens. I am sorry. I missed your question. Anyway, I was addressing an interesting question that you did not ask me. I am sorry.

Mr. OBERSTAR. It is an interesting question, nonetheless.

Professor ISAACS. Would you repeat the question?

Mr. OBERSTAR. Well, I think it was stated by Dr. Craven very well.

I said I did not think you, in overlooking or not commenting on it, did not mean to neglect the danger of disease-carrying microorganisms. There has to be some way of treating those in ocean discharge.

Professor ISAACS. Well, of course, the mortality, at least of *E. coli* in seawater is really quite rapid. There are viruses. I—

Mr. OBERSTAR. Well, I do not think anyone has found a way of treating a virus.

Professor ISAACS. No. I would just go back to the point that even in the case of quite primitive outfalls of sewage into the sea, there is no evidence of that source ever having been the route to any infection of man. After some dilution, of course, it is much more sanitary than a hand that you might shake or which might pass you a sandwich.

Mr. OBERSTAR. That is intriguing. You say that the life of *E. coli* is very short, and that the marine environment, in fact, serves as a treatment mechanism, in a sense, a treatment environment?

Professor ISAACS. Yes. I believe I am correct in that. Seawater is inimical to the survival of these normal coliform bacteria. The degree to which it increases mortality of other pathogens of one sort or another is not quite clear, but that apparently is also accelerated.

Mr. OBERSTAR. In another committee that I serve on, the Merchant Marine and Fisheries Committee, we have jurisdiction over other aspects of ocean discharges. That committee had extensive hearings on ocean discharge and received testimony from municipalities and local governments along the eastern seaboard. The witnesses were greatly concerned about the discharges from Philadelphia and New York. The ocean current moves that discharged material along the coastal beaches, messing them up and causing innumerable problems for those communities dependent on tourism.

But again, that sludge is the result of, in most cases, secondary treatment. You would then suggest some other form of treatment, say, go ahead and discharge that material out along those coasts, because it is good for the fish life.

Professor ISAACS. Yes; I realize there is excitement over the specter of sludge crawling out of the ocean onto the beaches of the east coast, but I do not know that there is any evidence—

Mr. OBERSTAR. Are you suggesting that we ought not to have secondary treatment but have some other form of treatment and benefit the ocean?

Professor ISAACS. I am suggesting that of course, the primary particles, which are essentially organic particles are certainly better food than these bacterial corpses which ordinarily form the particulate material of secondary sewage. This is generally unavailable material as food, and very slowly decays. And, of course, secondary sewage produces three times the particulate material that was originally in the sewage, by growing bacteria on it and then killing those.

Mr. OBERSTAR. Well, again, both you and Dr. Pearson challenge our thinking and our traditional approach to sewage treatment, and several years of testimony presented to this committee.

Obviously, I do not think the perspective you bring is something that we can digest or thoroughly explore within the confines of this limited hearing. But you do give us pause for thought and suggest new avenues of further inquiry by the committee and by our own reading and investigation.

Thank you.

Thank you, Mr. Chairman.

Mr. McCORMACK. Thank you, Mr. Oberstar.

Mr. ANDERSON. Mr. Chairman, could I just ask a 1-minute question of Dr. Pearson, because I may not be able to get back this afternoon.

Mr. McCORMACK. Certainly, Mr. Anderson.

Mr. ANDERSON. Dr. Pearson, in your statement before the Senate Subcommittee on Oceans and Atmosphere in 1973, you recommended that subcommittee provide leadership and guidance to appropriate governmental agencies, including the Environmental Protection Agency, concerning the development of realistic objectives and requirements for waste treatment and disposal, considering both waste water characteristics, as well as disposal locations and requirements.

Now, my question is, do you still believe in the leadership and guidance with respect to the EPA? Do you still feel that is needed?

Dr. PEARSON. It is needed even more today than it was needed then; I believe it.

Mr. ANDERSON. Thank you very much, Doctor.

Mr. McCORMACK. Thank you. We will recess until 1:30. At that time, we will reconvene. I understand, Dr. Craven, you have not yet testified, so we will work out with the staff who wishes to be here and who can testify at 1:30. We will reconvene then. Until then, we are recessed.

[Whereupon, at 12:20 p.m., the subcommittee recessed, to reconvene at 1:30 p.m. this same day.]

AFTERNOON SESSION

[At 1:40 p.m., the subcommittee reconvened, Hon. Ray Roberts presiding.]

Mr. ROBERTS. The subcommittee will be in order.

Again I want to apologize to the distinguished witnesses for the number of interruptions we have had.

The questions now will be directed to Professor Isaacs. Ms. Kovalic has questions.

Ms. KOVALIC. Dr. Isaacs, I notice that our bulletin board is changed. Would you like to explain that to us?

Prof. ISAACS. Did I get it correctly? It says—it is self-explicable, I think—"Experience is not at fault. It is our judgment that is in error."

Leonardo Da Vinci, about 1510 A.D., also went to nature for his answers. He often was criticized by the scientific hierarchy of the day, but always took refuge in the fact that he had gone to the true instructor for his answers, not to archaic theory.

Ms. KOVALIC. In the Los Angeles area, you mentioned there had been a problem with an ongoing discharge of DDT, which has since been terminated.

Are you aware of any recovery of the marine organisms in the Los Angeles area since the termination of the discharge of DDT?

Prof. ISAACS. I would like to defer to someone, a person who has all the answers on that question, Mr. Bascom.

There is a large reservoir of DDT remaining in the sediments in an area around the Whites Point discharge. This apparently remains from the period when large quantities were discharged from a single source for up to perhaps two decades, and is slowly diminishing through de-

composition and dispersal. The fish and other creatures in this area show increased levels of DDT in their flesh and livers, and one species, dover sole, suffers from a high incidence of fin erosion. DDT may be the cause but it appears that PCB is the culprit. The dover sole living in this area are also south of their usual range and are probably more susceptible to abnormalities than the better adapted species, which show only rare abnormalities in the area.

At any rate, the greatest and only serious impact of the waste discharges on the California coast is in the Whites Point region. No changes in practice of any sort will alter the diminishing effects of this reservoir of DDT and PCB, which is, as I say, slowly disappearing.

But the total burden of DDT in the area—that is, I believe, slowly dissipating.

Ms. KOVALIC. Let me follow up for a moment, and I will pick up with this when Mr. Bascom is with us tomorrow.

Given the fact that it appears that there is a termination of DDT discharge in that area, can you comment on the relationship between the ability of that area to replenish itself and a discharge of secondarily treated effluent or a continuation of an ocean outfall with something other than secondary treatment?

Professor ISAACS. Forgive me. The word "replenish" confuses me a little bit.

Ms. KOVALIC. Recover is a much better word.

Professor ISAACS. There are and have been more fish, more invertebrates, in the surrounding area. I am sure that if the waste field were reduced, the area would trend towards "normal"—that is, fewer fishes, fewer invertebrates.

Ms. KOVALIC. One last item, please.

Professor ISAACS. There is something wrong with the acoustics here. I am not getting you very well.

Ms. KOVALIC. Can you comment on what is known about the ability to measure ecological impacts?

Are they, in your opinion, transferable to predicting impacts from, for example, a relocation of an outfall pipe? Or, would we be better off to use these techniques to compare characteristics of similar marine areas?

Professor ISAACS. If I understand your question: Is there adequate knowledge to predict what will happen either with the cessation of outfall, change of outfall, or initiation of a new one, or change of location or design?

I think there is a great deal of information that could lend real predictive understanding of the results of various acts. My one reservation is that no one really knows what is the nature or effects of secondary effluent discharged into the sea.

As I said earlier, we do not know enough about the toxicity, the long-term state of metals, or the rate of uptake and stimulation, to predict effects of secondary discharge. But on the other alterations of practice there has been considerable experience. For example, the rate of recovery at the old Orange County, Calif., outfall was rather rapid, after discharge ceased.

"Recovery," I used that word. The conditions changed back to normalcy, or what is called the normal condition, in less than 1 year. That took place with return to almost identical "control" conditions, reduc-

tion of the number of organisms, reduction of the number of fish, and changes in species present from the period when the discharge was operating.

I would say if one knew enough about the nature of a particular secondary effluent, what it contained, but particularly any change that was not too great a departure from experience, predictive ability is very good.

Ms. KOVALIC. Thank you, Dr. Isaacs.

Thank you, Mr. Chairman.

Mr. ROBERTS. We thank you very much, and we know you want to catch a plane. And we appreciate sincerely your attendance and tremendous information you gave us.

We have already asked permission when we run down the scale, if we need some help, we will send you written questions.

Thank you very much.

Professor ISAACS. If I may sit here for a little while and listen, and let knowledge and understanding flow over me from my associates here.

Mr. ROBERTS. Great. Thank you.

Our next witness is Dr. John P. Craven, who has a dual career in ocean engineering and ocean law and policy. He is currently Hawaii State marine affairs coordinator, dean of marine programs at the University of Hawaii, and director of the Law of the Sea Institute. He was visiting professor of ocean engineering and political science at the Massachusetts Institute of Technology from 1969 to 1970.

Dr. Craven has participated in the following professional groups: The American Society of Mechanical Engineers, the Marine Technology Society for the American Institute of Aeronautics and Aerospace, and the American Society of International Law. He is a former president of the Marine Technology Society and was appointed to the advisory committee to the U.S. delegation to the Third United Nations Law of the Sea Conference.

Dr. Craven, we are delighted to have you. If I had known you had that background in Hawaii, I would not have made that statement that I made this morning.

TESTIMONY OF DR. JOHN P. CRAVEN, DEAN OF MARINE PROGRAMS, UNIVERSITY OF HAWAII

Dr. CRAVEN. I am very pleased to give my testimony this afternoon because it is now 8 o'clock in the morning in the 50th State. And if I had to testify this morning, I would not have fully been awake with the same ability to give testimony that I have at the normal hour for starting the day.

I appreciate the enumeration of my biography. I would like to stress that my background consists of more than 30 years in the engineering development of ocean systems and in the design of these systems. Although I am not a biologist, these systems have been designed to be functionally effective and of greater importance to blend with the environment. They are the Polaris missile system, the Navy's deep submergence systems, and Sealabs. Most recently, I have been involved with the development of ocean thermal engineering.

In the course of these developments, I have had numerous opportunities to study the disposal of waste at sea and the blending of the products of man with the ocean. And I conclude from these studies that my colleagues of this morning, Dr. Pearson and Dr. Isaacs, have correctly stated that wastes which are put in the ocean, or materials which are put in the ocean, should match the quality and environmental needs of the receiving waters.

If one, indeed, wishes to protect the environment.

In my testimony this afternoon I will not repeat many of the arguments that have been made very eloquently by Dr. Pearson and Dr. Isaacs, but will instead give a few examples from the State of Hawaii which reinforce some points that they made.

I would like to stress one point which I do not think has been adequately made by my colleagues this morning, and that is that the concern over secondary sewage treatment is not just a concern over cost effectiveness in the economy, but is a real concern for the environment.

Of the two means of discharging wastes into the ocean, one essentially in the raw stage and the other having gone through a treatment decreed by men, it seems to me—and I think it seems to my colleagues—that the one that is more suspect in terms of the environment is the secondary treatment. The case has not been proven that secondary treatment is not detrimental to the environment in the same way that the case is asked to be proven with respect to the primary treatment.

It would seem to me that when one has made a decision as to which of these techniques is to be approved, the same requisite measures ought to be applied to the case of secondary sewage treatment, as applied to primary sewage treatment.

The primary conclusion that we come to is that the ocean, in most areas, is nutrient poor; that in certain areas of natural upwelling—and I learned this morning that in certain geological times, other upwellings have come in areas which are now nutrient poor—certain oceans are nutrient poor, and the biological wastes, particularly in the form as produced by man, by marine mammals—such as whales and porpoises and others—will have—of ocean, sufficient to enrich and enhance the productivity of the ocean.

On the other hand, the same materials discharged from fresh water or in streams, or even in ocean waters, and which, for other reasons, have become nutrient rich, can provide an environmental detriment. In particular, some of the discharges that we regard as nonpolluting in freshwaters become polluting in ocean waters. Freshwater is, of course, a pollutant in seawater.

This fact is observed in the destruction of the coral reef every time a freshwater discharge pours out on the reef. Indeed, the natural harbors, such as Pearl Harbor and the Honolulu Harbor, were created by freshwater streams which came down through the coral reef and denied the normal environment of which corals can grow. They therefore provided an open—or channel or keyway in the coral environment.

Let me give you a tale of two treatments, if you will, or two tales of two treatments for two areas in Hawaii. On the far side of Honolulu, we have a bay called Kaneohe. The bay is still a subject of

legitimate concern. Some years ago, in a documentary called "Cloud Over The Coral Reef," it was pointed out that Kaneohe Bay, before the settlement by mankind, was a bay which had pristine corals and was a barrier, reef or coral environment. With the onset of population, the secondary sewage treatment plant was built and the effluent was discharged into the bay itself. As a result of this effluent discharge, there developed a noxious algae called dictospheria cavernosa, a green lettuce-like algae, which smothered the corals and smothered in particular, in the vicinity of the outfall.

There were two reasons this algae grew. We are sure they grew because of nutrients that were available, which would have occurred either with primary or secondary sewage. But there is some suspicion, not proven, that the reason the algae grew was because of the mineralization of the sewage as a result of the secondary sewage treatment process.

As was pointed out this morning, what happens in the secondary sewage treatment process is primarily the oxidation of biological wastes, and this oxidation results essentially in the mineralization or change into chemical fertilizer, if you will, of material that had previously been biological fertilizer. And there is very strong evidence that this fertilizer goes to the development of lower trophic forms of plant life, before going up the chain into fish life. Whereas primary productivity, the primary wastes are refractory to phytoplankton which, in turn, are eaten by fish.

So the one evidence in the Kaneohe Bay was the secondary sewage plant.

The second evidence is that the Navy maintained a station for the training of dolphins and whales, and there were some four whales and a number of dolphins. Each of these whales produced 200 pounds of fecal matter per day or the equivalent to that produced by 200 humans. Four whales represented essentially 800 human beings. And, of course, their wastes were not treated but went into Kaneohe Bay in a primary form.

The vicinity where the whales were kept was biologically rich, fish of every kind and variety. The waters were a desirable place to be. And one had clear evidence of what happens when you allow the ocean to behave—as John pointed out this morning—to behave as if it is, if you will, a web of life, fed by a waste material which is not dissimilar to human waste materials.

We have now constructed an outfall of Kaneohe Bay and discharging that sewage into the open ocean. And we are observing very carefully to see whether the bay is recovering. The time is too short to tell whether it has recovered or not. And I think we ought to study that particular outfall since we have the secondary sewage treatment plant. We continue to utilize it even though the sewage is now discharged in an ocean outfall.

And I suppose we will have some opportunity to observe in the future this effect on the open ocean environment.

The second case I would like to refer to is the—on the Honolulu side—and you have already mentioned the fact that we have a sewer outfall—Sand Island, which has been extended into the open ocean. Every year I take my class on a boat trip around Honolulu Harbor going from the center of Honolulu Harbor out to Pearl Harbor. And

even before the outfall was extended, I had to take the boat deliberately through the surface area where the ocean outfall was coming from Sand Island. I ask the students to observe the floatables, if they can, to observe the odor, if they can, and to observe any physical aspects that they could see or determine in the ocean environment itself.

Before the construction of the deep ocean outfall, you could observe a slight slick on the ocean surface in the vicinity of the outfall. It was not possible to observe any floatables. I have a prize which I give to the student who can observe a floatable. And I have not given the prize away. So that floatables are not observed, and the environment basically is satisfactory.

With the completion of the deepwater outfall, the students are now not able to tell when they are going over that outfall or when not.

There is a second case. As we approach Pearl Harbor, the approach to the harbor, it is so obvious to even those blindfolded by the odor coming from the secondary sewage treatment plant, which is in Pearl Harbor, and produces—the sewage plant will produce a not harmful, but an offensive odor. In addition, we in Hawaii are very proud of all the buildings and structures that we have on land. We are proud of our parks and trees, and here is a piece of Hawaiian real estate which is now filled with—though attractively built as possible—but nonetheless a not very attractive structure, a structure which seems to be needless and seems, in terms of use—there is one other problem, that is, that the Pearl Harbor sewage treatment effluent, which does come out, freshwater effluent, is discharged on the coral reef. And there is a clear and observable detriment to the coral reef as a result of that discharge.

It is for these precise examples that we have observed—which are not quantifiable scientifically, but clearly quantifiable in terms of observations that the people of the State of Hawaii has concluded that the most beneficial treatment for their sewage effluent will be the utilization of a partial primary where the trash has been removed and where defuses are utilized, to go out into the open ocean. This view is all pervasive in Hawaii. And at the Muskie hearings, which were held 2, 3, or 4 years ago. Every single environmental group in the State of Hawaii testified in favor of the utilization of primary plant as against the utilization of a secondary sewage plant.

I would like to make one or two other statements about primary plants in the ocean that people may not be completely aware of. The biological pathogens are fairly quickly terminated. We are very proud of the fact that the 90-percent death time; in 5 minutes in Hawaiian waters.

It is a little slower in California, John, but it is still reasonably rapid.

Another thing that our water resources center has observed and is now studying and does not fully understand is the fact that viruses die in the seawater around Hawaii. This is a very significant finding, and it is suggestive that there are properties in the particular ocean seawater that may be of long-range benefit to man, but are of benefit, at least to the waste waters as they discharge into the open ocean.

For these and all the factors enumerated this morning, it is our feeling that the burden of waiver or building with respect to open

ocean outfalls, should stand with the secondary sewage treatment plant and not with the primary plant.

Nonetheless, the original Clean Water Act required that all discharges be secondary, tertiary, and ultimately freshwater discharges. The Congress very wisely, in previous hearings in which essentially the same testimony was given this morning, was presented very wisely amended the act to permit waivers for plants that met the appropriate criteria.

As we all know, the Environmental Protection Agency has chosen to interpret this waiver in the most narrow fashion, and in a fashion which, in fact, vitiates, which I believe to have been the intent of Congress.

And I believe—if I may step aside from this particular issue—that it is, of course, a major problem of our society, that the regulatory process has been increasingly employed to frustrate, to bypass, or to expand upon legislative intent of the Congress and thereby create an entirely new domain of executive legislation, which was not intended by the Congress.

Mr. CLAUSEN. Would you mind repeating that?

Dr. CRAVEN. It seems it is a major problem of our society that the regulatory process has been increasingly used to frustrate, to bypass, or to expand upon the legislative intent of Congress and thereby create an entirely new domain of executive legislation. And when this procedure is used by an agency whose purpose is environmental protection, to perpetuate the well meaning but counterproductive environmental dogma, then it seems to me it is time for the Congress to act. And as a nation, we cannot afford to expend the capital assets of energy associated with counterproductive waste water treatments.

And as a people who care about our environment, we cannot continue to deny the coastal waters the abundance of protective biological nutrients, nor can we continue to assault them with non-productive waste waters.

Mr. ROBERTS. May I ask one question which may appear to be a little bit silly, but we are now requiring fishermen with small boats to have an enclosed head and a tank and so forth.

Based on your statement would that not be a little ridiculous?

Dr. CRAVEN. If the fishermen discharge in the pier where they are anchored, then it is not ridiculous. If you can be assured the fishermen will only discharge their waste products on the high seas, to require them to do so otherwise is to me, yes, ridiculous and wasteful.

Mr. ROBERTS. Thank you.

The gentleman from California.

Mr. CLAUSEN. Dr. Craven—

Mr. ROBERTS. Let me say this, and we are not just blowing smoke. We are so impressed with you three fellows that we want to have a picture with you. Do we not have a photographer here somewhere? Come up here.

[Short recess.]

Mr. CLAUSEN. In light of what appears to be apparent in all of your testimony, the fact so heavily involved and committed to the legislative effort and, particularly as a result of your last comment about the regulatory process, I am becoming increasingly convinced that while we have essentially finalized our legislative effort for the next

few years for the program, that one of the key requirements that our committee in the immediate future may very well be to direct our time, energy and efforts, and our expertise to a monitoring effort, oversight, evaluation, and review, to make certain that that which has been legislated is going to be properly and responsibly implemented.

I have discussed this, as you know, with the chairman, and the chairman and I have worked really hand and glove on this total legislative effort. And it will certainly be my intent, and I am convinced that he would join with me to look to the possibility of developing legislation this next year, maybe in the direction of coming up with a kind of equipment for monitoring. We may have to have that to monitor the entire water management, waste water management program.

Would you comment on that?

Dr. CRAVEN. Well, it seems to me that the Congress could only have the power, by its legislation, to limit and constrain the regulatory powers of various agencies. And this, of course, cannot be done, it seems to me, without a monitoring effort.

I think that the regulatory agencies—that there is a philosophical constraint that will exist or can exist if there is continuous monitoring. For example, I do not believe that the, for example, the resolution which the EPA promulgated was necessary for EPA to promulgate when one reads the language of the act, that there is indeed one or two clauses which are ambiguous in terms of the English language, as read without looking at the historical background of the act.

Mr. CLAUSEN. Could you follow up and spell that out in more detail for the record?

Dr. CRAVEN. Well, there is a particular one clause. I do not have the act in front of me. There is one clause in the amendment to the act which has been utilized by EPA as the basis for the grandfathering of the waivers. That is, the EPA is now interpreting that waiver—secondary treatment can exist only for existing discharges, and for existing treatment plants.

We are very much concerned in Honolulu, for example, as to whether even our completed outfall will qualify under the waiver procedure. And we are quite sure, unless this regulation is changed, that the Honouliuli outfall—do not even try to pronounce that. I had to practice it all night—which we have not yet built, will not qualify under the regulations as written.

There is an interpretation of a particular clause, and it is a sequential clause, and it depends on where you put the inflection in your voice as to whether your decision is that future wastewaters cannot be permitted to go to sea under primary treatment.

On the other hand, it seems to me that the testimony, legislative record is amply clear what the intent of Congress was; that the Environmental Protection Agency could have and should have issued a regulation which was constant with that intent and, at the same time, constant with an interpretation of the language.

Mr. ROBERTS. Counsel?

Mr. EDELMAN. During recess this afternoon, you made an eloquent, and I think, terribly significant statement. I would like to take the liberty of repeating it for the record.

You stated that if you really care for the environment, you should carefully examine the adverse impact, and the adverse effect of secondary treatment.

Is that a proper paraphrasing of your statement?

Dr. CRAVEN. Yes. I think that it seems stronger than that. If you love the environment, if you love the environment and you are a designer, and if you can see the total effect, which includes the land pollution, the coastal zone pollution of occupying a substantial portion of the land, with nothing more than a settling tank—as against using the ocean for its same effect—I remember 3 or 4 years ago, when we were having a similar debate with a staff member from the Senate, and we were talking about zones of mixing in the ocean. And he said that there shall be no zone mixing. I said:

Supposing that we put a net in the ocean and we put this net, circular net, in the ocean, and we called this net a secondary sewage treatment plant, and we discharged our sewage into the center of that net, and we make the net sufficiently large that all effluent coming out of the outfall would have satisfied all the BOD, there is no question that, functionally, that net would have met all the requirements of secondary sewage treatment. Can we do that and call that a secondary sewage treatment plant?

And the answer was no, it cannot be a secondary sewage treatment plant unless that net becomes a wall and that wall becomes a tank, and it is located on the land. And the same process which the ocean can carry out itself in a reasonable zone of mixing is carried out in an artificial zone of mixing on the land.

So that if you really love the environment, and the total picture, you want a total system which blends with the environment, both on the land and in the ocean. And it seems to me that the burden of the evidence, engineering evidence at the present time, is that the best way to blend the environment, land and sea is with an outfall and defuser, getting appropriate dilution, the appropriate mixing and placing into the medium an appropriate biological fluid.

Mr. ROBERTS. We will try to get back in time for us to go on. I guess we had better recess for 1 minute, and Mr. McCormack will take over as soon as he gets back.

Again we want to thank you.

[Short recess.]

Mr. McCORMACK [presiding]. The hearing will please reconvene. Counsel has a question.

Mr. EDELMAN. There has been considerable discussion in the press recently, quoting Presidential advisor Robert Strauss—and the Administrator of the Environmental Protection Agency, Douglas Costle—in somewhat shifting terms—to the effect—as we understand them—that some of our inflationary pressures may have been caused by the excessive environment expenditures. By that, I believe what has been meant is that there has been occasions where the costs expended had little relationship to the environmental benefits gained by the expenditures.

Do you believe that the expenditures for ocean discharges fall in that area?

Dr. CRAVEN. Very much so. These facilities are engineering intensive, and therefore costly in the area that we can least afford to be

costly in, primarily the negative balance of trade, which is one of the very heavy aspects.

Inflationary pressure is an energy imbalance, and we will—as far as—or very far in correcting the inflationary problem, if we can reduce energy consumption in many, many areas, probably even more so than the actual capital cost of construction. Indeed, if one looks at the history of cities that are based on the sea, they have been economically effective throughout history because they have used natural water waves and they have used the ocean, and they have utilized the total water environment in ways that are most costly to purely land based cities or cities which are not in such a zone.

And when we, for one reason or another, deny ourselves the use of those waterways, then we substitute a more expensive means of carrying out the economic function.

And noting that this is a committee on public works and transportation, I might just get a little word in here and point out that this applies to use of such things as mass transportation where we no longer use ferries or boats along our rivers or waterways for the movement of people and goods, in a way that we did at the time the cities were affected.

Mr. McCORMACK. Thank you.

Ms. KOVALIC. Just one question, Dr. Craven.

Could you comment, based on past experience, as to whether it is possible to predict with some level of accuracy, the effects of a discharge with certain defined characteristics on the ecology?

Dr. CRAVEN. This question also relates to a question which the Chair asked and I did not fully answer a little earlier in the session, having to do with the environment—the ability of monitoring the environment.

In the sense of precise prediction, when you are dealing with a complex organic process, no, you cannot predict precisely.

With respect to the qualitative and partially quantitative description, or prediction of net environmental change, the answers is a decided yes, provided that you make the measurements of the critical parameters in the ocean environment, both before and after having a substantial change in the utilization of the coastline for waste waters.

For example, in the Kaneohe Bay case, which I cited, it does not need very much precise monitoring to recognize that the bay was being taken over by dictospheria cavernosa. It did take some very, very carefully planned experiments, utilizing modern techniques of factor analysis, to distinguish the effects of the waste water from the effects of silt, the effects of other forms of pollution on the bay, and to precisely pinpoint the relationships between the changes in the coastal zone and the effects—if one had a supported program in monitoring the waste waters, that was a program that matched experimental, meaningful experimental design, then we could—over a period of time—acquire the evidence that would permit us to make the appropriate growth predictions of what would happen with a major change in effluent going into the ocean.

Ms. KOVALIC. Let me restate this. I think you have hit on the point, but I want to make sure I understand it.

In your opinion, do we know enough, given the state of the art, to be able to predict the impacts of an outfall pipe which is not yet

in place, that is can we predict what would happen if an outfall pipe were relocated to a different site?

Dr. CRAVEN. The only way you can handle this is with an example. This relates to a study we did on the mining of sand, offshore mining of sand. We did some experiments to find out how we could mine sand in an environmentally acceptable manner. And we designed a section system which was embedded in the sand, and caused sand to slump down and affect the environment as little as possible, as it was being drawn out, and then reran some experiments to discover whether this was going to work or not.

It worked very much as we thought it was going to work, with the exception—we startled the bottom organisms so, in the process of doing this, we created a food for fish. Very shortly thereafter, we had a very large population of a fish called weke that we never expected. As the diver went down to put the pipe in the sand, the weke followed him. So that here it turned out was a positive, in this case, benefit that was not predictable in precise details. One could not predict how the fish species would change. He could predict that the biomass would change but you could not predict exactly how.

This is what I mean by the difference in precise prediction in quantitative prediction. You can make predictions that when you change the outfall, that the biomass will increase and the fish will be better. But you may not be able to predict exactly which species will be better until we know a lot more about the subtleties of the environment, of the ocean environment, for any particular modification.

But what the gross parameters—we should be able to predict or will have enough intake to make an assessment of the usefulness of the change.

Mr. EDELMAN. Let me follow up that question that Ms. Kovalic asked because I think it is a particularly significant question.

Are you saying then that although you are not able to predict with preciseness, you feel that you can predict at least whether the overall effect will be beneficial or detrimental?

Dr. CRAVEN. Yes. I think I ought to use another analogy.

How does an organic gardener predict what he is going to have in his organic garden? He sets the environment in a way that he wants it and allows it to grow there, what grows. And he is successful as an organic gardener. If he knows the environment, he sets the environment in such a way that what grows there is roughly what he wanted, approximately what he wanted.

But if he is interested in the precise result, knowing precisely what is going to develop, he does not have the tools available to him, and at that point he switches over to a different kind of gardening—store bought commercial seeds, putting them in the ground in a precise manner, and gardening in an entirely different manner.

When you are dealing with the environment, you are dealing with a changing environment. If you deal correctly, you are dealing with a kind of organic gardening. Gardening on the coral reef, the intention is to change the environment the way the gardener changes the environment. And when you do that, you cannot precisely predict what is going to happen.

But if you do it properly, you can get a desirable result.

Mr. McCORMACK. Thank you, Dr. Craven.

Mr. Wood, do you have a question?

Mr. Wood. Thank you, Mr. Chairman.

Also Congressman Clausen could not get back here but he asked me to express his thanks to you for your testimony.

I have a comment and a question. A few moments back when Mr. Clausen asked a question with regard to monitoring, he indicated that he was considering the next congressional legislation to result in very large enhancement of our national effort of monitoring and understanding what is in our waters, and what is going on in our waters. And any comments that you might have on this would be appreciated along with comments from the whole scientific or engineering community that you or anyone else could organize.

Dr. CRAVEN. Well, as I indicated I would be highly supportive, with the caveat that it must be carefully introduced in the legislation, that there must be an experimental plan or program or design associated with the monitoring.

The one danger—and that danger has occurred in the past—is that a program developed in which a large number of parameters are monitored which, ad infinitum—whose significance is not known or not knowable or not relevant. And therefore in monitoring a program which should take place, which must take place, indeed, if you are concerned about the environment, the only way to know your concern is to monitor it.

So a monitoring program must take place. It is certainly in the national interest and ought to be done with that one limitation, that a careful design be associated with the parameters to be measured.

Mr. Wood. Any kind of organized response. And the scientific, engineering, and academic communities that would be provided, I know would be useful and appreciated.

Now, the question, from what we have been able to discern here today, it appears that there is no, what you would call, thorough environmental balancing when it comes to the secondary treatment plants.

On the one hand, waterfront land, recreation land, and other high use and utilization of high levels of energy—you burn gas or coal or whatever is producing, oxidizing, just strip mining coal in the West, the esthetics are something less than desirable. The site of the waste treatment works is less than desirable. Aerosols from sludge plants and so on—would you have any suggestions of some level or a requirement for a new secondary treatment plant that gets built on these types of sites, for a thorough environmental balancing rather than what often happens as a result of legislation, single-purpose environmental reviews, specifically water pollution?

Dr. CRAVEN. That is an excellent suggestion. Indeed, all the factors that you so well cited are on the negative side of the scale. And in those instances—and there are such instances as, of example, in confined estuaries or confined bays where secondary sewage or more elaborate sewage treatment is required, and I do want to make that point.

But it seems to me that you have hit the nub of the problem, that there is an environmental balance, and that one takes the total environment into concern, not just the ocean waters—plus the land, plus the total energy balance. Then I think far more meaningful regulations would result.

Mr. Wood. Thank you very much.

Thank you, Mr. Chairman.

Mr. McCORMACK. I have a couple of questions, if I may.

I hope you realize that we have been in and out because of the voting and other obligations.

Earlier on, Professor Isaacs or Dr. Pearson, one of the two of them, mentioned DDT. I am curious to know if the path and effect of DDT and its degradation products are known in ocean water, or is it just part of the general methodology?

Dr. CRAVEN. I think I am personally not qualified to answer that.

When asked similar questions, Dr. Isaacs referred that to tomorrow's testimony here—and he may be in the audience now, cringing as a result, and maybe having all evening to prepare—the limited knowledge that I have of DDT is that its detrimental effects have not yet been quantified or even perhaps identified in the ocean environment, but are presumed, and perhaps in this instance, fairly presumed.

But there is little information existing at the present time.

Mr. McCORMACK. Thank you. We will pick that up tomorrow if we can.

There is another question that I want to ask. I would like to ask you to comment, if I may.

It seems quite obvious to me that the argument against secondary treatment in many cases would be much stronger if it were possible to kill whatever organisms might be hazardous in ocean water. One technology, of course, would be radiation, heavy gamma radiation.

Have you thought about this prospect or do you know of others that may have thought about it as a secondary treatment, following the type of preliminary treatment that Professor Isaacs described earlier on? Heavy gamma radiation which would sterilize the effluents from the primary treatment system?

Dr. CRAVEN. The general conclusion which I have come to—and I believe Professor Isaacs has come to—is that in saltwater, salt ocean water, that this is not a requirement.

Let me elaborate a little bit on that and talk about some studies that Professor Isaacs alluded to.

There are two types of health hazards that one is concerned about—one is what is associated with swimming in waters in which there has been a waste discharge. That first has been extensively studied, extensively studied, and the studies are convincing beyond a shadow of a doubt that there is not significant difference between the health of individuals who swim in unpolluted water or swim in polluted water, that there is a high statistical difference between swimmers and non-swimmers in terms of colds, ear infections and various other kinds of infections.

Mr. McCORMACK. Swimmers in general?

Dr. CRAVEN. Swimmers in general. But there is no deviation.

And the British conducted a 5-year study on the British public bathing beaches. Updated a 5-year followthrough of swimmers on nonpolluted beaches and polluted beaches, and found absolutely no statistical significance between these two, and no diseases that could be directly traceable.

This is not true of freshwater, but this is true of saltwater. And when you look at the mechanisms that are involved, one discovers that the saltwater terminates the bacteria very rapidly.

Now, there is a second health problem, and that is the viruses. And it is not the viruses being picked up by the swimmers. It is the viruses which settle in shellfish and there is a serious hazard that these are feeders, and they are able to acquire these viruses. And so, therefore, shellfish which are grown in polluted waters are suspected and may result in hepatitis, and other viral infections.

Now, this means that a great deal of care must be taken with respect to shellfish which are consumed. I note that many of you are members of a committee concerned with aquaculture, and it is my hope that someday all shellfish which we eat in this society are produced by aquaculture techniques which would obviate the danger associated with this hazard.

Mr. McCORMACK. What you are saying is that sterilization is probably not necessary in seawater?

Dr. CRAVEN. That is what I am saying.

Mr. McCORMACK. By any mechanism?

Dr. CRAVEN. Other than the seawater itself.

Mr. McCORMACK. OK.

Now, there is an unspoken assumption that seems to be coming out. I guess I am asking questions about Professor Isaacs' testimony earlier. If you do not feel you can answer, do not feel obligated to answer them.

There was in Professor Isaacs' comments an undertone that seemed to be saying, an inference, that human activity in terms of withdrawal of nutrients from the ocean and releasement of those nutrients was a substantially greater effect than the natural phenomenon that had been going on for millions of years. I am curious to know if my impression is indeed a correct one.

Is Professor Isaacs saying that the removal of nutrients from the ocean by human activities or the diversion of nutrients from normal procedures on the land by human activities such that it makes greater impact on the ocean than the natural leaching of the chemicals from the soil is still going on today in spite of man's activities?

Dr. CRAVEN. I do not think that is quite what he meant. But let me put it from my own perspective.

What I think he meant essentially goes this way. The ocean, as a producer of protein at the present time, is limited by the amount of natural upwelling, natural upwelling—

Mr. McCORMACK. Fundamentally phosphorus?

Dr. CRAVEN. Fundamentally phosphorus.

For example, an upwelling that comes from natural ocean currents, that comes against the shore—for example, we have the Kurishiro current—at the present time, the total fish protein that is taken from the ocean is very close to the estimate of maximum sustainable yield, some 70 million metric tons of fish per year.

There is no way of increasing that yield unless one increases the upwelling by artificial means, and there are proposals to do that—or unless one provides some incremental—unless one provides nutrients to the ocean as one would do in ocean farming.

And essentially what I think Isaacs is saying is when you take that 70 million metric tons of fish out of the sea that you have harvested all that the land can harvest or harvested all that the water can harvest, and that you owe it to yourself to put at least that much back

into the ocean in places where it could be productive again, if you want to increase and sustain that yield.

Mr. McCORMACK. One could accomplish it the same way by imposing some sort of artificial upwelling system.

Dr. CRAVEN. One of the most interesting developments in this regard is the ocean farmer-energy conversion process which is being developed primarily as an ocean thermal energy producing device, and which many of us feel is most effective as an artificial upwelling device.

Mr. McCORMACK. Cold water?

Dr. CRAVEN. Surface. And cold water is nutrient-rich water, and you could look at the ocean thermal energy as either an energy producer—which has nutrients as a biological product—or you can look at it as a nutrient producer with energy as a byproduct.

My own opinion is nutrient producer with energy as a byproduct.

Mr. McCORMACK. Operating near enough to the bottom, would you actually disturb the bottom?

Dr. CRAVEN. No, no. The ocean has a layer that has no nutrient in it, because all the nutrients go down below. But you get about 1,000 feet below the surface of water, then the ocean becomes nutrient rich. So it is a matter of having all this fertilizer just 1,000 feet away.

Mr. McCORMACK. We have ocean-grazing facilities, equatorial areas, central Atlantic, will still—will occur there, increase in nutrients, and supply—out in the mid-Atlantic?

Dr. CRAVEN. That is my understanding.

Mr. McCORMACK. Now, I would like to ask one more question, which goes back to the first question of the day, which would have been asked if I had been here. This is something on which we have been receiving a lot of testimony, but without explicitly, I think, expressing what really is the exact purpose of secondary treatment as being proposed by the EPA regulations? What is it designed to do exactly?

Dr. CRAVEN. The regulation—I may not be answering this correctly because I may miss the implication of this question.

The regulation is, as it is now presumed, vitiates as now proposed—vitiates the waiver, that the waiver applies only to grandfathered installations and not to new installations. And what it does is restore the previous requirement that wastewater treatment is independent of quality of the receiving waters, that the wastewater is independent of the quality of receiving waters.

I believe that that was a fundamental—perhaps I used political philosophy or political-economic philosophy—that preceded the construction of the first Water Quality Act, the notion that treatment process should be independent of the quality of receiving waters.

Mr. McCORMACK. Let us proceed on the technical side of the same question.

What would be actually accomplished by the secondary treatment of fecal—what are we removing? What manner, shall we say, are we improving municipal sewage by secondary treatment—just looking at the system, installation—what does it accomplish?

Dr. CRAVEN. The primary thing that secondary sewage treatment does is to oxidize the waste matter and settle out a great deal of it. And the net result of this is that you reduce the oxygen demand and you reduce the uptake of oxygen from the water into which it is discharged.

This is an absolute requirement for a limited body of water which is becoming heavily nutrified. The reason that secondary sewage treatment plants were originally designed—this goes back—when I was a civil engineering student in Cornell in 1944, and at that time we were told—we used to go around with slogan, “The sewage has to have the perfect BOD.” Very, very, old treatment process.

And the primary purpose of it, it is to not take the oxygen out of the receiving waters. And this is an absolute requirement for streams and for lakes and for rivers which are overloaded.

It is an irrelevancy for the ocean.

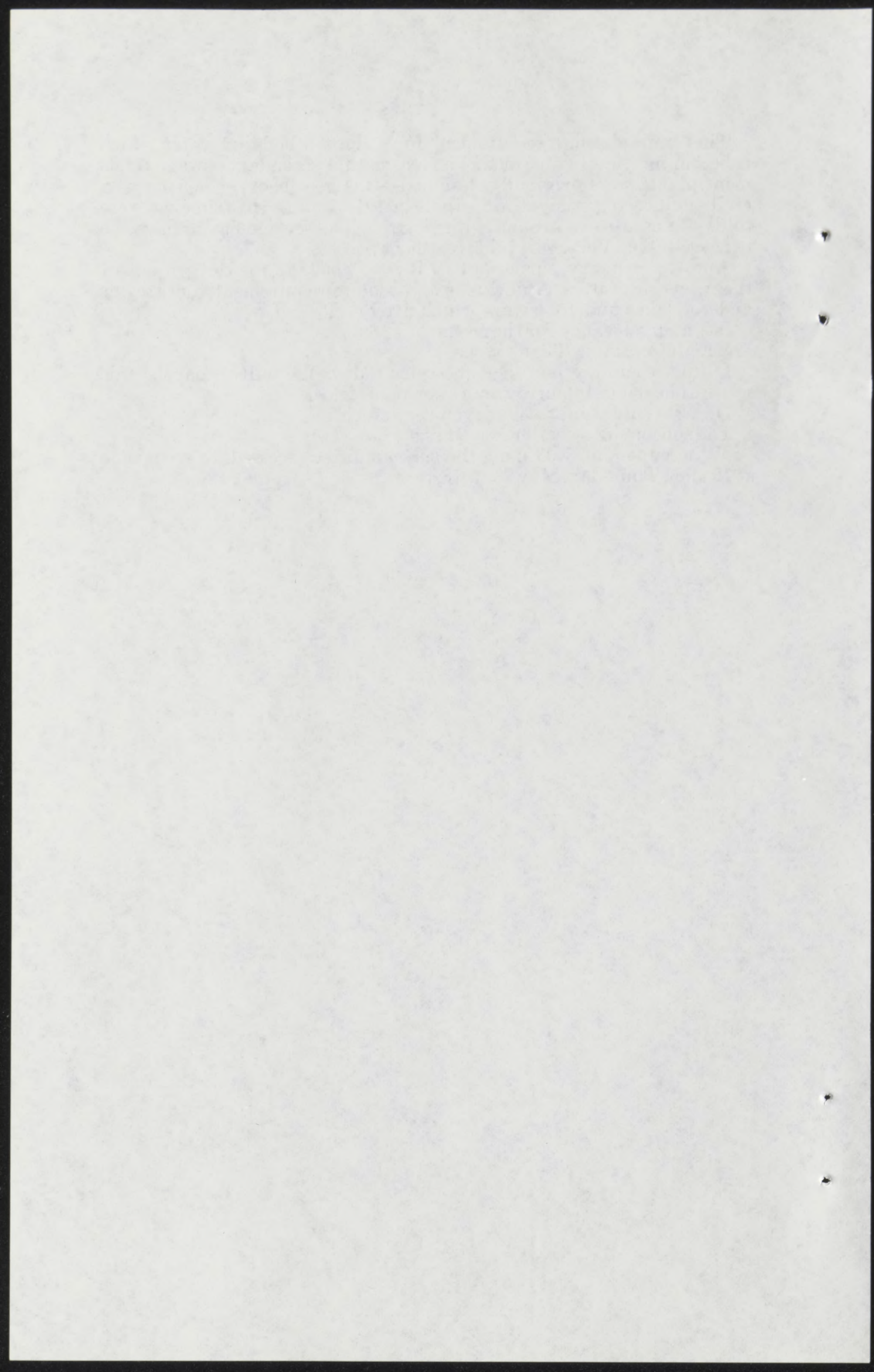
Mr. McCORMACK. Thank you.

I think there are no other questions today. We will reconvene this series of hearings tomorrow morning at 10 o'clock.

Dr. Craven, I want to thank you very much.

The subcommittee will now recess.

[Whereupon, at 3:05 p.m., the subcommittee recessed, to reconvene at 10 a.m., Thursday, May 25, 1978.]



MODIFICATION OF SECONDARY TREATMENT REQUIREMENTS FOR DISCHARGES INTO MARINE WATERS

THURSDAY, MAY 25, 1978

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON WATER RESOURCES,
OF THE COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:15 a.m., in room 2253, Rayburn House Office Building, Hon. Ray Roberts (chairman of the subcommittee) presiding.

Mr. ROBERTS. The subcommittee will come to order.

This morning, we will hear again from a distinguished panel of witnesses concerning the impacts of secondary treatment on the ocean environment and the scientific considerations that should be taken into account in modifying the secondary treatment requirement.

Yesterday, we received some excellent testimony from distinguished gentlemen, both from international experience and experience in the United States. We are looking forward this morning to hearing the views of these gentlemen who, like yesterday's folks, have traveled great distances to be with us, and we are pleased and deeply appreciative of it.

Mr. Clausen is here on my left and is the ranking minority member, and Dr. McCormack is our resident scientist.

Mr. CLAUSEN. Mr. Chairman, let me just take a brief moment to welcome my fellow Californians before the committee. We appreciate very deeply the fact that you have conceded to our request to come here to give us the benefit of your thinking and hopefully, to have a cross section of input from those of you that are in the scientific community.

Thank you.

Mr. ROBERTS. Our first witness this morning is Dr. Norman Brooks.

Dr. Norman H. Brooks is a distinguished expert in the area of hydraulics and water resources with a summa cum laude doctoral degree in civil engineering and physics from the California Institute of Technology. He is currently the James Irvine professor of environmental and civil engineering as well as the director of the environmental quality laboratory at Cal-Tech.

Dr. Brooks is a member of the National Academy of Engineering, and has twice been the recipient of the Rudolph Hering medal presented by the American Society of Civil Engineers. He is the Cal-Tech delegate to Universities Council on Water Resources. He has chaired

the Committee on Environmental Issues, for the California Legislature. Dr. Brooks also served on the Environmental Research Assessment Committee, National Academy of Sciences.

Dr. Brooks has extensive experience in designing ocean outfall structures for the Orange County Sanitation District, California, and the Suffolk County Sanitation District, Long Island and has served as a consultant to several of these areas.

Please proceed.

TESTIMONY OF DR. NORMAN BROOKS, DIRECTOR, ENVIRONMENTAL QUALITY LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY

Dr. Brooks. Thank you, Congressman Roberts.

I have prepared a brief statement which I would like to have put in the record. I will paraphrase it, though, in order to proceed quickly.

Mr. ROBERTS. Without objection, the statement will appear in full in the record at this point.

[Statement referred to follows:]

STATEMENT OF NORMAN H. BROOKS, JAMES IRVINE, PROFESSOR OF ENVIRONMENTAL AND CIVIL ENGINEERING; AND DIRECTOR, ENVIRONMENTAL QUALITY LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIF.

SECONDARY TREATMENT WAIVERS AND OCEAN OUTFALLS

1. This statement relates to the subject of waivers for secondary treatment for certain ocean discharges according to Section 44 of the Clean Water Act of 1977. In past years I have participated in the design of most of the major outfalls along the California Coast and at Honolulu as a special hydraulics consultant and am presently so engaged for the City and County of San Francisco (as a special consultant to the consulting firm of PBQ&D, Inc., San Francisco).

At Caltech, I have been involved in research on dispersion and mixing of wastewater discharges, and am presently Director of the Environmental Quality Laboratory, an interdisciplinary policy study center for environmental problems.

However, my comments are given here as an individual and not as representing either Caltech or any of the sewerage agencies.

2. The principal technical reason for having a waiver provision for secondary treatment for municipal discharges is that for some outfall systems the dilution is so high that very good ambient water quality can be achieved with less than secondary treatment. Therefore, the criteria for a waiver of the secondary treatment requirement must give full consideration to the dilution obtained by the outfall system. In a high performance outfall diffuser, such as those used by major discharges in California and Hawaii, initial dilutions are typically 100:1, and may range up to 1,000:1 in very favorable circumstances.

3. The dilution for an outfall system is achieved in stages which can be designated as initial dilution and subsequent field dilution. The initial dilution is that which occurs immediately in the vicinity of the outfall diffusion structure as the result of the buoyancy and momentum of the discharge fluid during the first few minutes after discharge. The mixing process in this phase is determined by the kinetic and potential energy of the discharge itself. The subsequent field dilution, however, occurs as a result of natural oceanic turbulence as the sewage plume drifts away from the discharge site. For engineering and regulatory purposes, it is better to consider just the initial dilution as has been done by the State of California because: (a) it is much larger than the subsequent dilutions for a well designed outfall diffuser; (b) it is more predictable; (c) it is more easily measured; (d) it is under the control of the design engineer.

The initial dilution is determined by: (a) the characteristics of the diffuser (overall length, number of ports, diameter of ports and orientation of ports and overall diffuser structure); (b) depth of water; (c) the ocean currents; (d) the water-column density stratification (by temperature or salinity gradients); and (e) the effluent flow rate.

Typical diffuser geometry and depths for major west coast outfalls have been tabulated by Koh and Brooks (see Reference 1 and Table 1). The effect of all of the parameters above (diffuser geometry, depth, currents, stratification and flow rate) are explained in that same paper. Additional information on modeling is given in References 2 and 3. The state-of-the-art is now such that it is possible to predict dilutions by computer simulations as has been done for the design of major California and Hawaii outfalls. After outfalls are built and are operating, the dilutions can also of course be measured in the field. Like other water quality measures, the dilution is a quantity which varies in time and space; hence, for setting criteria or regulations, the frequency distribution of dilution must be considered.

TABLE 1.—SUMMARY OF CHARACTERISTICS OF MAJOR PACIFIC OCEAN OUTFALLS (UNITED STATES)

	Year operation began	Pipe diameter (inside inches)	Length of main outfall (excl. diff.) (ft)	Length of diffuser L_d (ft)	Depth of discharge (ft) (nominal)	Design average flow Q (ft ³ /sec)	Port diameters ^a (inches)	Port spacing ^b (average) (ft)	Velocity of discharge (nominal) for average flow (fps)	Area factor (total port area/pipe area) OL/d (ft ² /sec)
Sanitation Districts of Los Angeles County: Whites Point No. 3	1956	90	7,900	2,400	200-210	232	6.5-7.5	24	8	0.097
City of Los Angeles at Hyperion	1960	144	27,525	7,920	195	651	6.75-8.13	48	13	.082
San Diego	1963	108	11,500	2,688	200-210	363	8.0-9.0	48	15	.135
Sanitation Districts of Los Angeles County: Whites Point No. 4	1965	120	7,440	4,440	165-190	341	2.0-3.6	6	9	.077
Metropolitan Seattle (West Point)	1965	96	3,050	600	210-240	194	4.5-5.75	3	6	.323
Sanitation Districts of Orange County, Calif.	1971	120	21,400	6,000	175-195	450	2.96-4.13	12	13	.075
Honolulu (Sand Island)	1975	84	9,120	3,384	220-235	164	3.00-3.53	12	10	.048

^a Exclusive of end ports, which are usually somewhat larger.^b Length of diffuser divided by number of ports; real spacings on each side of the pipe are twice the values indicated.^c Blocked by orifice plates with openings of 6.5 to 7 in for early years' low flow.

Source: Koh and Brooks, "Fluid Mechanics of Waste-Water Disposal in the Ocean," Annual Review of Fluid Mechanics, vol. 7, 1975, p. 192.

4. One question raised by the new law (Sec. 301(h)(1)) is what to use as "an applicable water quality standard specific to the pollutant to which the modification is requested. . ." Since the key technical idea behind the waiver provision is high dilution in ocean waters, the appropriate effluent limits would be derived from ambient water quality standards by a back calculation based on dilution. If ambient dissolved oxygen is used as an ambient water quality parameter, then it may be inferred that BOD¹ increment is allowable after dilution, and then, by multiplying by the dilution, the effluent BOD limit is obtained. For example, if the BOD of the mixture after initial dilution is to be kept less than 1 mg/l and the dilution is 150, then the effluent could have up to 150 mg/l of BOD.

This approach of deriving effluent limits by a back calculation from ambient limits has recently been adopted in California's Revise Ocean Plan (Reference 4) for toxic material ("Table B") after extensive study. This same approach can logically be applied to all pollutants.

5. These remarks should not be construed to imply that the statement "Dilution is the solution to pollution" applies to all pollutants. For certain pollutants which are natural ecosystem products (such as carbon, nitrogen, phosphorus) the statement is true, i.e., the best strategy is to disperse them back into the marine ecosystem. These elements are widely dispersed in nature, and the main difficulties man has encountered are due to excessive local concentrations.

On the other hand, wide dispersal is not an appropriate strategy for toxic substances, which can most effectively be contained at their sources rather than be released to public sewers, to become part of either sludges or effluents.

REFERENCES

1. Koh, R. C. Y., and N. H. Brooks, "Fluid Mechanics of Wastewater Disposal in the Ocean," Annual Review of Fluid Mechanics, Vol. 7, 1975, pp. 187-211.
2. Brooks, N. H., "Dispersion in Hydrologic and Coastal Environments," W. M. Keck Lab. Report KH-R-29, California Institute of Technology, December 1972, 136 pp. (Also Environmental Protection Agency, Ecological Research Series, EPA-660/3-73-010, August, 1973.)
3. Baumgartner, D. J., D. S. Trent, and K. V. Byram, "User's Guide and Documentation for Outfall Plume Model" (Working Paper #80, EPA Pacific Northwest Water Laboratory), 1971.
4. California State Water Resources Control Board, Water Quality Control Plan for Ocean Waters of California, January 1978 revision.

Dr. BROOKS. The first point that I make in this statement is that my experience and interest in outfalls is related to the engineering design of outfalls and the laboratory research that we have been doing at Caltech for a number of years.

I have, in addition to being a professor at Caltech, served as a special consultant on the functional design of outfalls for a number of agencies on the west coast and in Hawaii. Typically, I work as a special consultant to a consulting engineering firm, which does all of the detailed design work with my advice and guidance on design procedures.

One of the most important features of an outfall design is the dilution that it achieves. The capability to predict outfall dilution is well established, and therefore outfalls can be designed to achieve prescribed dilutions and water quality.

And we have found by experience that these design predictions are confirmed.

In my prepared statement, I describe some of the factors that affect the dilution of an outfall. An outfall is carefully designed to fit in with the characteristics of the environment and the characteristics of the wastewater, and the performance depends on such things as the overall length of the diffuser, the number of ports and their diameter,

¹ Biochemical oxygen demand.

the depth of the water, the ocean currents, the temperatures and salinities in the ocean, and of course, the flow rate.

In the table in my prepared statement, I have given some of the characteristics of the major west coast outfalls. They happen to all be projects with which I have had some association.

It is also interesting to note that outfalls are designed for a particular purpose, or a particular set of requirements, such as the California ocean plan.

In other words, as I am currently doing with the city and county of San Francisco, one can make a back calculation, starting with the requirements, and decide what configuration is needed for an outfall.

I want also to make it clear that I do not think that "dilution is the solution to pollution," but rather, that we have to be very selective about strategies for various types of contaminants. Substances like organic carbon, nitrogen, phosphorus, which are natural elements of the ecosystem can very well be dispersed back into the environment, from where they came, but—

Mr. CLAUSEN. Would you say that again?

Dr. BROOKS. Natural organic wastes like organic carbon, and the nutrients, like nitrogen and phosphorus—these substances are produced by man from many places—can very well be dispersed back into the global supply of these basic elements. There is nothing toxic about these materials. The troubles we have had in the past are often due to poor dilution. If there is high dilution, the concentrations of these substances are low enough to be favorable additions to the ocean's supply of nutrients, and are not deleterious—at least when you have a situation like the west coast.

On the other hand, for heavy metals or persistent organic chemicals, the best strategy is to control them at the source; that is pretreatment. If they are allowed to enter the sewage system and the sewage receives secondary treatment much of these toxic materials will become part of the sludges. In southern California there is a major governmental study in progress now to evaluate alternative strategies for sewage sludge disposal, which will be a very large problem if full secondary is implemented. The presence of toxic materials in the sludge is probably one of the key obstacles to developing easy options for disposal of that material.

So I am in favor of keeping the toxic materials out of the system entirely. The agencies in California are making vigorous efforts in that direction.

I would be happy to respond to your questions.

Mr. ROBERTS. I am real pleased, Dr. Brooks, at your statement with reference to predictability, that if you build the proper models and do the proper engineering, that you can predict what is going to happen pretty well.

Could you expand just a little bit on that?

Dr. BROOKS. Yes.

Mr. ROBERTS. And the reason we are concerned is that we have been told you cannot predict these things, regardless of all the know-how you have.

Dr. BROOKS. No. You absolutely can predict how an outfall will perform. In fact, I would like to refer to a brief paper which I wrote

last year, entitled, "An Overview of the Functional Design of Ocean Outfalls for Waste-Water Discharge."

Mr. ROBERTS. Could we have a copy of that for the record?

Dr. BROOKS. Yes.

Mr. CLAUSEN. Mr. Chairman, I would ask unanimous consent that Dr. Brook's statement that he just presented be added as an addendum to his testimony.

Mr. ROBERTS. Without objection. [See page 99.]

Dr. BROOKS. I think it is useful for me to describe what I would call the systems aspect of waste-water disposal. You cannot design an outfall without considering the three parts of the system.

The first is the source control or the pretreatment of industrial sources. The second is the main municipal waste treatment plants. And the third is the ocean outfall that goes with it.

Now, with regard to different pollutants. You can use different strategies—I am not talking from a legal point of view, but rather from a technical point of view.

For example, if you do a good job on source control, then you have more options on what you can do with the waste-water and sludge, because the toxic material is reduced as a problem; then, the use of dilution is a good technique. For instance, if you have only primary treatment combined with a very long outfall, such as those designed on the west coast giving a very high dilution, then you can achieve the same results as if you had full secondary treatment but a poor outfall.

I have always maintained that the initial 1972 act made a mistake in not considering the outfall as part of the overall system, because sewage treatment is not the end of the system. You have to dilute it and dispose of it.

And it turns out that use of long, deep outfalls, when you have good receiving waters, are much cheaper than treatment.

All right. Once you recognize the systems aspect, then you can study various alternative combinations of the degrees of treatment and the characteristics of the outfall.

Now, an outfall is designed to achieve a particular dilution. We do various kinds of research at Cal-Tech, and these are some of our reports, on the fluid dynamics of mixing in the ocean, with the density stratification. From these results, developed from actual laboratory experiments, computer simulations have built up gradually into an engineering practice or an engineering design procedure. To design an outfall you also need measured ocean data at the site including the temperature profiles and the ocean currents at all different times of the year. This information is used in the computer simulations to develop a functional design which will have a certain predicted performance.

It is just like any other engineered project—a spacecraft or a bridge is designed for a particular purpose and the engineers who are responsible for it have procedures for developing an economical, effective design. Outfalls too are designed for particular objectives. Particularly I can say that is true for these west coast outfalls mentioned in the table because I did that kind of work, in association with the engineering groups, for all of those projects.

The design of an outfall includes, of course, the consideration of costs and the size of the pipe and whether it will be pumped and so on, but these are all engineering details which are, of course, important, but do not bear especially on the issue you raise.

In summary, you can predict the dilution, and from the dilution, then you can predict the chemical concentrations of the elements that you will get after dilution, and following the initial dilution, you can predict, then, the subsequent dilution and how the material is carried away by the currents.

We are just learning pretty well how to predict the deposition on the bottom and are working more and more with biologists and chemists to get comprehensive prediction capability.

We are doing some of this kind of work now for sludge discharge in the ocean, even though that is not very popular, but it is a subject which is also subject to a rational, physical, chemical, biological study of what happens for different systems of discharge.

The State of California has recognized the predictability of dilution in its new ocean plan and has a system for relating the effluent limits for toxic materials to the ambient levels which are considered to be safe and prudent, and with a back calculation, then, using the dilution obtained for each particular outfall system to establish effluent limits.

If you would like a set of the California ocean requirements introduced into the record, I would be happy to do so.

Mr. ROBERTS. Without objection, they will be introduced into the record. [See page 102.]

Mr. ROBERTS. Could I ask one question, just out of personal interest. Did you have anything to do with the design of the sand flat Honolulu outfall, which is the most fantastic I have seen?

Dr. BROOKS. Yes, sir, I did.

Mr. ROBERTS. Well, it is a fantastic operation.

Dr. BROOKS. A colleague of mine, Dr. Robert Koh, and I were special consultants to the company which did the design for the city and county of Honolulu. I was instrumental in determining the general layout and the length and size of that outfall.

Mr. ROBERTS. The reason I thought you might be was because you talked about the tides and the currents, and certainly, they have an unusual situation there. But it has been eminently successful.

Mr. Clausen?

Mr. CLAUSEN. I have a few questions.

Would health officials in the State of California—or, for that matter, whoever you come in contact with—would they agree with your assessment and the recommendations that you have made that you have presented to this committee? Would they agree with you?

Dr. BROOKS. I am not familiar with what the people in the Department of Public Health would say, but I think the people in the Water Resources Control Board would generally agree with what I said, and I think it is reflected in the requirements which they have adopted. In other words, secondary treatment is not part of the required treatment in the California ocean plan.

They do recognize the predictability of the ocean in the way they have prepared the requirements.

Mr. CLAUSEN. Well, would there be any reason for the Public Health people to challenge the thrust of your recommended designs?

Dr. BROOKS. Well, it is hard for me to speculate what somebody else would do for a challenge, but personally, I do not see any basis for a Public Health challenge, provided that a system of monitoring is in effect. After you build an outfall and put it in operation, it is desirable to monitor public health parameters, like bacterial concentrations, to confirm its satisfactory operation.

Let me add one further thing. I believe that the ocean provides an unusually large public health protection for the disposal of waste water, because the public health interface with the ocean is much less than with freshwater systems; in other words, the potential for contamination of drinking water just is not there, because it just is not a drinking water source.

Mr. CLAUSEN. Now, when you refer to monitoring, do we have adequate equipment to do the kind of monitoring job that you think is necessary, or should we be addressing this in some form?

Dr. BROOKS. I think I would like to have you ask that question of Dr. Bascom, who will be coming up later. He is more in the business of measurement and monitoring in the ocean.

But I think in a general way, the answer is yes. I think perhaps I might say in the general area of biological systems is perhaps the greatest latitude of uncertainty.

Mr. CLAUSEN. You talk about effluent limits. Could you give us an indication of what you would describe as the effluent limits on pulp and paper; we have on the west coast some discharges from pulp and paper plants.

I guess what I am really thinking about is what would be required to control it in terms of eliminating any possible adverse impact on fish and marine life, or is there any reason to be concerned about the effluent?

Dr. BROOKS. Well, I have not worked with pulp and paper discharges, so I am not immediately acquainted with the exact waste water parameters or the requirements. But I think in general, I would say, though, that given any particular waste water stream and given a set of water quality requirements, there is an optimal system which combines treatment and dispersal, taking account again of the kinds of pollutants you have, whether they are just organic carbon, or whether you have toxic materials which need to be controlled. I have every confidence that if I were hired as a consultant, and I was informed that "These are the waste water characteristics, and these are the environmental characteristics; what shall we do," that it would be perfectly feasible to make a system design.

Mr. CLAUSEN. Well, would you design it so that it would be self-contained, and contain some recycling arrangement, or would you design it on the basis of potential outfall—or both?

Dr. BROOKS. Often mixed strategies turn out to be optimal. But it is very difficult to design any system without some discharge of residuals and waste water.

I would certainly not discharge paper waste without treatment. But I am not able to say exactly what level of treatment, without considering a specific situation.

Mr. CLAUSEN. You made reference to mixing zones.

Dr. BROOKS. Yes.

Mr. CLAUSEN. Could you give us an indication of what the overall parameters or the boundaries of the mixing zones would be for these outfalls?

Dr. BROOKS. Yes; the initial mixing zone is often identified because it is the place where the initial buoyancy and the momentum of the discharge produce a lot of turbulence, agitation, and stirring resulting in large initial dilution. The process occurs within the first few minutes after discharge.

And it usually occurs within a relatively short distance of the diffusion pipe. For example, I was just looking at some data from METRO Seattle. The end of the mixing zone is within 100 meters of the West Point outfall. Of course the mixing zone will bend over in the down current direction, or it will reverse when the current reverses, but all within a few hundred feet or 1,000 feet at the most.

These discharge diffuser pipes are often quite long, too. They may be several thousands of feet long. But the mixing zone occupies only a local, small area around the diffuser. When you look at a map of the coastline, and you draw the initial mixing zone around an outfall, it is really relatively quite a small region.

Mr. CLAUSEN. Right. Well, following this somewhat, yesterday we heard testimony regarding upwelling of nutrient-rich waters in the lower levels of the sea.

Now, what would be the magnitude of the discharge from a city like Los Angeles as compared to the volume of the natural upwelling?

Dr. BROOKS. Well, would I be correct if I inferred that the discussion was referring to the nutrient input?

Mr. CLAUSEN. Yes.

Dr. BROOKS. I believe that the input of nutrients from the outfalls in southern California is of the same general amount as the nutrient input by upwelling in the vicinity of the outfalls, but is significantly less than natural upwelling for the whole southern California bight.

Mr. CLAUSEN. You say it is comparable to that which is coming naturally?

Dr. BROOKS. That is right, for the local areas around a major outfall.

Mr. CLAUSEN. Now how far from the diffuser are reasonably measurable quantities of pollutants detectable?

Dr. BROOKS. It depends a lot on which pollutant. If you are talking about something very persistent, like PCB's or, in earlier times, DDT, it might be picked up a number of miles away. But if you are talking about ammonia, which decays relatively rapidly within a matter of one-half hour, then you would not pick it up more than a mile away.

I think the nutrients, as another example, would be probably spread around over tens of miles, but they would be at such a low level compared to background that you could not tell whether they came from the outfall or whether they came from another source.

It is hard to try to put a cutoff point for detection. If you put fertilizer in the garden, how much can you detect that you put there. Well, you are not quite sure after a while whether you put it there or—

Mr. CLAUSEN. What percentage of the outfall would actually be diluted and picked up by the natural ecosystems, as contrasted with the amount that would actually settle and go to the bottom of the ocean?

Dr. BROOKS. As I recall, the studies that have been made around the Los Angeles County Sanitary District's outfall system show that even though there is some deposition of particles on the bottom, that most of the fine particulates are dispersed far away from the outfall, probably out into the deep ocean. So that a small part of the material does reach the ocean bottom.

Mr. CLAUSEN. All right. Now, the final question, and then I will ask some others in writing for you to respond to, so that I may yield to the other members.

I am sure you are familiar with that which took place in Italy, with the mussels, where there were some health problems with this outfall in that area.

Now, based upon the recommendations that you have made for design, and the control over the quality of the water and so forth, based on fish life, do you have any concern about health problems and eating fish that would be in that general area, knowing what you know?

Dr. BROOKS. No, provided an outfall is properly designed and operated; but this is not the case for many Italian outfalls.

Mr. CLAUSEN. Thank you.

Mr. ROBERTS. The gentleman from Washington?

Mr. McCORMACK. Thank you, Mr. Chairman.

Dr. Brooks, I have three or four sort of relatively unrelated questions. Yesterday's suggestion that we allow ocean dumping or ocean diffusion of sewage after primary treatment, provided that we have monitoring for potentially harmful organisms, heavy metals, organic poisons, such as certain insecticides—I take it this is what you are suggesting; is that correct?

Dr. BROOKS. Well, yes; let me see if I understand you correctly. In my opinion, secondary treatment does not provide a useful function for discharge into deep waters such as off the States of California or Hawaii. It is not a kind of treatment which is specific to the problem in the ocean.

The main thing that secondary treatment does is to provide an in-plant biochemical oxidation which can be done perfectly well in the ocean, because when you have a high dilution, there is plenty of oxygen capacity in the ocean to carry out in a perfectly natural way the reduction of these organic elements back to their basic nutrients.

Particulates, which can make turbidity problems in the ocean, are removed by primary treatment or advanced primary treatment, with chemical additions (such as polymers). The Los Angeles County Sanitation Districts has been successfully experimenting with advanced primary treatment in order to be specific to that particular ocean problem—in other words, to get more of the particles along with the toxic substances out of the sewage without trying to make a whole onshore oxygenation system; that is, secondary treatment.

Does that answer your question?

Mr. McCORMACK. Yes, it does. This requires monitoring for various categories of potential hazardous materials.

But once we build a system, and once it is in operation, then if we find that we are exceeding the concentrations, isn't it too late to

modify the system to handle the particular contaminants? Isn't it really saying that we have made a miscalculation?

Dr. BROOKS. No, I don't think so, because you have to understand that experience is gathered over many years. The various sewage agencies have been in operation a long time. Their plans are constantly being evolved. They respond to new information.

The Los Angeles County Sanitation Districts, for example, has for a number of years now careful records on trace elements concentrations. It is a big system, and they have an ongoing source control program. In fact, I have some data here from the districts which show the general trend of the trace contaminants.

In other words, there is not an opportunity for surprises, and rather, what you can do is if, as a result of your for example when ongoing monitoring indicated that there was a patch of the bottom which was found to be anoxic around the L.A. County outfalls due to too many solids, the agency upgraded the system for removing solids and advanced the primary system, and the spot is shrinking.

What I am saying is that many of these effects in the ocean, with the exception of highly toxic trace organics, are quite reversible.

If you stop an outfall, a study in Orange County showed that in a few years, the ocean recovers. It recovers much faster than—

Mr. McCORMACK. Here we are on a day-to-day process, where we are handling millions of gallons of sewage and effluent, and all of a sudden, we spot this problem; we are exceeding limits of something or other. How do we handle that situation? We cannot just turn it off. We have to handle the problem.

Dr. BROOKS. Usually, if something really goes bad, and you find a big jump in something, there is a reason for it. And I am sure that in any agency, the industrial waste inspectors would be going out into the sewer network and taking samples at different places.

It is just like detective work. You can chase right up the trunk sewer system to where this particular illegal discharge is coming from, and cause it to be stopped in a matter of a few days. The system is not perfect. That is right, you have a few risks. But I think that is the problem you have with all environmental systems: How are you going to keep people from spilling things illegally?

Mr. McCORMACK. I see. Well, Dr. Brooks, I am playing the devil's advocate with this question, and I think you can appreciate that, but the fact is, this is the sort of atmosphere in which we are living, particularly in Congress, with a lot of emotional groups with which we are dealing, and they are saying to us, "Prove to us that it is perfect," which of course is not possible.

Dr. BROOKS. May I make another comment?

Mr. McCORMACK. Certainly.

Dr. BROOKS. You know, if somebody dumped in a large slug of heavy metals, you could throw the secondary treatment plant all out of kilter, too. It would be upset—it could be upset for several days, and the secondary treatment would have a poor performance. The sludge digesters could be thrown out of whack.

In other words, there is not any system that is immune from some kind of an upset that is unscheduled or irresponsible.

Mr. McCORMACK. Thank you. Now, on a different subject, the gentleman from California asked about how far away one could detect

various contaminants. Isn't it true now that when detection systems are operating, we can detect 1 part in 10^{12} , or something of that sort, in many of these contaminants, so that we are dealing—

Dr. BROOKS. No; I do not think that is generally true. I think you have to be pollutant specific. If I release some special tracer material like sulfur hexafluoride, SF_6 , that is true, you can detect them at that level. But I think ordinary heavy metals, for example, you could not detect at that low dilution, because the background level is far higher on that.

Mr. McCORMACK. All right. So you can detect them, but you are below background. You can detect the presence of those substances with neutron radiation, for instance.

Dr. BROOKS. Yes; but again, you have to go through it element by element and talk about which concentration. You could not get dilutions—I do not think you could measure dilutions of 1 in 10^{12} .

Mr. McCORMACK. The thrust of my question is that it is possible, with our present detection systems, to go down to such low concentrations for virtually everything that we would be below background in most cases.

Dr. BROOKS. Right, I understand what you are saying. Let me put it in perspective. You know, I have worked on this area for 25 years, and I have seen a tremendous growth in the analytical capabilities of chemical detection.

What you find is that many of the problems seem to be recently measured—

Mr. McCORMACK. With new analytical technologies—

Dr. BROOKS [continuing]. With the new analytical technology, that is right, so that sometimes, I think people get the mistaken impression that suddenly, our environmental problem has taken a very sharp turn for the worse, which is not the case, but rather, that a lot of things are being measured which could not be measured before.

Mr. McCORMACK. Mr. Chairman, may I ask one more question?

Mr. ROBERTS. Go ahead.

Mr. McCORMACK. All of our discussion has to deal with bypassing secondary treatment, designing treatment possibilities of other approaches, such as using raw sewage as process water in certain chemical technologies, such as, for instance, coal gasification, where everything is incinerated and you are working with very high temperatures.

Has there been any study on this sort of thing, that you know of?

Dr. BROOKS. Well, let me speak a little more generally. There are many opportunities for reuse of water. The key to the reuse of water, though, is the quality that is necessary for the process for which you are using it.

Mr. McCORMACK. That is why I said coal gasification, because there are virtually no limits except salt concentrations.

Dr. BROOKS. I am not so sure, though, because the water has to be run through various kinds of equipment and processes, and it may be more optimal just for an in-plant optimization to treat the water so you will have less maintenance of the parts of the coal gasification equipment,

So I think that is more of an in-plant optimization question. But in the general sense, you can use many kinds of waste water for many kinds of industrial purposes, everything from cooling towers to make-up water, and that, I would certainly agree with.

Mr. McCORMACK. Can sludge be incinerated, Dr. Brooks?

Dr. BROOKS. Yes; if you want to. That is one of about 17 different alternatives being studied in southern California. But, I do not think you would want to do that in southern California, because you would add to our serious pollution problem and you would release toxic materials—or at least, the heavy metals would be released as very fine particulates into the atmosphere—

Mr. McCORMACK. Wouldn't you be able to scrub the metal oxides out?

Dr. BROOKS. Well—

Mr. McCORMACK. You would be getting the phosphorus back anyway.

Dr. BROOKS. Yes; but these techniques are never completely efficient, and then you still have the problem of what to do with the residuals then. That is, you have not closed the residuals loop. If you want to take what you get out of the scrubber and take it to a landfill, then one can say, "Well, maybe it will get in the drinking water"—

Mr. McCORMACK. Phosphorus would go back in the food chain, deliberately, as fertilizer.

Dr. BROOKS. Yes; if sludge is used as fertilizer.

Mr. McCORMACK. Thank you.

Thank you, Mr. Chairman.

Mr. ROBERTS. Counsel has some questions.

Ms. KOVALIC. Dr. Brooks, can you describe for us the importance of temperature and salinity stratification in the ocean and also the concept of a submerged sewage field?

Dr. BROOKS. Yes; one of the most interesting things that we have learned in the last 20 years, and many of the things that are described in the laboratory work we have been doing, has got to do with what we call density-stratified flow.

For example, off southern California, typically, the water at the bottom is 50° Fahrenheit, and at the top it may be 65, just by gradation of temperature. And when you introduce an outflow of discharge into the bottom water and it mixes with that cold bottom water, the density of the mixture is such that it stops rising maybe only halfway up. And therefore, this mixture of the ocean and the sewage water may be completely out of sight from the surface—this is what is called a submerged sewage field. It may be anywhere from 50 to 100 feet submerged below the ocean surface.

In fact, our present outfall technology allows us to predict the amount of submergence, and it is measured in the different outfall sites.

For example, at Orange County before construction, we predicted that the sewage flow would be submerged 11 out of 12 months of the year; in other words, you would never even see it during that time. When submerged you cannot even see anything at the surface right over the discharge point. And that has been confirmed; the slime has very rarely been seen reaching the surface, and only in winter. The same protection occurs at Honolulu, and at Seattle.

The reason this is a very important and interesting development is because most of the life zone in the ocean, the very rich life zone—the kelp areas—are all in shallower waters, say, up to 60 feet. Those are the zones where the light penetrates the most. So if you put this waste-

water cloud down at a lower level, it has less interference with the use of the upper waters, and it also provides an additional public health barrier against transmission of viruses and bacteria, and that it is prevented from approaching the shore. That is the reason, Mr. Roberts, why in Honolulu, the Sand Island outfall is doing so well: there is also stratification there, and the outfall is designed to take the advantage of it. It is a phenomenon that is peculiar to these outfalls in deep water, because you have the ability to get down under that stratification which is usually not possible to do on the east coast, which is typically shallower.

Ms. KOVALIC. Can you elaborate a bit on the comparison between the characteristics of the east and west coasts, with regard to temperature, salinity, currents, depth, and amount of dilution?

Dr. BROOKS. Yes. You know, I sometimes summarize it for my students this way. I say, on the west coast we have a poorly ventilated atmosphere but we have an ocean that really flushes well; and on the east coast we have an ocean which is much more stagnant but we have a generally pretty well ventilated atmosphere, because you have a lot more wind here. So, coming out of Washington, we tend to get too little for air pollution control for us Californians, and too much water pollution control, because you have the inverse situation as far as what is what.

More specifically, anyway, the east coast has a broad continental shelf that runs out for over 100 miles, and the water is shallower, the flushing if the shelf water in exchange with the deep ocean is a great deal less.

For example, off Palos Verdes (Southern California), we have water that is 2,000 feet deep within about 5 miles of shore, and yet off the east coast, you would have to go 100 to 200 miles to find such deep water.

Generally speaking, because of this, the ocean currents are greater off California, because the water is deeper, and the major ocean currents come closer to shore.

Ms. KOVALIC. Is it possible to design an outfall pipe on the east coast that will compensate for the conditions that you are describing, such that the net cost might still be less than that associated with secondary treatment?

Dr. BROOKS. It depends on the site, but generally, no. You have a matter of economics here. To get a high dilution, you may find that the length of outfall you need to build on the east coast to get to that deep water is prohibitively expensive. You might find that it is much cheaper to go to secondary treatment and have a lesser outfall system.

In California, if you can build an outfall like Orange County, for \$9 million, or the last one that Los Angeles County built, which was 15 years ago, for \$5 million—but they would probably cost three times as much now. Those are still relatively modest sums compared to a secondary treatment plant now, which may run to something like \$60 million per 100 million gallons per day capacity.

These are large outfalls, which benefit from an economy of scale.

If the system is only medium size, you may find that secondary treatment is cheaper than getting an outfall which will go way, way out.

On the other hand, if you have a good coastal situation, it may be just much cheaper to use a good outfall system, and less treatment.

As an engineer, I really like to see an optimum arrangement of facilities. If you have an opportunity to do something at a much reduced cost and get the same result, I would like to see the law and the regulations fixed so that that is possible.

Ms. KOVALIC. You have made several comments this morning about predictions, the ability to predict. Do I understand you to be saying that it is possible to make an accurate predictive judgment as to whether an unconstructed but proposed pipe would meet specific water quality, physical, chemical, and biological criteria?

Dr. BROOKS. Yes, it is, and I do that for my professional work.

Ms. KOVALIC. Could you give me your assessment of EPA's proposed regulations implementing section 301(h) of the Federal Water Pollution Control Act? In particular, I am curious about your thoughts on the proposed definition of the term, "existing discharge".

Dr. BROOKS. Yes. As I understand, their interpretation is that as of the December 1977 date, the evaluation for waivers is to be based only on what is actually in place and in use at that time. That seems to me to be unduly restrictive; it squelches the initiative of agencies and engineers—prevents them from carrying out planning, design improvements of facilities which they may determine to be most cost effective. It prevents the engineering of new developments, of new innovations, which I think could be reasonably proven to be of such quality as to provide a technical basis for a waiver, even though they may not have been in place at that particular cutoff date.

For any branch of technology, you would not want to say, "Let us freeze the technology at what was actually in place last year," if you had another good idea just coming along that you are already developing, and it has been shown to be much cheaper and cost effective and would have the same result as previous works already in use. Then it would seem to me it would be very uneconomical to prevent such further developments of the same kind and character.

Ms. KOVALIC. Thank you, Dr. Brooks.

Mr. ROBERTS. Doctor, there seems to be one main assumption in your statement—that you cannot have one set of plans or one idea that suffices for every operation, is that right?

Dr. BROOKS. Absolutely right. Everything is custom designed to a particular situation.

Mr. ROBERTS. Mr. Clausen had one more question.

Mr. CLAUSEN. To place on the record what we have heard here today in the form of a summary, would this come fairly close? The engineering profession has the capability to determine mixing, dispersion, or dilution rates for discharges from outfalls.

Dr. BROOKS. Yes, sir.

Mr. CLAUSEN. Now, your actual experience confirms your predictions; there is no mystery. Is this correct?

Dr. BROOKS. That is correct. If you like, I will introduce the titles of some of these reports into the record.

Mr. ROBERTS. Would you have copies of those that we could not put in the record, but as part of the file on this case; do you have copies of those?

Dr. BROOKS. Yes; I would be happy to leave this with you.

Mr. ROBERTS. We appreciate it very much, sir.

Dr. BROOKS. One of these is an EPA report that was written by me.

Mr. ROBERTS. OK.

Mr. CLAUSEN. Thank you very much.

Mr. ROBERTS. Dr. Brooks, we appreciate it very much.

Dr. BROOKS. Thank you for the opportunity to testify. I have been interested in the subject a long time, and I really welcomed the opportunity to speak to you.

Mr. ROBERTS. Thank you.

[Dr. Brooks' submission for the record follow:]

AN OVERVIEW OF THE FUNCTIONAL DESIGN OF OCEAN OUTFALLS FOR WASTEWATER DISCHARGE

(By Norman H. Brooks)

1. SYSTEMS ASPECTS

The design of ocean outfalls for wastewater discharge must be considered as an overall system with many interacting factors. First, for producing a given ambient water quality in the ocean there is always a trade-off between increased degree of treatment and increased outfall performance (increased length and depth of an outfall diffuser, and distance of the diffuser from shore). The ocean itself provides a high assimilative capacity ("treatment") for oxidizing wastewater if the effluent is properly dispersed.

Another systems aspect involves the choice of diameter of an outfall pipe. When larger it is more difficult to provide necessary physical stability of the line for withstanding earthquakes, scour by currents and wave attack in the breaking wave zone. On the other hand, smaller pipe sizes, although cheaper, require more pumping head, or installing a pump station when one otherwise might not be required. The balance of all these factors is very much site dependent both with respect to the environmental characteristics of the ocean, the discharge requirements, and the economics of construction.

As in any system there are constraints, such that not all factors are variable. For example, in accordance with present federal law, secondary treatment is a requirement for all municipal discharges, although the recent report of the National Commission on Water Quality recommends that some deferrals and waiver of this requirement be provided in an amendment to the legislation.¹ In some cases, an outfall may be designed, built, and put into operation for primary or screened effluent, before secondary treatment facilities are provided. The design must take this into consideration as well as the slight possibility that secondary facilities may never be built if the outfall performance with primary effluent is outstanding and meets all State requirements, and if the federal law should be relaxed. The design requirements for outfalls for primary vs. secondary effluent are not very different because the water quality improvements resulting from secondary treatment are not the ones that are critical for ocean discharges. If high dilution of the order of 100:1 is not required for maintaining dissolved oxygen, then it would be required for control of the impact of nutrients which may not be significantly reduced by secondary treatment. Furthermore, for protection of public health both primary and secondary effluent should be far enough from shore so that there is adequate mortality of bacteria and viruses without the necessity for effluent disinfection which is a costly operating expense.

Finally, the physical factors of the outfall design, such as soil conditions, earthquake faults, waves, and local submarine topography near the outfall terminus may dominate the local considerations for outfall alignment; in other words, water quality predictions may not be sensitive to minor shifts in location (1000 feet or so) and so the detailed location is often governed by these other factors.

2. OBJECTIVES

The objectives of an outfall system are clearly to disperse the effluent sufficiently into the ocean current so that the ecosystem products of the effluent (the organic carbon, nutrients, etc.) can be kept within allowable limits. Toxic materials in significant quantities should of course be controlled at their sources in the sewer system.

¹ Report to the Congress by the National Commission on Water Quality, Mar. 18, 1976.

The California Ocean Plan regulations presently require initial dilutions of 100:1 (median) and 80:1 (90-percentile). Individual permits may be more stringent, or even less stringent in a few cases. Furthermore outfalls should be far enough from shore so that the bacterial requirements can be met without the use of disinfection (if feasible).

Federal regulations do not deal explicitly with outfalls because they do not encompass the systems point of view described above in Section 1. Requirements are set in terms of effluent limitations corresponding to secondary treatment regardless of the method of discharge into the receiving waters and the location. (There are, however, general requirements relating to permits and ocean discharge (PL 72-500, Secs. 402 and 403).)

3. REGIONAL VIEW

The functional design of an outfall starts from the large-scale and works back to the small. In the planning stages the general characteristics of the collection system and the general location of the outfall and the receiving body of water are selected. However, as part of the final design effort the ocean circulation and stratification data must be analyzed to confirm that the general location and distance from shore are optimized, taking account of shoreline constraints on siting of facilities. The depth and length of the diffuser at this stage in the consideration are still kept as open variables depending on the dilution analysis described below.

In general it is found from experience that the marginal cost of additional outfall length is really rather small compared to the whole cost of the outfall, along with the cost of collection and treatment systems. Design experience on the west coast of the United States has confirmed that choice of long outfalls has been a wise investment and has enabled some systems to absorb an upgrading in requirements without modification of the outfall system. However, in some instances where outfalls have been built to minimum distances to meet current requirements, costly future modifications have been necessitated.

4. DIFFUSER LOCATION, DEPTH, AND DISTANCE FROM SHORE

With the general regional location settled, the next step is to strike a balance between diffuser length, depth and distance from shore. The outcome of the balance depends on costs and the slope of the ocean bottom as well as hydrodynamic calculations of dilution. One of the simplest ways to grasp the trade-off is expressed by the line plume formula for buoyant discharge into a quiescent unstratified ocean, as follows:²

where:

$$S_c = 0.38 \left(\frac{\Delta \rho}{\rho} g \right)^{1/3} y L^{2/3} Q^{-2/3}$$

Q = the total effluent discharge

L = length of the diffusion structure

y = depth

$\frac{\Delta \rho}{\rho}$ = relative density difference between effluent and sea water

g = acceleration of gravity

S_c = dilution on the centerline of the plume at the surface

$$\log y = -0.328, \log x = -0.905$$

y = the water quality objective to apply when chlorine is being discharged;

x = the duration of uninterrupted chlorine discharge in minutes.

(No allowance for surface effects is included in this simplified formula.)

Although this formula is too simplified for design purposes, it does show that under the most simplified conditions for equal Q and S_c , the factor $yL^{2/3}$ equals a constant; therefore, for the same initial dilution the required length is inversely proportional to the $3/2$ power of the depth. Since the diffuser cost is practically the same as for the outfall pipe itself, the economics of this trade-off is easy to work out for a rough first approximation.

² N. H. Brooks, "Dispersion in Hydrologic and Coastal Environments," W. M. Keck Laboratory Rept. No. KH-R-29, California Institute of Technology, December 1972.

R. C. Y. Koh and N. H. Brooks, "Fluid Mechanics of Waste-Water Disposal in the Ocean," Annual Review of Fluid Mechanics, Vol. 7, 1975, pp. 187-211.

In addition to the tradeoffs based on initial dilution, there is also an analysis which considers the mortality of microorganisms between the outfall location and the shore based on the overall distance and the current patterns and travel times. For example, the optimum tradeoff for initial dilution may result in a solution which is too close to the shore to get adequate die-off, and in such a case the location should be pushed further offshore.

The final tradeoff of all these factors depends on a detailed hydrodynamic analysis for outfall performance assuming various trial configurations. With the approximations based on experience, the design proceeds successively to narrow down the options with a complex computer analysis which takes account of the effects of ocean currents, the thermal and salinity stratification, natural ocean diffusion, and die-off or decay of non-conservative pollutants. For this analysis typical port spacings and jet velocities are assumed, although the solution at this stage is not highly sensitive to those variables (i.e. these are details which are settled later). The state of the art of modeling of outfall discharges is not yet completely satisfactory and there are a number of judgmental factors involved. There is no omnibus program that just requires a list of inputs; rather, models are usually built on a site-specific basis because of the varying importance of different characteristics. For example, in the San Francisco case the depth is relatively shallower than in some cases and a different method of handling the effect of the current on the initial dilution is required. (See for example a publication by P. Roberts.³ The models for initial dilution and subsequent spreading and advection of the sewage field also have to be coupled in an empirical way as we do not understand all of the hydrodynamic factors of relating the end of the jet mixing phase with the ambient advection phase in the ocean. This is especially true when we have stratified ocean current—a problem for which laboratory research is still going on at the W. M. Keck Hydraulics Laboratory at Caltech.⁴

When the model is developed and the various conditions are run corresponding to the different times of the year (different stratification), and at different tidal and current conditions, a whole range of predicted dilutions and plume behaviors is generated. The comparison of what these results are for different outfall configurations may not give a clear-cut comparison as to which configuration is better, as some may look better at some conditions and some better at other conditions. Thus judgmental decisions must be made regarding the final design, including full consideration of physical factors, construction, and costs.

5. DIFFUSER HYDRAULICS

After the oceanographic analysis has been made, the detailed diffuser hydraulics is worked out, i.e. the selection of port sizes and spacing and the steps in pipe diameters along the outfall diffuser. It is important to realize that this is a final part of the hydraulic design and is not the determining one. Many of the dilution calculations are not very sensitive to the actual port spacing and jet velocities because the diffuser is primarily creating a line source.

To work the manifold hydraulics problem a computer program is used which takes account of the discharge characteristics of the individual ports and does a numerical integration of the hydraulic conditions port by port with a trial and error optimization of pipe and port sizes considering the various discharges and constraints.

Experience indicates that the range of discharges to be handled has an important relationship to the allowable change in depth along the diffuser. It is sometimes necessary to run the diffuser essentially along an ocean bottom contour in order to get a good distribution of flow among the various ports over a wide range of flow. If the bottom has a substantial slope to it (greater than 1 percent) the hydraulic necessities to the manifold flow may be the dictating requirement for the alignment of the outfall diffuser.

6. DIAMETER OF OUTFALLS AND POSSIBLE PUMPING STATION

A discharge agency always likes to avoid the necessity of an outfall pumping station and hopes that outfalls can be made to flow by gravity. The key question

³P. J. W. Roberts. "Dispersion of Buoyant Waste Water Discharge from Outfall Diffusers of Finite Length". W. M. Keck Laboratory of Hydraulics and Water Resources, Report No. KH-R-35. California Institute of Technology, 183 pp., March 1977.

⁴Steven J. Wright. "Effects of Ambient Cross Flows and Density Stratification on the Characteristic Behavior of Round, Turbulent Buoyant Jets". W. M. Keck Laboratory of Hydraulics and Water Resources, Rept. No. KH-R-36, California Institute of Technology, 254 pp., May 1977.

is whether it is cheaper to use smaller outfall pipes and to install and operate a pumping station, or to use larger diameter pipes and to withstand increased wave and earthquake forces, and face possible maintenance problems due to deposition because of low velocity.

Because the head loss is a quadratic function of the discharge, an economical arrangement is often one in which the flow is by gravity for a large part of the time and the pump station is only used for a relatively small fraction of the time to handle the larger flows. In this way the actual energy consumption is not large and the uncertainties in factors such as outfall friction do not have to be decided on a very conservative basis in order to be absolutely sure that gravity flow can take care of the situation. Put another way, the uncertainty of the outfall friction and the future real flow rates can be absorbed into the number of hours that the pump station is required to operate.

If the system does flow by gravity then the excess head must be dissipated before the flow enters the outfall system. Chutes with hydraulic jumps or vortex structures are possibilities. For all but the very largest flows the head to be dissipated is quite significant, and represents a waste of energy if the water is pumped up to the required forebay level from some pump stations elsewhere in the sewerage system.

7. PHYSICAL FACTORS

Thorough analysis of wave attack on the outfall is important, and requires the selection of sizes of ballast stone to hold the pipe in place under maximum breaking waves. Since most California outfalls go out to depths of at least 80 feet (frequently 200+ ft.) the largest waves at the site will break in depths through which the outfall must run. (The breaking wave height is about 79 percent of the depth.) The wave defense may involve burial of the pipe with riprap to protect it further in case of local scour or sand profile change. It will probably be found that the wave defense is an important component in the relationship of outfall cost to diameter. The same is true probably also for earthquake resistance.

In analyzing the stability of the pipe it is important to realize that the submerged weight of the outfall under water is much less than it would be on land. In fact the entire volume of effluent inside the pipe actually provides a slight buoyancy rather than a net weight. This is especially important to realize in the earthquake analysis that when the ground accelerates laterally the entire mass of the pipe and its contents along with the ballast stone must also be accelerated. (There is also an apparent mass affect in the ocean water.) But on the other hand the mass of water inside the pipe does not contribute anything to friction on the sea bed. Obviously this problem gets more severe as the diameter of the pipe increases and the mass of water inside the pipe increases as the square of the diameter.

(An analysis of wave resistance and earthquake stability along these lines has been conducted for the Orange County outfalls and Honolulu outfalls by Drs. F. Raichlen and R. F. Scott.)

8. CONCLUSION

From the foregoing discussion it is clear that there are many interconnections in the design process so it is truly a system which is being developed. Experience in previous outfall designs is important in expeditiously sorting out promising from unpromising approaches and in helping to make all the design factors converge on an optimum design. Furthermore, if critical oceanographic data on water characteristics and currents are missing, they must be identified and obtained as part of any final design effort.

State of California, the Resources Agency

STATE WATER RESOURCES CONTROL BOARD RESOLUTION No. 78-2—WATER QUALITY CONTROL PLAN FOR OCEAN WATERS OF CALIFORNIA

(The 1978 Amendments to the "Water Quality Control Plan for Ocean Waters of California" were adopted by the State Board at its January 19, 1978 meeting and will become effective upon approval of the Environmental Protection Agency.)

Whereas:

1. The Board adopted the "Water Quality Control Plan for Ocean Waters of California" on July 6, 1972;

2. In the period between July 1972 and December 1977, the Board has received additional information regarding ocean water quality and wastewater management needs.

3. The Board conducted an extensive review of the 1972 Plan, prepared a draft set of amendments, prepared and circulated a draft initial study and negative declaration in accordance with the provisions of the California Environmental Quality Act, and on October 19, 1977, held a public hearing regarding the draft amendments.

Therefore be it resolved that:

1. The Board adopts the "Water Quality Control Plan for Ocean Waters of California 1978" and the Negative Declaration and Initial Study pertaining thereto.

2. The Board hereby declares its intent to determine from time to time the need for revising the Plan to assure that it reflects current knowledge of water quality objectives necessary to protect beneficial uses of ocean waters and that it is based on latest technological improvements.

3. The Board hereby declares its intent to require continual monitoring of the marine environment to assure that the Plan reflects the latest available data and that the water quality objectives fully protect the marine environment.

CERTIFICATION

The undersigned, Executive Director of the State Water Resources Control Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on January 19, 1978.

LARRY F. WALKER,
Executive Director Water Quality.

California State Water Resources Control Board

WATER QUALITY CONTROL PLAN FOR OCEAN WATERS OF CALIFORNIA (AS AMENDED, 1978)

INTRODUCTION

In furtherance of legislative policy set forth in Section 13000 of Division 7 of the California Water Code (Stats. 1969, Chap. 482) and pursuant to the authority contained in Section 13170 (Stats. 1971, Chap. 1288) the State Water Resources Control Board hereby finds and declares that protection of the quality of the ocean waters for use and enjoyment by the people of the State requires control of the discharge of waste¹ to ocean water² in accordance with the provisions contained herein.

¹This Plan is applicable, in its entirety, to point source discharges to the ocean. Non-point sources of waste discharges to the ocean are subject to Chapter I—Beneficial Uses, Chapter II—Water Quality Objectives, Chapter III—General Requirements, Chapter IV—Table B (wherein compliance with water quality objectives shall, in all cases, be determined by direct measurements in the receiving waters), and Chapter V—Discharge Prohibitions.

This Plan is not applicable to discharges to enclosed bays and estuaries or inland waters nor is it applicable to vessel wastes, and the control of dredging spoil.

Provisions regulating the thermal aspects of waste discharged to the ocean are set forth in the Water Quality Control Plan for the Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California dated May 18, 1972.

²Ocean waters are waters of the Pacific Ocean adjacent to the California coast outside of enclosed bays, estuaries, and coastal lagoons.

Enclosed bays are indentations along the coast which enclose an area of oceanic water within distinct headlands or harbor works. Enclosed bays include all bays where the narrowest distance between headlands or outermost harbor works is less than 75 percent of the greatest dimension of the enclosed portion of the bay. This definition includes but is not limited to: Humboldt Bay, Bodega Harbor, Tomales Bay, Drakes Estero, San Francisco Bay, Morro Bay, Los Angeles Harbor, Upper and Lower Newport Bay, Mission Bay, and San Diego Bay.

Estuaries and coastal lagoons are waters at the mouths of streams which serve as mixing zones for fresh and ocean waters during a major portion of the year. Mouths of streams which are temporarily separated from the ocean by sandbars shall be considered as estuaries. Estuarine waters will generally be considered to extend from a bay or the open ocean to the upstream limit of tidal action but may be considered to extend seaward if significant mixing of fresh and salt water occurs in the open coastal waters. The waters described by this definition include but are not limited to the Sacramento-San Joaquin Delta as defined by Section 12220 of the California Water Code, Suisun Bay, Carquinez Strait downstream to Carquinez Bridge, and appropriate areas of the Smith, Klamath, Mad, Eel, Noyo, and Russian Rivers.

CHAPTER I.—BENEFICIAL USES

The beneficial uses of the ocean waters of the State that shall be protected include industrial water supply, recreation, esthetic enjoyment, navigation, and preservation and enhancement of fish, wildlife, and other marine resources or preserves.

CHAPTER II.—WATER QUALITY OBJECTIVES

This chapter sets forth limits or levels of water quality characteristics for ocean waters to ensure the reasonable protection of beneficial uses and the prevention of nuisance. The discharge of waste shall not cause violation of these objectives.³

A. Bacteriological characteristics

1. Within a zone bounded by the shoreline and a distance of 1,000 feet from the shoreline or the 30-foot depth contour, whichever is further from the shoreline, and in areas⁴ outside this zone used for body-contact sports, the following bacteriological objectives shall be maintained throughout the water column:

(a) Samples of water from each sampling station shall have a concentration of coliform organisms less than 1,000 per 100 ml (10 per ml); provided that not more than 20 percent of the samples at any sampling station, in any 30-day period, may exceed 1,000 per 100 ml (10 per ml), and provided further that no single sample when verified by a repeat sample taken within 48 hours shall exceed 10,000 per 100 ml (100 per ml).

(b) The fecal coliform concentration based on a minimum of not less than five samples for any 30-day period, shall not exceed a log mean of 200 per 100 ml nor shall more than 10 percent of the total samples during any 30-day period exceed 400 per 100 ml.

2. At all areas⁴ where shellfish may be harvested for human consumption, the following bacteriological objectives shall be maintained throughout the water column: The median total coliform concentration shall not exceed 70 per 100 ml, and not more than 10 percent of the samples shall exceed 230 per 100 ml.

B. Physical characteristics

1. Floating particulates and grease and oil shall not be visible.

2. The discharge of waste shall not cause esthetically undesirable discoloration of the ocean surface.

3. The transmittance of natural light shall not be significantly⁵ reduced at any point outside the initial dilution zone.⁶

4. The rate of deposition of inert solids and the characteristics of inert solids in ocean sediments shall not be changed such that benthic communities are degraded.⁷

³The Water Quality Objectives and Effluent Quality Requirements are defined by a statistical distribution when appropriate. This method recognizes the normally occurring variations in treatment efficiency and sampling and analytical techniques and does not condone poor operating practices.

⁴Body-contact sports areas outside the shoreline zone set forth in Chapter II.A.1. and all shellfishing areas shall be determined by the Regional Board on an individual basis.

⁵A significant difference is defined as a statistically significant difference in the means of two distributions of sampling results at the 95 percent confidence level.

⁶Initial dilution is the process which results in the rapid and irreversible turbulent mixing of wastewater with ocean water around the point of discharge.

For a submerged buoyant discharge, characteristic of most municipal and industrial wastes that are released from the submarine outfalls, the momentum of the discharge and its initial buoyancy act together to produce turbulent mixing. Initial dilution in this case is completed when the diluting wastewater ceases to rise in the water column and first begins to spread horizontally.

For shallow water submerged discharges, surface discharges, and nonbuoyant discharges, characteristic of cooling water wastes and some individual discharges, turbulent mixing results primarily from the momentum of discharge. Initial dilution, in these cases, is considered to be completed when the momentum induced velocity of the discharge ceases to produce significant mixing of the waste, or the diluting plume reaches a fixed distance from the discharge to be specified by the Regional Board, whichever results in the lower estimate for initial dilution.

For the purpose of this Plan, minimum initial dilution is the lowest average initial dilution within any single month of the year. Dilution estimates shall be based on observed waste flow characteristics, observed receiving water density structure, and the assumption that no currents, of sufficient strength to influence the initial dilution process, flow across the discharge structure.

The Executive Director shall issue guidelines to be used by the State and Regional Boards for determining the initial dilution achieved by each ocean discharge.

⁷Degradation shall be determined by analysis of the effects of waste discharge on species diversity, population density, contamination, growth anomalies, debility, or supplanting of normal species by undesirable plant and animal species.

C. Chemical characteristics

1. The dissolved oxygen concentration⁸ shall not at any time be depressed more than 10 percent from that which occurs naturally, as the result of the discharge of oxygen demanding waste materials.

2. The pH⁸ shall not be changed at any time more than 0.2 units from that which occurs naturally.

3. The dissolved sulfide concentration of waters in and near sediments shall not be significantly⁸ increased above that present under natural conditions.

4. The concentration of substances set forth in Chapter IV, Table B, in marine sediments shall not be increased to levels which would degrade⁷ indigenous biota.

5. The concentration of organic materials in marine sediments shall not be increased above that which would degrade⁷ marine life.

6. Nutrient materials shall not cause objectionable aquatic growths or degrade⁷ indigenous biota.

D. Biological characteristics

1. Marine communities, including vertebrate, invertebrate, and plant species, shall not be degraded.⁷

2. The natural taste, odor, and color of fish, shellfish, or other marine resources used for human consumption shall not be altered.

E. Radioactivity

1. Radioactivity shall not exceed the limits specified in Title 17, Chapter 5, Subchapter 4, Group 3, Article 3, Section 30269 of the California Administrative Code.

CHAPTER III.—GENERAL REQUIREMENTS FOR MANAGEMENT OF WASTE DISCHARGE TO THE OCEAN

A. Waste management systems that discharge to the ocean must be designed and operated in a manner that will maintain the indigenous marine life and a healthy and diverse marine community.

B. Waste discharged to the ocean must be essentially free of:

1. material that is floatable or will become floatable upon discharge.

2. settleable material or substances that form sediments which degrade⁷ benthic communities or other aquatic life,

3. substances toxic to marine life due to increases in concentrations in marine waters or sediments,

4. substances that significantly decrease the natural light to benthic communities and other marine life, and

5. materials that result in esthetically undesirable discoloration of the ocean surface.

C. Waste effluents shall be discharged in a manner which provides sufficient initial dilution to minimize the concentrations of substances not removed in treatment.

D. Location of waste discharges must be determined after a detailed assessment of the oceanographic characteristics and current patterns to assure that:

1. pathogenic organisms and viruses are not present in areas where shellfish are harvested for human consumption or in areas used for swimming or other body-contact sports.⁹

2. natural water quality conditions are not altered in areas designated as being of special biological significance, and

3. maximum protection is provided to the marine environment.

⁸ Compliance with the water quality objectives of Chapter II shall be determined from samples collected at stations representative of the area within the waste field where initial dilution is completed.

⁹ Waste that contains pathogenic organisms or viruses should be discharged a sufficient distance from shellfishing and body-contact sports areas to maintain applicable bacteriological standards without disinfection. Where conditions are such that an adequate distance cannot be attained, reliable disinfection in conjunction with a reasonable separation of the discharge point from the area of use must be provided. Consideration should be given to disinfection procedures that do not increase effluent toxicity and that constitute the least environmental and human hazard in their production, transport, and utilization.

CHAPTER IV.—QUALITY REQUIREMENTS FOR WASTE DISCHARGES (EFFLUENT QUALITY REQUIREMENTS)

This chapter sets forth the quality requirements for waste discharge to the ocean.⁸

Table A limitations apply only to publicly owned treatment works and industrial discharges for which Effluent Guideline Limitations have not been established pursuant to Sections 301, 302, 304, or 306 of the Federal Water Pollution Control Act of 1972.

Table B limitations apply to all discharges within the jurisdiction of this Plan.

The State Board is authorized to administer and enforce effluent requirements established pursuant to the Federal Water Pollution Control Act of 1972. Effluent limitations established under Sections 301, 302, 306, 307, 316, 403, and 405 of the aforementioned Federal Act and administrative procedures pertaining thereto, are included in this Plan by reference.

Compliance with Table A limitations, or Environmental Protection Agency Effluent Guideline Limitations for industrial discharges, shall be the minimum level of treatment acceptable under this Plan, and define reasonable treatment and waste control technology.

TABLE A.—MAJOR WASTEWATER CONSTITUENTS AND PROPERTIES

	Unit of measurement	Limiting concentrations		Maximum at any time
		Monthly (30-day average)	Weekly (7-day average)	
Grease and oil.....	mg/l.....	25.0	40.0	75.0
Suspended solids.....	mg/l.....	(*)	(*)	(*)
Settleable solids.....	mg/l.....	1.0	1.5	3.0
Turbidity.....	JTU.....	75.0	100.0	225.0
pH.....	Units.....	(†)	(†)	(†)
Toxicity concentration ¹⁰	tu.....	1.5	2.0	2.5

* 75 percent removal.

† Within limits of 6 to 9 at all times.

¹⁰ This parameter shall be used to measure the acceptability of waters for supporting a healthy marine biota until improved methods are developed to evaluate biological response.

a. Toxicity Concentration (Tc)

Expressed in Toxicity Units (tu)

$$Tc (tu) = \frac{100}{96\text{-hr. TLM}\%}$$

b. Median Tolerance Limit (TLM%)

The TLM shall be determined by static or continuous flow bioassay techniques using standard test species. If specific identifiable substances in wastewater can be demonstrated by the discharger as being rapidly rendered harmless upon discharge to the marine environment, and the TLM may be determined after the test samples are adjusted to remove the influence of those substances.

When it is not possible to measure the 96-hr. TLM due to greater than 50 percent survival of the test species in 100 percent waste, the toxicity concentration shall be calculated by the expression:

$$Tc (tu) = \frac{\log (100 - S)}{1.7}$$

S=percentage survival in 100% waste.

TABLE B—TOXIC MATERIALS LIMITATIONS

Effluent limitations shall be imposed in a manner prescribed by the State Board¹¹ such that the concentrations set forth below as water quality objectives, shall not be exceeded in the receiving water upon the completion of initial dilution, except that limitations indicated for total chlorinated pesticides and PCB's and Radioactivity shall apply directly to the undiluted waste effluent.

¹¹ Effluent limitations for substances identified in Chapter IV, Table B, with the exceptions of Radioactivity and Total Identifiable Chlorinated Hydrocarbons, shall be determined through the use of the following equation:

$$C_e = C_o + Dm(C_o - C_s) \quad (1)$$

where:

C_e = the effluent concentration limit,

C_o = the concentration to be met at the completion of initial dilution,

C_s = background seawater concentration,

Dm = minimum probable initial dilution expressed as parts seawater per part wastewater.

The State Board shall assist the Regional Boards in the evaluation of Dm , the minimum initial dilution for a specific waste discharge. Discharging agencies will be informed of the basis for the determination of minimum initial dilution.

Waste constituent:	C_s mg/l
Arsenic	0.003
Cadmium	0.000
Total chromium	0.000
Copper	0.002
Lead	0.000
Mercury	0.00006
Nickel	0.00
Silver	0.00016
Zinc	0.008
Cyanide	0.000
Phenolic compounds	0.0
Total chlorine residual	0.000
Ammonia (expressed as nitrogen)	0.0
Toxicity concentration (in toxic units)	0.00

The six-month median effluent concentration limit shall apply as a moving median of daily values for any 180 day period in which daily values represent flow weighted average concentrations within a 24-hour period. For intermittent discharges, the daily value shall be considered to equal zero for days on which no discharge occurred.

The daily maximum effluent concentration limit shall apply to flow weighted concentrations within 24 hours.

The instantaneous maximum shall apply to grab sample determinations.

Discharge requirements shall also specify effluent requirements in terms of mass emission rate limits utilizing the general formula:

$$\text{lbs/day} = 8.34 \times C_e \times Q \quad (2)$$

The six-month median limit on daily mass emissions shall be determined using the six-month median effluent concentration as C_e and the observed flow rate Q in million of gallons per day. The daily maximum mass emission shall be determined using the daily maximum effluent concentration limit as C_e and the observed flow rate Q in millions of gallons per day.

Any significant change in waste flow shall be cause for reevaluating effluent quality requirements.

If a calculated C_e value falls below the limit of detection of the test method specified in the Code of the Federal Register, 40 CFR 136, the limit of detection shall serve as the limiting effluent concentration. The State or Regional Board may, at their discretion, specify test methods which are more sensitive than those specified in 40 CFR 136. Total chlorine residual is likely to be a "limit of detection" effluent requirement in many cases. The limit of detection of total chlorine residual in standard test methods is less than, or equal to, 0.02 mg/l.

Due to the large total volume of powerplant and other heat exchange discharges, special procedures must be applied for determining compliance with Table B limitations on a routine basis. Effluent concentration values (C_e) shall be determined through the use of Equation 1 considering the minimal probable initial dilution of the combined effluent (in-plant waste streams plus cooling water flow). These concentration values shall then be converted to mass emission limits which will then serve as requirements applied to all in-plant waste streams taken together which discharge into the cooling water flow. The procedure described above shall apply to all Table B materials except limitations on total chlorine residual and radioactivity which shall apply to, and be measured in, the combined final effluent.

CHAPTER V.—DISCHARGE PROHIBITIONS

A. Hazardous substances

The discharge of any radiological, chemical, or biological warfare agent or high-level radioactive waste into the ocean is prohibited.

B. Areas of special biological significance

Waste shall be discharged a sufficient distance from areas designated as being of special biological significance to assure maintenance of natural water quality conditions in these areas.

C. Sludge

The discharge of municipal and industrial waste sludge directly to the ocean, or into a waste stream that discharges to the ocean, shall be prohibited. The discharge of sludge digester supernatant directly to the ocean, or into a waste stream that discharges to the ocean without further treatment shall be prohibited.

D. Bypassing

The bypassing of untreated wastes containing concentrations of pollutants in excess of those of Table A or Table B to the ocean is prohibited.

CHAPTER VI. GENERAL PROVISIONS

A. Effective date

This Plan is in effect as of the date of adoption by the State Water Resources Control Board.

Unit of measurement	Limiting concentrations		
	6-mo median	Daily maximum	Instantaneous maximum
Arsenic.....	mg/l 0.008	0.032	0.08
Cadmium.....	mg/l .003	.012	.03
Total chromium.....	mg/l .002	.008	.02
Copper.....	mg/l .005	.020	.05
Lead.....	mg/l .008	.032	.08
Mercury.....	mg/l .00014	.00056	.0014
Nickel.....	mg/l .02	.08	.2
Silver.....	mg/l .00045	.0018	.0045
Zinc.....	mg/l .020	.08	.2
Cyanide.....	mg/l .005	.02	.05
Phenolic compounds.....	mg/l .03	.12	.3
Total chlorine residual.....	mg/l .002	(*)	(*)
Ammonia (expressed as nitrogen).....	mg/l .6	2.4	6.0
Toxicity concentration ¹⁰	tu .05		
Total chlorinated pesticides and PCB's ¹²	mg/l .002	.004	.006
Radioactivity.....	(†)	(†)	(†)

* See footnote 12.

† Not to exceed limits specified in sec. 30269 of the California Administrative Code.

¹² Water quality objectives for total chlorine residual applying to intermittent discharges not exceeding two hours, and 24 hours and instantaneous (1 minute) maximum objectives applying to continuous sources, shall be determined through the use of the following equation:

$$\log y = -0.328, \log x - 0.905$$

where:

y = the water quality objective to apply when chlorine is being discharged;

x = the duration of uninterrupted chlorine discharge in minutes.

¹³ Total chlorinated pesticides and PCB's shall be measured by summing the individual concentrations of DDT, DDD, DDE, aldrin, BHC, chlordane, endrin, heptachlor, lindane, dieldrin, and polychlorinated biphenyls.

The Executive Director shall undertake a preliminary investigation into the presence and hazards posed by the other halogenated hydrocarbons which may be present in wastewater discharges. Such review shall lead to a recommendation regarding the necessity for regulation, gathering of necessary data, or other appropriate actions which should be taken by the State Board.

As part of the preliminary investigation, the Executive Director may impose additional monitoring requirements on discharging agencies to assess the occurrence of halogenated hydrocarbons other than those specifically mentioned in this Plan.

B. Waste discharge requirements

The Regional Boards may establish more restrictive water quality objectives and effluent quality requirements than those set forth in this Plan as necessary for the protection of beneficial uses of the ocean.

Regional Boards may impose alternative less restrictive provisions to those contained within Table B of the Plan, provided an applicant can demonstrate that:

Reasonable control technologies (including source control, material substitution, treatment and dispersion) will not provide for complete compliance or;

Any less stringent provisions would encourage water reclamation;
Provided further than;

(a) Any alternative water quality objectives shall be below the conservative estimate of chronic toxicity, upon which this Plan is based, and such alternative will provide for adequate protection of the marine environment;

(b) A receiving water toxicity objective of 0.05 tu is not exceeded; and

(c) The State Board and the Environmental Protection Agency concur in the Regional Board findings and alternative limits.

C. Revision of waste discharge requirements

The Regional Board shall revise the waste discharge requirements for existing discharges as necessary to achieve compliance with this Plan and shall also establish a time schedule for compliance in accordance with State Board Resolution 74-5.

D. State Board review of time schedules

The State Board shall review proposed time schedules for all municipal discharges throughout the State and shall recommend to the Regional Boards specific schedules to assure the maximum benefit from, and equitable distribution of, available state and federal grant funds.

E. Monitoring program

The Regional Board shall require dischargers to conduct self-monitoring programs and submit reports necessary to determine compliance with the waste discharge requirements, and may require dischargers to contract with agencies or persons acceptable to the Regional Board to provide monitoring reports. Such monitoring programs shall comply with Guidelines for Monitoring the Effects of Waste Discharges on the Ocean which shall be issued by the Executive Director of the State Board.

F. Areas of special biological significance

Areas of special biological significance shall be designated by the State Board after a public hearing by the Regional Board and review of its recommendations.

G. State Board exceptions to plan requirements

The State Board may, subsequent to a public hearing, and with the concurrence of the Environmental Protection Agency, grant exceptions to any provision of this Plan where the Board determines:

(1) The existence of unusual circumstances not anticipated at the time of the Plan's adoption;

(2) The exception will not compromise protection of ocean waters for beneficial uses, and

(3) The public interest will be served.

Mr. ROBERTS. Our next witness is Prof. Willard Bascom, director of the southern California coastal water research project.

Mr. Bascom is presently director of the Southern California Coastal Water Research Project. He is a former president of Seafinders, Inc., and is the founder and past president of the Ocean Science and Engineering Group.

He organized and directed the National Academy of Science's mo-hole project; was director of the Maritime Research Advisory Committee of the National Academy of Sciences; field researcher for the

University of California, and research engineer for the Scripps Institution of Oceanography. Also, Professor Bascom has a long list of books and articles. We are pleased also to have you here, sir.

Proceed, if you will.

TESTIMONY OF PROF. WILLARD BASCOM, DIRECTOR, SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Dr. BASCOM. Thank you. I have prepared a statement, which I would like to read.

I am an oceanographer and have been involved in the study of the ocean since 1945. For the last 10 years I have lived high above the beach at Long Beach so that I look down on the harbor and out across the sea to Catalina Island every morning and every night. My ocean activities have included the study of waves, beaches, and geological problems as well as ecology. I have also had some experience in ocean drilling, mining, and dredging and have written numerous books and papers on these subjects. For the last 5 years I have been director of the southern California coastal water research project and for the last 2 of those years I have also been an adjunct professor of ocean science at the University of California at San Diego and the Scripps Institution of Oceanography. I have consulted with the governments of Greece and Israel about pollution problems off their coasts.

I am also a member of the Ocean Science Board of the National Academy of Sciences, which pertains to this.

I would like to say a few words about the group by which I am employed. The Southern California Coastal Water Research Project, called SCCWRP, was established in 1970 to find out the facts about man's influence on coastal waters—particularly those caused by the discharge of municipal waste waters.

So we have a staff of scientists who are expert in chemistry and biology and physics, as appropriate to these matters. We have people at sea several times a week, taking samples. We sample the bottom and the animals, we take underwater photographs by the thousands, of all these areas.

Our laboratories can identify at least 4,000 kinds of animals, which is quite a few, in our coastal waters, and we make very precise, low level tests of toxicants on animals. As far as I know, they are as low as anybody measures in the world. We operate down in the parts per billion area on chronic bio-assays.

We study particles down in the range of one micron, one-millionth of a meter, and we measure the levels of pesticides and elements in the sea down at levels of fractional parts per billion and sometimes lower. We report these in the regular scientific journals, and we publish annual reports, of which I have brought a couple of examples—like so—which are first class pieces of scientific work and which are generally accepted by scientists everywhere as being the equivalent of other kinds of professional publications.

One of the reasons I would like to go over what I have written here with you is that I specifically went over it with both my staff and my consulting board, to make sure that they concurred with me on these views. And since they represent roughly 20 or 30 people, it is a bit more than myself simply saying it.

I would like to begin by restating our national objective and that is that "The overall environment of the United States—land, sea and air—must be made clean and kept clean." We heartily concur with that.

We kind of hope that it will be accomplished with the thoughtful use of energy and manpower, and materials.

I feel qualified particularly to speak on the matter of the protection of ocean waters, coastal waters, where the main question is what solutions to the problem of municipal waste disposal will result in non-polluted coastal waters without increasing air or land pollution, or wastefully using energy or requiring excessive expenditures.

I would like to congratulate the Congress for having permitted EPA to consider exceptions to the previous rule of total secondary treatment by considering the natural characteristics of disposal areas. These are, of course, a national asset. The fact that you cannot do something in one place does not mean you should deliberately restrict yourself from doing that someplace else. That would be foolishness.

Unfortunately, EPA's complex regulations expressed in this document we are reviewing here, which were intended to implement the law, seem to me much more like road blocks than guide posts, because they do not really take into account either common sense or recent scientific findings on the subject.

It is quite evident that discharges into important sources of drinking water may require higher treatment than disposal into ocean waters, where there is no particular reason to have such precise and delicate treatment.

My point is that the action should be fitted to the local circumstances, whatever these may be. And as long as the original objective is met—which it should be—I cannot think of any reason why it makes any difference how we get there.

Enough money and effort is going to be consumed by any solution we take, to make a careful study of the possibilities worthwhile. And the objective of studies that should be made would be to determine how to prevent pollution in the most efficient way, whatever that way may be.

And I note that off the California coast, the effects of waste in the past have been shown to be not very longlasting and quite reversible; if we look at outfalls that were once used and are now abandoned, they reverted, in most cases within a year or so, to the original condition, whatever that was.

That is not to say that they were badly spoiled before, and that they are better now, only that they have returned to the original conditions.

And the situation around all the existing outfalls is steadily improving anyway—or at least, almost all of them; there might be an exception.

This means there is no real concern that the situation is going to get very greatly worse while we are doing our homework. Things are getting better anyhow.

The proposed EPA regulations use many words and phrases which cannot readily be defined and which are sure to cause controversy, and I have listed some examples here.

For example, phrases like, "biologically sensitive", "balanced indigenous population", "critical time of the year", "biostimulatory ef-

fects", "relative sensitivity of the receiving ecosystem", "toxic species", "nuisance or trash species", "biogeographic zone".

My scientific associates and I are not certain what those phrases mean. We suspect the writer is not clear on them either; they should either be properly defined or deleted from this kind of a document.

The regulations also propose a number of arbitrary rules which I presume are intended as obstacles, since they do not contribute to the solution of the problem in any way.

For example, there should be a "state water quality standard specific to the pollutant". Now, of course, most states do not have such standards, and the EPA does not really have any either. That seems like an unnecessary block.

And, "EPA will not consider the effect of outfall or treatment modifications". Well, it seems to me as long as modifications produce the desired result, there is no reason not to have them modified. We should do whatever is appropriate to the situation.

I think the EPA is sort of playing games by setting up these artificial barriers, instead of getting at the essential question, which is, "How does our country get to the best answer?" And I do not believe Congress intended them to barge blindly ahead, ignoring the scientific findings and treating the ocean like it were a shallow lake in the Midwest.

But the most frustrating part of these regulations from our point of view is their attitude, which shows very little understanding of either the ocean or the biological processes in the ocean. Let me give you some examples, taken from their proposed regulations.

The first deals with physical assessment.

The PLUME program specified for determining dilution does not take ocean currents into account although currents virtually always exist that aid in dilution and dispersion. Currents are quite different between outfalls; they are not the same everywhere.

It turns out that if you make the computations required, in one of the areas we are dealing with, there are 105 different variations of flow, port size, and season, to get what they have asked for "all possible PLUME configurations", and they want the answer within 10 meters of accuracy—which creates laughter among our physicists.

The accuracy of sea water density measurements required far exceeds what is meaningful or useful in this kind of work. Whoever wrote it simply does not understand the problem.

Under biological assessment, there is no known relationship between low level bioaccumulation of certain pollutants and their toxicity, but EPA's questions suggest that uptake into animals is necessarily harmful. I am quite sure that is not so, but there is no real supporting scientific data either way.

Fresh water and seawater data is mixed as though the two were equivalent, and of course, as far as animals' behavior is concerned, they are entirely different, because it has to do with the osmotic conditions that the animals are used to living in.

A principal characteristic of ocean animal communities is change. Under natural conditions, sea animals change with season, temperature, food supply, wave action, predators, and various long-term events, and probably some other things that I have left out.

The idea that change equates with damage or pollution is very naive. There is no clear connection between initial dilution zone and the response of bottom animals beneath the initial dilution zone. I presume they intended to say beneath the fallout area, and if there is fallout, then of course, there can be a change. But to whether the dilution zone has any connection is an entirely different matter.

They placed emphasis on acute bioassays, not because these give correct results, but because they are relatively easy to run and some data from them happens to be available. EPA ought to do the homework properly.

Under chemical assessment, a number of toxic pollutants named are so volatile and likely to escape from the waste samples that special precautions must be taken in sampling to prevent the normal escape that these would undergo upon reaching the ocean.

That is to say, you cannot take these on a regular 12- or 24-hour sample. You have got to take the sample under very special conditions, all by hand, just to make sure the pollutants are kept in there long enough so you can measure the pollutants. Otherwise, they would go off with the air like they would do naturally. These include the chlorinated ethanes, chloroform, dichloroethylenes, benzene, and some other ones. It is very unlikely that these highly volatile compounds could exist at any toxic levels in the ocean.

And now let me get back to reality. I think that if we are concerned about the effects of wastes in the sea, we ought to look for our answers in the sea. Without direct information based on measurements of ocean response, we will be relying on the unsupported opinion of a bunch of landlubbers, and our money will go into solving the problems they imagine instead of the real problems that exist in the sea.

Nearly any substance can be a pollutant—this includes freshwater and table salt, and a lot of other common things that we are used to. Plus all the elements that humans and sea animals, all animals, require for nutrition.

But pollution does not exist unless there is damaging excess of some substance. That is the guts of the whole thing that we are looking at, is the phrase, "damaging excess." All of these things exist everywhere—nearly everywhere.

We can also be sure that our coastal waters are not polluted if their quality is suitable for the highest uses that people wish to make of these coastal waters.

These include swimming and diving, the harvest of seafood from the sea, the protection of marine life, and the maintenance of esthetic values. Every location should meet those tests. I do not think there should be any exceptions. All we are dealing with is the question of how we get there.

Southern California's disposal practices in the past have harmed sea life but the worst offenses were stopped several years ago. The sea's surface waters—which are the parts used by people—are now clean—that is to say, they meet these criteria—and the damaged bottom areas, which do exist, are several miles offshore, and with one exception, they are quite small.

Nature's own physical-biological processes are steadily readjusting to make these areas more like they were before man came.

A change to secondary effluent would not greatly speed up this process. Neither would zero discharge. That is to say, if you stopped doing everything today, you are not going to make any material difference in how well those bottom areas are cleaned up. That must be done by the sea. We have got to wait for storms, currents, and scavenging animals to cover, disperse, and digest these old sediments. They will do that and they are in the process of doing that.

This does not mean that no action at all is needed. Some very important steps should be taken to prevent further pollution. And there is no question we have had pollution; we still have some. Our coastal waters are getting better, but we should take some action.

Two kinds of materials deserve attention. One of these is the chlorinated, or halogenated hydrocarbons, mainly including DDT and PCB. Most of the other ones that we have had a chance to examine have turned out to be non-problems for various reasons. But especially these two pollutants, which can cause serious problems, are best controlled at their source, and good strides have been made in that direction already.

But in any case, the amounts of these things discharged at present are low. They do not come from identifiable sources—that is mainly true, anyway—and secondary treatment will only reduce their discharge by half.

There is no magic to secondary treatment. It does some things, it does not do some things. But the approximate average levels of those two hydrocarbons being discharged together in the effluent is about 2.5 parts per billion, and that is immediately diluted by at least a factor of 100, so right off the bat in the sea, you are talking about a level in the initial dilution zone, which is .025 parts per billion and rapidly decreasing from there on. That is in the water.

A second problem that is worth looking at is this organic solids business. Now, the organic solids discharge, sometimes gets called suspended solids, or sludge, or by various other names, but scientists cannot deal with the phrase, "sludge," directly, because it has no real scientific meaning, but "suspended solids" we can get a grasp on, and that is mainly organic materials.

This material is just as good food for sea organisms as it is for land plants. Nobody seems to think anything about the problem of spreading it on land for many thousands of years. Why it should suddenly not be acceptable as food in the sea is one of the mysteries of my life.

At some locations, some of these solids—and I am talking about between 2 percent and 10 percent of the total solids discharged—that amount of the total solids has fallen to the sea floor in the outfall areas, and does cause a disagreeable accumulation.

It is very much like an excess of food spread out on land that is allowed to rot. It is unpleasant, and it has all the bad characteristics that you would have from spreading food on land.

But these solids are generally useful: it is nutrient-rich material, and when it is concentrated in a small area, it does then become a damaging excess. It becomes a pollutant, but not because it is intrinsically a pollutant, but because there is simply too much of it in one spot. Obviously, that should not be permitted.

The solution proposed by the EPA, total secondary treatment, is to destroy this valuable food with bacteria, which is basically what the

secondary treatment process is, thus converting it into virtually unusable secondary sludge.

It seems to me there is another and possibly better solution, and that might be to insure that the organic particles released simply remain so small that they will not settle to the bottom near the outfall, but become much more widely dispersed, and consequently feed animals over a larger area.

Now, that is what 90 percent of this stuff already does. All I am saying is that if the other 10 percent should be released in such a fashion that when it is discharged and mixed with seawater at 100 to 1, or whatever, it simply does not fall to the bottom. It stays in minute particles, it is carried off by the currents, it feeds a very much larger area and you will not have that problem that does exist some places today.

I believe that the two materials I have just talked about, the chlorinated hydrocarbons and the suspended solids, can be dealt with by processes other than full secondary treatment.

The other pollutants named by EPA are simply not problems in the ocean. There is no evidence that the dissolved oxygen in the water has ever been seriously reduced around California outfalls, or that tiny pH changes—that is the alkalinity or the acidity—makes any difference at all.

Metals in the States and at the concentrations that derive from diluted waste have not been found to be toxic in the ocean.

A great deal has been said about metals. My opinion, after having reviewed tens of thousands of metal measurements in the water, in the bottom, and in the animals, is that they simply are not toxic in the forms and at the concentration that one finds them in the ocean.

In the regulations we have seen, EPA hints that it is not possible to forecast the response of the sea to future effluents, and it asks the question: How can EPA make an accurate predictive judgment as to whether a nonexistent discharge will meet certain water quality criteria?

I believe that our laboratory can answer that question, at least for southern California. Our group has recently made a set of forecasts. We did this for a project called LA/OMA, which stands for consortium of the Los Angeles and the Orange County groups who pooled some money together to study the question of what to do with sludge.

The LA/OMA group, then, said, "This is what we expect to be discharging beyond a certain date," and named the date, which happens to be January 1, 1983. And they said, "See if you can forecast what will happen."

And I will say that even some of our own staff members threw up their hands at first. But once we really tackled this problem, it turned out we could think of 10 separate ways of making forecasts based on the same kind of data and on our background of information. And then we forecast what would happen around each of three outfall areas. I have brought a copy of that report with me. It has not yet been released by LA/OMA. I will come back to that in a moment.

But I am quite sure that we can make alternative forecasts for other kinds of discharges, for other outfalls, for other areas, using this same

kind of techniques if there is a sufficient backlog of information on the chemistry and biology and physics of the areas around the outfalls.

I believe that treatment and disposal practices should be fitted to the situation and that Congress could encourage the EPA to be flexible and reasonable.

I believe that better and less expensive solutions are at hand and will produce results that are at least equivalent to full secondary treatment as far as the sea is concerned. And I say "as far as the sea is concerned" because I think some of the specifics that have gone with their requirements are not very sensible.

But from the point of view of honestly protecting the marine environment—and man, and so forth—I believe there are other more useful solutions.

And I believe that continued scientific research by groups such as ours will pay for itself a hundred times in savings to various levels of government, if they will make use of it.

One of the frustrating problems of doing scientific work is that even the people who pay for it sometimes do not pay any attention to it.

But let me say that we have found out a great many important and useful things about the sea.

I would like now to refer to some tables, beyond the material I have just been reading from.

The first table is called table 2. This was simply removed from other reports that we had, conveniently located.

[Table referred to follows:]

TABLE 2.—METRIC TONS OF METALS, PESTICIDES, AND SOLIDS ADDED ANNUALLY TO THE COASTAL WATERS OF SOUTHERN CALIFORNIA COMPARED WITH LEVELS NATURALLY PRESENT IN THESE WATERS

	Metric tons annually added by man to the sea off Southern California				Metric tons naturally present in ocean		
	Via power plants	Via aerial fallout	Via streams	Via 6 major outfalls	In subsurface current (moving past outfalls each year)	In offshore current (moving past southern California each year)	Dissolved amount naturally present in world ocean
Chromium	0.6	6.5	60.0	570.0	950	4,000	280,000,000
Copper	2.1	31.0	42.0	470.0	950	60,000	280,000,000
Lead	.8	240.0	210.0	160.0	95	6,000	28,000,000
Zinc	1.8	150.0	240.0	1,010.0	2,400	200,000	40,000,000
DDT		1.8	.3	1.0			
PCB's		1.8	.3	2.5			
Solids		200,000.0	274,000.0	278,000.0	(1)	(1)	(1)

¹ Average annual discharge from the Ventura River is 400,000 metric tons.

Dr. BASCOM. If you will look for a moment at table 2, it compares man's present output with the natural outputs in the sea. This is, by the way, from a report of our Commission to the general public in Los Angeles, which will be issued within the next 2 weeks; I simply picked out a couple of tables from that.

You are some typical items that are believed to be problems. These are chromium, copper, lead, zinc, DDT, PCB's, and solids.

We have shown the input into the sea from powerplants, aerial fallout, streams, outfalls. We have also shown the amounts in the dilution water, what is in the offshore current, and what is in the ocean as a whole.

I ask that you compare columns 4 and 5; what comes out the outfalls with the water it is diluted with. You will see that there is more of all these materials in the dilution water, roughly twice as much, as there is in the outfalls themselves.

Table 3 shows the range of natural levels of so-called pollutants in our control areas. Now, one of the things that is important to do in any of these studies of the coast, is to determine what areas really are clean so you will have some basis for deciding what is happening in an outfall area.

[Table 3 follows:]

TABLE 3.—ANALYSIS OF THE UPPER INCH (2 cm) OF SOFT BOTTOM SAMPLES TAKEN AT 29 STATIONS IN AREAS ALONG THE SOUTHERN CALIFORNIA COAST THAT ARE VIRTUALLY UNAFFECTED BY MAN¹

	Lowest	Highest	Median
Infaunal index.....	80	99.6	92
Percent sand.....	5.2	86.8	44
Percent volatile solids.....	1.4	10.0	3.0
Chemical oxygen demand of sediment (parts per million).....	9,200	69,400	22,100
Nitrogen (parts per million).....	295	1,360	665
Acid volatile sulfides (parts per million).....	<0.003	.06	.011
Metals (parts per million):			
Cadmium.....	<.1	2.4	.2
Chromium.....	7.8	43.0	23
Copper.....	2.8	40.0	7
Lead.....	1.4	12.0	5
Nickel.....	4.9	51.0	14
Silver.....	<.1	<1.5	.3
Zinc.....	10.0	110.0	37

¹ Samples were collected between May and August 1977 at a depth of 190 ft; all values were calculated on a dry weight basis. Note the wide range of values within samples, all of which seem to represent natural conditions on the California coast.

Dr. BASCOM. So these areas, generally far away from any outfalls, have been determined on other grounds to be pristine, as far as we know, for California.

There we have put together some of the characteristics of things that are regarded as pollutants—volatile solids for example, which is roughly equivalent to suspended solids on the bottom; we have looked at nitrogen and a number of metals and so forth.

You will see that in these absolutely pristine areas the range of variations in those things is a factor of 10, from the least to the largest.

This means that there is no specific number that one should attain. There is a very wide range, naturally, of all the things you could call pollutants in the sea.

The next table is titled, "Summary of Effluent Characteristics Now (1976) and Those Under Full Secondary Treatment (1983)."

[Table follows:]

SUMMARY OF EFFLUENT CHARACTERISTICS NOW (1976) AND THOSE ESTIMATED UNDER FULL SECONDARY TREATMENT (1983)

	Mass emission rates in LA/ONA effluents							
	Los Angeles County				Los Angeles City			
	5 mile		7 mile		5 mile		7 mile	
	1976	1983	1976	1983	1976	1983	1976	1983
Flow (MGD).....	353.0	275.0	359	365	4.1	4	182.0	215
(Liters x 10 ⁶).....	1,336.0	1,041.0	1,359	1,380	15.5	15.2	688.0	814
Sus. solids.....	138,900.0	19,900.0	36,300	15,700	56,200	58,000	32,300.0	8,940
Percent vol. solids.....		69.0		78		65		78
Trace metals (ton/yr):								
Silver.....	6.3	1.9	5	3.3	4.9	7.0	2.5	.65
Arsenic.....	3.4		5	2.5	7.6	1.3		
Cadmium.....	12.8	2.3	10	2.0	7.4	8.0	10.0	1.65
Chromium.....	370.0	50.0	95	23	66	96	48.0	8.5
Copper.....	200.0	32.0	85	24	95	93	91.0	19
Mercury.....	157.7	100.2	90	.25	21	18	35.0	30
Nickel.....	108.0	40.0	15	6.1	9.4	11	28.0	14
Lead.....	650.0	160.0	109	50	120	100	140.0	43
Zinc.....								
Chlorinated hydrocarbons (kg/yr):								
DDT.....	940.0	150.0	25	9.9	18	16	31.0	9.9
PCB.....	1,300.0	170.0	110	120	120	120	990.0	660
TCH.....		320.0		130		140		660
Chlorine.....								
Benzenes.....		2,800.0		650		4,400		1,900

Dr. BASCOM. I would ask you to ignore most of the numbers of that page. The 1983 forecast of effluent during full secondary treatment conditions was made by the LA/OMA group, not by ours. We compared those with our numbers for 1976.

I have indicated items I thought were most important. If you will look opposite the PCB numbers, you will see that it actually shows an increase in the amount of PCB coming out the outfall under secondary treatment—for what reason, I am not sure—and generally, a relatively small change in the reduction of many of these pollutants.

The point of this is simply that secondary treatment does not do everything. You must not expect magic out of it. It will get rid of about half of the things that have been called pollutants—and some of those, as I have said before, I do not think are pollutants anyway.

Next is a list of independent forecasts which our group made for the LA/OMA project. I will not bother to go through it, but there is a list of 10 items there. In some of them we used mathematical models and physical data, some we used indicator organisms, some we used biomass, some we used fish and epibenthic invertebrates, which are mainly crabs and things like that. We looked at diseases in fish, we looked at changes in the water column, we looked at sport and commercial fish catches, the bacterial levels—10 different ways of forecasting are given here.

[List referred to follows:]

These papers forecast the situation that will exist around 3 large outfalls if full secondary treatment were to start on Jan. 1, 1983 and at one year and 5 years after that time.

1. Changes in the bottom near Whites Point and Orange County as determined by a mathematical model using data on organic carbon, DDT, and copper. (Dr. Terry Hendricks)

2. Changes in indicator organisms as reflected by the Infaunal Index. (Jack Word)

3. Changes in the biomass of benthic infauna. (Dr. Alan Mearns)

4. Changes in epi-benthic invertebrates. (Jack Word)

5. Changes in the abundance of bottom fish. (Dr. Alan Mearns)

6. Changes in fish health (tumors, fin erosion, liver condition). (Marjorie Sherwood)

7. Changes in water column and plankton (Dissolved oxygen, phytoplankton, zooplankton). (Dr. Alan Mearns)

8. Changes in sport and commercial fish catches. (Dr. Alan Mearns)

9. Changes in nearshore bacterial levels. (Henry Schafer)

10. Changes in chlorinated hydrocarbons and metals. (Dr. David Young)

Dr. BASCOM. So I think it is entirely possible to make good forecasts of the future, and I will leave with you a copy of that report. It is unbound. We made a copy from our original. This is our report to LA/OMA with the details of those 10 forecasts in it.

And by the way, people tend to be suspicious of our scientific work, so the LA/OMA had our group reviewed by a thing called the State marine and estuary committee, mostly composed of people from the State water resources board in California with some members of the EPA on it, and we went over this in considerable detail with the members of that advisory group. They made a few suggestions, which we used in the final version.

But in the main, it is unchanged from our original version, and whereas I think they had a fairly jaundiced view of what it was possible to do when we started; after they had reviewed it with us, I

think they were convinced that we could indeed make meaningful estimates of what would happen in the future.

The next item I have given you is called "forecasts based on biological measurements and mathematical models." I will not go into much on that page, but let me just say this is the forecast for two of the outfalls under the conditions listed there.

FORECASTS BASED ON BIOLOGICAL MEASUREMENTS AND MATHEMATICAL MODEL

	Orange County Station B0-B5						Los Angeles County Station 60-3C					
	Natural back- ground range	Pre- change 1977	Start 1983	1 yr. 1984	5 yr. 1988	1993	Pre- change 1977	Start 1983	1 yr. 1984	5 yr. 1988	Eventual 1993	
Percent organic carbon (large particles removed)	0.5-2.0	1.7	1.8	1.5	1.3	1.3	12.6	12.6	10.5	7.5	6.0	
Copper ppm	2.8-40.0	60	65	40	22	21.2	43	8.5	7.1	4.3	1.0	
DDT ppm	0	<0.05										
Infaunal index total lineal distance to background level (both sides of pipe)	75-80+	8km	8km		<0.5		48km	48km			14km	
Solids discharge metric tons/yr	70-100	25,000	(32,300)	8,940	8,940		138,000	19,900			450	
Excess standing crop of benthic organisms metric tons		549	848	280	110	89	13,392	13,392	5,000	600		
Liver somatic index (Dover sole)	0.7-1.0	1.5					2.2-2.6			>1.5		
Percent prevalence of fin erosion in Dover sole	0						45	16	14	9		

Dr. BASCOM. I call your attention particularly to Los Angeles County, which is the righthand side of that table. You will see in the first two columns, at the second level where there is a gap, you will see opposite DDT, under Los Angeles County, it says for DDT in the bottom, before the change in 1977, the amounts in the bottom were 43 parts per million. Before any secondary treatment has gone into effect—that is, the day when the forecast begins in 1983—that number is already down to 8.5.

That change is quite independent of anything done by man, or by the present outfalls. And then, as you will see, it slopes on down, actually at the same rate, although it looks more gentle, because what happens is the DDT on the bottom is entirely independent of the present outfalls or the present treatment; it is simply another matter.

And if you look a little bit further down, still under Los Angeles County, under a thing called Excess standing crop of benthic organisms, you will see that under the prechange conditions, the number given is 13,392. That is tons of additional animals living in the outfall area now. Those are there, in effect, because we are feeding them.

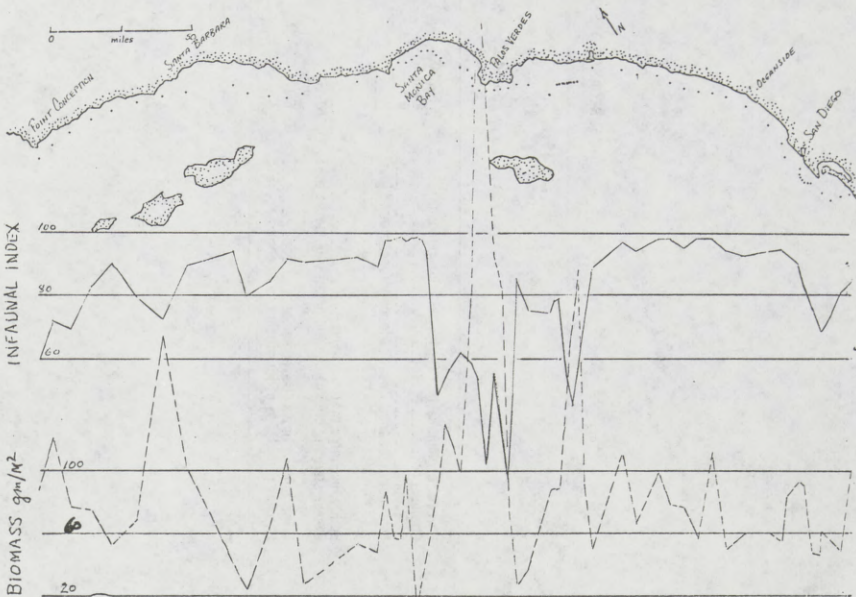
With the change over to secondary discharge—we have held the number at the present level because we have no basis for adjusting it up or down, until the start of secondary treatment in 1983, at which time we begin removing the animals' food from the sea. You will see the tonnage slopes on down, until it reaches equilibrium at an additional excess crop of 450 metric tons per year.

So if you want to look at it that way, we have killed 13,000 tons of animals by going secondary.

Those figures have not been quarreled with so far.

I also have a graph which I have shown several times before in Washington, and it has attracted considerable attention.

Actually, I usually show two of them, but in this case, I plotted them both on the same page, just so it is a little bit easier to understand them.



Dr. BASCOM. At the top side is a map of the coast of California, which runs from Point Conception on the northwest to San Diego or the Mexican border to the southeast.

And you see the whole coast of California, with the islands plotted out. Each of those little dots shown are sample stations. We sampled along the whole coast, just to see what it was like everywhere, at a depth equivalent to that of the outfalls, which is 190 feet; the 60-meter survey, we call it.

The uppermost of those two graphs at the bottom is called the infaunal index. We have selected a series of indicator organisms—actually, that is 25 taxa; that is not quite the same as a specie, such taxa gives you a little bit more range; in some cases, it is genera or an order—but we selected those because of their feeding characteristics.

At one end of this spectrum of animals is a group of animals which loves to live in clear water under pristine conditions. At the other end of the spectrum is a group of animals which loves to eat material out of the sea bottom.

Whether, in the sight of God, there is any difference in these animals, I do not know. We simply deliberately selected them for their feeding characteristics because that is one way of determining one of the effects of an outfall.

What the outfall does is put additional organic matter on the sea bottom, and the animals that live off that tend to congregate there.

So you will see that in the upper chart, opposite the outfalls, you get a deep canyon in what is called the Infaunal index, because it is a measure of the feeding characteristics of the species.

The graph below shows the mass of animals that live there.

So you will see that as the diversity of the animals decreases, the number of animals goes up. Instead of having a few animals of a lot of species, you have fewer kinds of animals, but you have a heck of a lot more of them.

Now, I have no idea whether that is better or worse to have it that way. I do not think any man can ever answer that question.

We do have a recent paper, a Science magazine article by a famous ecologist on the west coast named Prof. Joe Connell, who describes a position already held by a number of other famous ecologists: that stability really means fewer species and more of each species. In his paper, he dealt mainly with coral reefs and with tropical rain forests, but he left no doubt that he meant that to indicate other kinds of areas, including the ocean areas off California.

So maybe what you are looking at around an outfall is stability of a population, as defined by Professor Connell in this recent piece in Science. And I suppose the ecologists of the world are probably divided between these two views, whether you are better off or worse off. But I do not think any man here can say that it is better to have one or the other.

That concludes the items I wish to say to you. I will be delighted to try and answer your questions.

Mr. ROBERTS. Thank you. May I ask, for the sake of the record, that we get a list of the people in your group—it is a very impressive group—and I think it would lend weight, since all of them have agreed basically with your philosophy and your statement. And we would like to have the names for the record.

Dr. BASCOM. Yes. I think about seven of them are Ph. D.'s. Some of the ones that are not, are equally qualified, but they do not have the subscript. I will be glad to get that for you.

Mr. ROBERTS. Thank you, sir.

[The following was received for the record:]

SENIOR MEMBERS OF SCCWRP PROJECT

Dr. Alan Mearns, head of biology at SCCWRP expert on fisheries matters.

Dr. David Young, head of chemistry at SCCWRP expert at synthetic organic and metals measurements in the sea, Member of national committees on pollutants.

Dr. Terry Hendricks, physical oceanographer, engineer, modeler of physical-chemical conditions.

Dr. James Herring, physical oceanographer, geologist, expert in particulates in the ocean.

Jack Word, invertebrate marine biologist, taxonomist inventor of infaunal index.

Marjorie Sherwood, vertebrate marine biologist, expert on fish diseases.

Phillip Oshida, invertebrate marine biologist expert on low level toxicity studies.

Henry Schafer, marine biologist working on levels of sludge and chemicals on the sea bottom.

Jack Mardesich, engineer, developer of instruments, camera systems and electronic measuring devices.

Leslie Harris, marine botanist and biologist working on kelp problems.

Michael Moore, marine biologist, concerned with sea sampling and identification.

Harold Stubbs, marine coordinator directs sea operations, navigation, sampling.

Ted Heesen, chemist, synthetic organics.

Tsu-Kai Jan, chemist, trace elements.

Mr. ROBERTS. That was a very impressive statement. I noted that you were a little facetious when you said there is no magic in secondary treatment; I assume you would extend that to the next degree, as far as tertiary treatment is concerned?

Dr. BASCOM. In every case, you must look at what your objectives are, and you should do the best you can to meet those objectives with minimum effort. That is all.

Mr. ROBERTS. Thank you.

Mr. McCormack?

Mr. MCCORMACK. Thank you, Mr. Chairman.

Professor Bascom, you struck a particularly sympathetic chord when you commented that anything could be a pollutant, and you used freshwater and table salt as the example.

This leads me to a problem that I have wrestled with in my own mind for some time, and that is the use of the word "toxic."

It seems to me that it would be far better if we were simply to attempt to establish maximum permissible concentrations for any substance of interest in any medium of interest. It seems to me that that would be a higher degree of intellectual integrity than treating substances as toxic or not.

The problem that we have is that once we list something as toxic, under any conditions at all in the law, it is frequently regarded as toxic under all conditions and under all circumstances in the regulations.

Dr. BASCOM. Yes, sir.

Mr. MCCORMACK. I am curious to know what your reaction would be to attempts to eliminate the word "toxic" from the law and simply substitute a program of maximum permissible concentrations for each individual substance.

Dr. BASCOM. Well, the way we like to look at it—and I do not claim to be an expert in anything except the items that I have talked about: what happens in the ocean is my area—is that we are mostly concerned with what is called a chronic toxicity of these things. That is, over a long period of time, at what level could there be any effect on the sea life. We are mainly concerned with sea life because we think the other things that some people claim concern over are not really problems.

So we really look at the sea life because that is a very delicate indicator. This means that these animals must be able to live with some low level of a toxic substance and survive with it and reproduce with it over long periods of time. Obviously, those are difficult measurements to make.

The one we looked at particularly from this point of view was chromium, simply because the State of California obviously made a mistake of at least an order of magnitude in stating their chromium restrictions, so we looked at that particularly.

The State happened to pass a law which said when you discharge material, you may not have more than five parts per billion of chromium—and it specifies total chromium, by the way.

There are three of four things wrong with that. First of all, when it is diluted, immediately upon discharge, the concentration immediately drops to five-hundredths of a part per billion as the amount that is present in water.

The experiments on which the chromium data were based were made in freshwater, under fairly specialized conditions, where you deliberately put the chromium into solution by putting it in a form that becomes ionic. That kind of material is indeed discharged into the sewers of Los Angeles, and it does get to the treatment plant; there is no question about that point. So their original concern was certainly understandable.

However, in passing through the treatment plant, the chromium at this toxic valence, which is a valence of 6, is then reduced so it becomes a valence of plus-3, which is what is actually discharged.

Now, chromium with a valence of 3, on reaching the sea, immediately becomes a hydroxide precipitate and falls to the sea bottom. We have had animals living in it for 6 months at a time, showing that it has zero toxicity.

So indeed, you cannot put the pollutant in the sea; even if you tried to, you could not do it, sir. So why they should make the requirement for this special toxicant especially low and difficult to meet, I do not know. It simply does not jibe with the scientific results.

The same kind of an argument can be made for many other things as you go down the line. There has been a great deal of concern expressed over mercury in the sea. What the regulations should say is organic mercury in the sea. Now, the mercury material discharged at Minemata Bay, in Japan, was the direct product, in the form of methyl-mercury, released by a plastics plant on the bay. It is terribly toxic; there is everything wrong in the world with doing that.

On the other hand, we simply cannot find any evidence that more than about two-tenths of 1 percent of the total mercury going into the sea off California is in the methylated form.

Now, a big number going into the sea would be like 1 part per million or something like that, or a few parts per billion. So 0.2 percent of that is a terribly tiny number.

It was then also alleged that somehow, if the mercury went into the sea in some other form, for example, as a metallic mercury, the form that you are familiar with—as a matter of fact, most of it comes from broken thermometers and things like that—when that goes to sea, that somehow could be converted by bacteria into the sea into the toxic organic form.

So we very carefully looked at that. We made thousands of measurements of mercury in the bottom and in the animals, and we discovered that the ratio remained unchanged; that there is, in fact, no change of mercury from the relatively un toxic form at very low levels into this highly toxic form which caused the problem off Japan.

But the regulations require the discharger to measure total mercury and worry about it as though it was a serious pollutant, and that is simply not a fact.

Mr. McCORMACK. Thank you, Mr. Chairman.

Mr. ROBERTS. Mr. Clausen?

Mr. CLAUSEN. Thank you, Mr. Chairman.

I would like to ask a followup question to one that I had asked Dr. Brooks earlier, and this relates to the upwelling. I will ask you exactly as I put it to him.

Yesterday, we heard testimony about the upwelling of nutrient water from lower levels of the seas. What is the magnitude of the discharge of a city like Los Angeles compared to the volume of the natural upwelling?

Dr. BASCOM. Well, there are a lot of questions I have to go into to get at that one. First of all, you have to say the difference between nutrients and food—they are not the same thing.

Ordinarily, one thinks of nutrients as fairly basic chemicals—nitrogen, phosphorus, such as that. Food, which is a little bit of a different question, is this highly processed material process by animals, like humans, which is discharged as particles into the sea. So they are not quite the same.

Then, one has to be concerned with which area you are talking about. Now, upwelling is generally a process which takes place over what you think of as a very large area—many square miles—at very low velocities, and nobody really knows how to measure vertical motion in the ocean. Let me say that is a very difficult measurement to make directly. We get at it in an indirect fashion.

So you cannot exactly compare these two things. Generally, anything that man does, whether it is adding either food or toxicants to the sea, is so tiny in comparison to what the ocean is doing that it is almost insignificant.

We are not going to feed the ocean greatly, and we are not going to hurt the ocean greatly, simply because man's contribution is so tiny.

In fact, I just made a calculation the other day of Santa Monica Bay. If all the material discharged during the year stayed in the bay, the dilution would still be 100 to 1. You are dealing with very small inputs by man in comparison to what happens in the ocean.

I computed one time, by the way, that it takes 4 years for all the outfalls of California to discharge 1 cubic kilometer of waste, which is relative to the 600 million cubic kilometers in the Pacific Ocean, or something like that.

Mr. CLAUSEN. Well, I think I heard Dr. Brooks describe the ocean as a biological kettle. And if you were to look at the west coast and the Pacific Ocean as that biological kettle, and you were going to be dumping into that kettle the effluent from the Los Angeles basin, let us say that kettle had a capacity of 5 gallons. Now, what would be the percentage of Los Angeles outfall into that biological kettle?

Dr. BASCOM. Into a 5-gallon kettle? That is a submicrodrop of some kind. I do not know what it is. That is unbelievably small.

Mr. CLAUSEN. I just wanted to draw a comparison.

Dr. BASCOM. There must be 100 rivers flowing into the ocean that put in more water in half an hour than Los Angeles puts in in a year, or something—it is a very tiny number.

You should know that there are large amounts of metals present in the ocean—and by the way, they sometimes are present in relatively toxic forms; that is to say, unchanged ionic forms.

It is generally believed that the metals in upwelling water—everything kindly gets said about upwelling, but they do contain metals in ionic form which in theory could be difficult for sea life. It is almost certain that as those metals upwell into coastal waters, they are almost immediately taken up or complexed in some fashion with the other material in coastal waters, so that they are made nontoxic simply by adding them to the coastal waters.

Mr. CLAUSEN. Now, the dispersal of sludge is one of the larger problems that they face in dealing with waste management. And yet, everyone recognizes that down in the depths of the ocean—I think there are certain areas where you get down below the area where there is sea life or marine life, to the point where there is practically nothing on the bottom—

Dr. BASCOM. I am sorry, sir, that is simply not true. There are huge amounts of sea life nearly everywhere on the bottom of the ocean, even in very deep water, under the most remote areas, where you cannot see any evidence of what they feed on.

There are some very tiny areas, which are anaerobic basins. We happen to have one off California that is not near the outfalls or related to them; it is the Santa Barbara basin. There happens to be zero oxygen on the sea bottom, and it is a very tiny area by comparison with the Pacific. The Black Sea happens to be an anaerobic basin, so there are some in the world, but they are very rare, where there is no sea life.

Mr. CLAUSEN. Well, should we be looking into or studying the feasibility of depositing sludge in the ocean depths?

Dr. BASCOM. Well, I think you are still thinking of sludge as though it is something you really want to get rid of. And the point of view that we have heard expressed, and which I agree with, is that most sludge, is organic solids that are released. From that point of view, it is perfectly good food for the sea, as it is for the land, and you want to release it where you are conceivably going to help out a little bit. It is not going to make much difference, because it is so tiny by comparison with what is in the California current to start with; it is a very tiny part of it, but it will help a little bit. There is no particular need to throw it away or to put it someplace. If you disperse it, the animals are going to make very good use out of it.

Mr. CLAUSEN. So you would not have any serious reservations about entering into the disposal of sludge by dumping it out into the depths of the ocean?

Dr. BASCOM. Well, some of the words that you used have connotations to them, so I do not like to get carried away with that.

But if you are talking about in some fashion adding these organic wastes to the sea in a thoughtful manner so that it can be utilized, yes, I think that is a fine idea.

Mr. CLAUSEN. Thank you.

Mr. ROBERTS. The gentleman from Pennsylvania?

Mr. ERTEL. I have no questions, Mr. Chairman. I appreciate hearing his testimony.

Mr. ROBERTS. Does counsel have questions? You were interested in monitoring, I know, and here is the expert, so you had better ask your monitoring questions.

Ms. KOVALIC. First off, Dr. Bascom, could you describe for us your funding sources and the role that these sources play in directing your research?

Dr. BASCOM. Yes. We are mainly supported by the cities and counties of southern California and/or their discharging sections.

We get one-half a million dollars a year as a sort of central fund, and of course, before the project was started, everyone was concerned that this was a question of the fox watching the chicken coop, and that somehow, the scientific work would be biased in some fashion if we received money directly from the people who were doing the discharging, and who had a stake in the outcome.

So it was deliberately funneled through five Commissioners, who are good people, I am sure, who know very little either about sewage or about the ocean; they are simply there to keep everything honest.

They hand the money pretty much to me, and I direct the activities of the scientists that I have named off. There are about 20 people qualified as scientists, plus some helpers.

We also receive funds at the moment from the National Science Foundation, where we are making a study really of nonfood chains in the sea. Most of what has been said about food chains in the sea is probably not true, and more than likely, materials in the sea are spread rather evenly through the food web by opportunistic feeding of one sort or another—anyway, we are looking into that for the National Science Foundation.

We have received money at various times from NOAA, the National Ocean and Atmospheric Administration, from the EPA, from the State water resources control board, the University of California, and possibly some other people.

I do not believe that we have ever had any hint of this—that anybody has ever tried to influence our findings and I am quite sure that our people are quite stubborn enough that you could not persuade them to change their scientific views no matter what you thought.

Ms. KOVALIC. Have you assessed the monitoring requirements in the proposed regulations that were published April 25?

Dr. BASCOM. I read them. I did not clearly understand them. I think some of the things that were suggested are not a good way to do monitoring. I think there are better ways that are less costly and more effective.

Ms. KOVALIC. I was wondering, Dr. Bascom, if perhaps, not now, but later for the record, you might give us a critical assessment of these requirements—and by that, I mean a constructive assessment—that is, looking at the monitoring requirements and the questions that

are being asked. What they are supposed to answer, whether in your judgment they can be answered; if not, what might be appropriate, and what you know about the cost involved. I would hope that your experience and your work might be a basis for that sort of judgment.

Dr. BASCOM. Sure. You must understand that those requirements are then set up to meet the other numbers for toxicity levels that are set forth in this proposal. Now, I do not think the other numbers are the right ones to meet either, you see. So it seems to me it is much more straightforward to just go directly to the problem and say, "Well, what is wrong in the ocean, and let us be sure we fix that, and let us fix it with a little safety factor."

I thought your question before was sensible: How do you know that something is not going to change a few years from now. You need a little cushion in it to make sure that you are not making a big mistake and that some measurement has not gone wrong in the past.

That is perfectly achievable without going to anything like the numbers and requirements that are set forth in this document. So I think you ought to have a monitoring program that is aimed at answering the national questions of: Are the oceans clean, and how do you keep them that way, instead of answering these nonsensical regulations.

Ms. KOVALIC. Yesterday, Dr. Isaacs said that you were the perfect person for me to ask a question of, so I would like to follow up on that.

You made some references this morning to the deposits of DDT that exist, I believe in the general area of the Los Angeles County outfall.

Dr. BASCOM. Yes.

Ms. KOVALIC. At what point in time was that discharge of DDT terminated?

Dr. BASCOM. It was apparently discharged over a period of 10 years, roughly. I understand that as soon as it was discovered that this particular chemical company was discharging DDT excesses into the outfall, it was stopped almost immediately, and the effects are still with us, and they will be with us for some time.

Many tons were permitted to accumulate on the sea bottom off the Palos Verdes Peninsula, in the area where the discharge was affected. That was stopped some time ago, about 1970.

We believe—and it is stated in some detail in this document on the forecast—that the DDT and the sediments off there have a half-life of about 7 years. That is to say, every 7 years, you will have half as much as you have now. And of course, you never get it perfect again; you come out ultimately with some very low number. But in any case, the DDT is at present decreasing. It will continue to do so, entirely independent of what the discharge is. Whether you discharge or do not discharge is not related to that. That is what is going to get fixed up by the storms and the animals and so forth off there.

Ms. KOVALIC. But would, for example, the imposition of secondary treatment or the continuing of the outfall in any way speed up or slow down the ability of that area to recover?

Dr. BASCOM. I do not believe it is going to have any effect at all.

Ms. KOVALIC. Assuming that pretreatment and source controls do not remove heavy metals or toxic organics to levels that are going to meet applicable water quality standards, can you give suggestions as to what type of treatment alternatives might be available?

Dr. BASCOM. I am not the person to ask about treatment questions. I perhaps should point out to you something that is not generally recognized. A few years ago, maybe 5 years ago, it was generally believed that these synthetic organic toxicants—and they are indeed toxicants; I do not mean to depreciate that in any way—were uniquely made by man, and that this was something very special and new that ocean animals could not deal with.

It has since been discovered by scientists at the Scripps Institute of Oceanography that very similar compounds—halogenated hydrocarbons with fluorines and chromiums and bromines and so forth—are made by certain classes of red algae in the sea, and that they are specifically consumed by other animals in the sea, have apparently been doing this for many millions of years, and that they are not unique to man; that they are normal in some way in the sea. So it is not quite the situation that we thought in the beginning.

Mr. ROBERTS. Red algae being sometimes what we call the “red tide” in certain areas?

Dr. BASCOM. No; that is another kind of a question; anyhow, these certain kinds of algae do in fact make these compounds, and they are highly toxic, but they are also natural in the sea, and they are made by it, and made and used by sea animals. So it is not quite what we thought it was before.

I do point out—and maybe I have said it before—but the concentrations being discharged are quite small, and I believe that the secondary treatment process, in many of the discharges, anyway—they are all a little bit different, so I cannot speak for all of them—is not going to cut it right down to zero. I mean, it is going to cut it down some, maybe one-half or maybe three-quarters under some circumstances.

And I do not have any suggestions for what you do that is better, short of simply not manufacturing the stuff in the first place.

At the moment, the aerial fallout of DDT on the sea surface is greater than what comes out of the outfall, and you had better think of some other way to control that.

Ms. KOVALIC. You indicated earlier this morning that heavy metals are in a nontoxic form by the time they hit the ocean water. Do you have any evidence that they are transformed into a toxic form after they have been in the ocean waters for any period of time?

Dr. BASCOM. No. I think it is actually the contrary, although I am not really good at that. There is a recent paper out on the subject of arsenic. By the way, arsenic is not thought to be a problem much around our area. It turns out, by the way, that there is both more copper and more arsenic in the drinking water than we are permitted to discharge out there—the drinking water that comes from part of the Owens Valley, anyway.

This recent paper has to do with arsenic and lobster tails which are imported into the United States. Lobsters cannot distinguish certainly between the trace elements around them, and this particular bunch of lobsters takes up arsenic and the tails are loaded with it.

But the conclusion of the scientists that did this work, extensively studying arsenic, was that the arsenic was made less toxic by sea animals, just to give one example.

My guess is that this is not going to make much difference. These metals are easily complexed. They simply become biologically unavailable as far as we can tell.

Now, as fair as the uptake into animals is concerned, we have some evidence there are actually less metals in some of the fish around outfalls than there is at a distance, although that may be an artifact in which the growth of the fish has changed that situation slightly.

As for the invertebrates, the so-called filter-feeding animals which make a living by processing seawater, the highest uptake we have ever found was, I think, something like 10 parts per billion of a metal; that is to say the normal for that animal is 1 part per billion, and now it has 10 parts per billion. Well, we do not believe that level is toxic. There is no evidence that that is. It is certainly a change.

Ten parts per billion, by the way, is like 1 cent in \$1 million. So it is a pretty small amount. I would bet that your kidneys and livers run hundreds of parts per billion with all these toxicants that you are talking about. So you are very much worse off than sea animals are.

Mr. CLAUSEN. Just one summarizing point. You basically consider it to be a waste of tax dollars, as I understand your situation, as well as energy, to require secondary treatment on most of the west coast where there can be properly designed ocean outfalls; is this a fair summary of your point of view?

Dr. BASCOM. I would like to rephrase that. I do not like to be in the position of testifying about treatment processes, because I have stated that I am not an expert on that.

What we do see is a vast difference between outfalls out there. In some circumstances, the outfalls have barely caused any disturbance on the bottom at all. And in every place, it is a pretty small area where you can see something has happened. In other cases, a very large disturbance. It does not make much sense to treat them all the same way. I mean, you should do what you need to do to solve the problem in each area.

And there is enough money involved in this business, and sea conditions are not getting any worse. It seems to me you can afford to study the darned thing and then do the right thing, whatever that turns out to be. It does not make much sense to me to do the same thing everywhere.

Mr. ROBERTS. I think in justification of some of these regulations, which we thoroughly disapprove of, that the city of Los Angeles will say, "Well, San Francisco did not have to do this; therefore, we ought not to have to do it," you see. And of course, then it gets into politics, and you just say, "Well, everybody is going to do all the bad things," or all the good things. But that is the only justification I can make for it.

Mr. CLAUSEN. I think you were right the first time—the justification is for all the bad things.

Mr. ROBERTS. Professor Bascom, your presentation has been most interesting and tremendously informative, and we appreciate very much your being here.

Dr. BASCOM. Thank you. It was a pleasure.

With your permission, Mr. Chairman, I would like to offer, for this record, the full report to LA/OMA on Task Order No. 3: Forecast Effects (under the conditions of the baseline alternative).

Mr. ROBERTS. Without objection, so ordered.

[Report referred to follows:]

1. The first part of the report deals with the general situation of the country and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics. The second part of the report deals with the economic situation of the country and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics.

2. The third part of the report deals with the social situation of the country and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics. The fourth part of the report deals with the cultural situation of the country and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics.

3. The fifth part of the report deals with the political situation of the country and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics. The sixth part of the report deals with the international situation of the country and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics.

4. The seventh part of the report deals with the future of the country and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics. The eighth part of the report deals with the conclusion of the report and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics.

5. The ninth part of the report deals with the appendix of the report and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics. The tenth part of the report deals with the bibliography of the report and the position of the various groups of the population. It is a very general survey and does not contain any detailed statistics.

REPORT TO LA/OMA

on TASK ORDER NO. 3

FORECAST EFFECTS

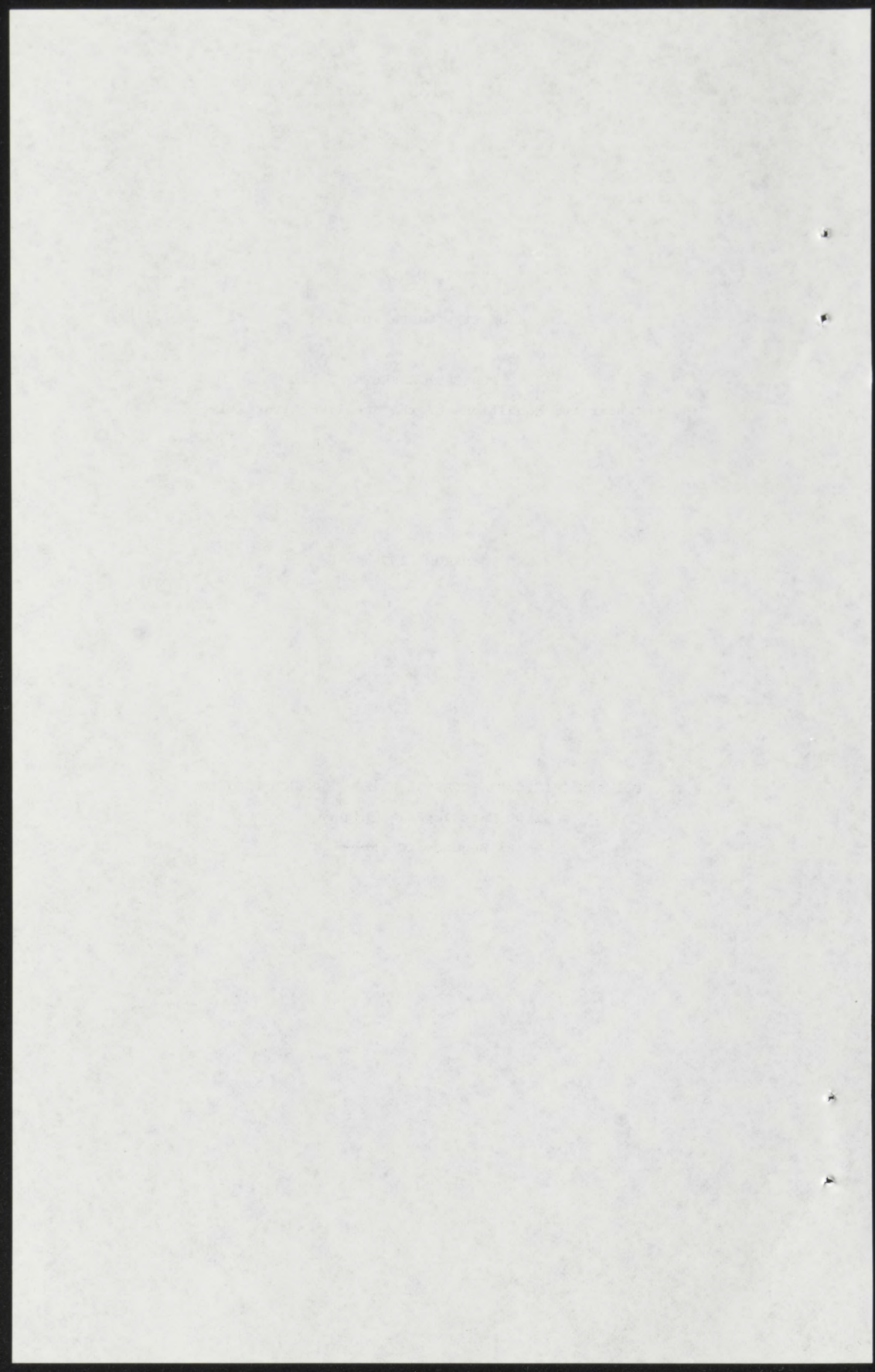
(under the conditions of the Baseline Alternative)

MARCH 1978

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

1500 East Imperial Highway

El Segundo, CA ~~90245~~



ABSTRACT

In element No. 1 of the Work Description we were asked to do two things that are covered in great detail in Task 2 and in our previous publications. We will not repeat that work here but will proceed directly to Element No. 2 which is to "forecast the probable marine impacts under conditions of the baseline alternative".

We began by requesting LA/OMA to provide us with the composition of the effluents under the baseline alternative and the date these would be effective. The information we received is included as Appendix one. Then we made the list of assumptions which follow to make sure all forecasters used the same conditions. Next we selected the times for which the forecasts would be made. These start on Jan. 1, 1983 when the changes are completely in effect and are estimated for 1 year afterward, 5 years afterward, and (in some cases) eventual equilibrium. We present here 10 independent forecasts, each based on a different kind of data and each attributable to a specific scientist. The net effect is a picture of conditions that will exist around the outfalls if changes are made in treatment as proposed by LA/OMA. These are summarized, by outfalls.

There are, of course, all sorts of problems and uncertainties in each forecasting method. We would not like anyone to place great reliance on any one number or method; however, we believe the collective view is probably correct.

General Assumptions used in this forecast and assessment of each

1. The present conditions of discharge will continue essentially unchanged until January 1, 1983. On that date all outfalls will have been converted to the discharge conditions postulated by LA/OMA in their communication of November 8, 1977.

This assumption may prove not to be exactly correct with respect to the phrase "essentially unchanged until Jan. 1, 1983". We are aware that new filters, centrifuges, and other treatment facilities are being (or will be soon) added that may improve the effluent before the date given. We cannot say what that improvement will be or when it will be effective with sufficient accuracy for use in the forecast. "Present" is defined as the most recent adequate data available.

2. There will be no major changes in the inputs of pollutants from other specific or diffuse sources (other than the assumed changes in municipal wastewaters) during the period of this forecast.

There will certainly be some changes in pollutant input from other sources over the next four years. There could be an oil spill or chemical spill, or an increase (or decrease) in the use of pesticides or fuels. We believe these will stay at about the present levels.

3. There will be no changes greater than the normal variations in ocean conditions (temperature, currents, waves, etc.) or in biological input to the Southern California Bight (plankton, larvae, fish, etc.) over the period of the forecast.

Our forecasts concerning changes in the diversity and abundance of marine life near outfalls are based on both average and specific conditions observed during the past five years. We recognize that major climatic and biological episodes (50 and 100 year floods, invasions, and mass strandings) can affect the diversity, abundance, and biomass of marine life of nearshore and kelp bed communities. The magnitude of these changes and their duration are uncertain, but we do not believe they affect basic aspects of nearshore community structure and diversity over periods of several decades.

4. Sludge is equivalent to suspended solids in municipal wastewater that reach the sea, whatever their origin. The settling velocity distribution beyond 1983 will be 1) the same as in 1973, or 2) the estimated curve shown in Figure 2, p. 14.

The present Settling Velocity Distribution (SVD) is based on past experiments of settling velocity. Most of these experiments probably show a high SVD which means that particle dispersion fields could be slightly larger than those predicted by the SVD. Pending further experimentation the assumption is a reasonable first approximation.

If suspended solid particle size is reduced by future treatment techniques, particles will settle more slowly as long as no increased aggregation also results from the treatment. If the settling velocity distribution is reduced as shown in the hypothesized curve, Figure 2, the area over which the particles are dispersed prior to reaching the bottom will increase. Additional processing of suspended solids in the future (full secondary treatment) may cause this to happen.

5. There is no significant desorption of either chlorinated hydrocarbons or metals from particulates on entering the sea.

The low solubility and rate of desorption observed for DDTs and PCBs indicates that this is a reliable assumption for such trace synthetic organics. The assumption is less reliable for trace metals. However, metal desorption rates generally are lower than typical dilution rates following discharge. Thus, concentrations of dissolved metals should not be elevated much above background (this has been confirmed by field tests).

6. The die-off rate of coliforms, pathogens, and viruses reaching the sea will be the same as that measured in the past.

We have no direct information that would allow us to predict an increase or decrease in the die-off rate. Some organisms surviving secondary treatment could be more resistant than those presently discharged and a

change in the ratio of bacteria to solids could cause a significant change (increase or decrease) in the die-off rate.

7. Elevated levels of metals in filter-feeding or deposit-feeding animals is due to consumption of or contact with waste particles either directly from an outfall or stirred from the bottom, but not to metals in solution.

Although marine animals will accumulate trace metals from solution for this to occur it appears that aqueous concentrations must be well above ($>> 1$ ppb) those encountered near submarine discharges (≤ 1 ppb).

8. Any elevated levels of chlorinated hydrocarbons in bottom-feeding fish or invertebrates are related to chlorinated hydrocarbons on waste particulates in the bottom.

This assumption is based on the fairly similar rates of decrease observed for DDT-PCB in bottom sediments and benthic organisms around the JWPCP and OCSD discharges.

List of independent forecasts made under this contract	<u>Page</u>
1. Changes in the bottom near Whites Point and Orange County as determined by a mathematical model using data on organic carbon, DDT, and copper. Dr. Terry Hendricks	9
2. Changes in indicator organisms as reflected by the Infaunal Index. Jack Word	22
3. Changes in the biomass of benthic infauna. Dr. Alan Mearns	29
4. Changes in epi-benthic invertebrates Jack Word	37
5. Changes in the abundance of bottom fish. Dr. Alan Mearns	40
6. Changes in fish health (tumors, fin erosion, liver condition) Marjorie Sherwood	41
7. Changes in water column and plankton (Dissolved oxygen, phytoplankton, zooplankton) Dr. Alan Mearns	51
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9. Changes in nearshore bacterial levels. Henry Schafer	55
10. Changes in chlorinated hydrocarbons and metals. Dr. David Young	59

SUMMARY OF FORECASTS

The 10 independent forecasts that follow this section each deal with a phenomena and describe how it effects each area. However, we appreciate that the sponsors of this work are interested in outfalls as independent units. Therefore, this summary cuts crosswise across the other forecasts by describing the general situation and then one outfall at a time. In each case the LA/OMA data is used and the stated assumptions apply.

Forecasts that apply to all outfalls

Forecasts, or parts of forecasts, numbered, 2, 5, 6, 7, 8, and 9 apply to conditions around all outfalls, as follows:

Generally the overall abundance of bottom fish will decrease at all sites but some species now missing will return. Where the changes in bottom conditions are small the natural variations will probably mask this trend.

Tumors in fish (either skin tumors or lip papillomas) do not appear to be related to municipal discharges; thus the percentage of fish with tumors will continue at about the same level.

The level of dissolved oxygen in the water is not substantially changed by the present discharges so there will be no measurable increase in oxygen after the changes are implemented.

At present phytoplankton may be slightly enhanced at the LA/OMA sites because of the increase in available nitrogen. There may also be some slight toxic effect of the

present effluents on the phytoplankton (these effects are not proven). After the changeover we doubt there will be any demonstrable change in the phytoplankton. There could be a slight increase in the incidence of plankton blooms if the toxicity decreases and the light penetration increases. This will be very hard to detect because there is so little useful data available for comparison.

We expect no measurable change in the abundance of zooplankton.

Generally, among trawl-caught invertebrates (such as ridge-back prawns, sea hares, and sea urchins) the number of individuals will decrease in abundance when the solids emissions are reduced.

No measurable change is expected in total sportfish landings or catch per unit effort of fish in the LA/OMA zone although the number of white croaker will decrease.

There will be a one-to-two order of magnitude drop in the number of coliform bacteria at the nearshore sites monitored by LA/OMA dischargers.

Within a period of 5 to 20 years the predicted distance to natural Infaunal Index values will be 4 to 10% of the present distances.

Forecasts that apply to specific outfalls

Orange County Outfall.

By means of a mathematical model that simulates physical processes it is possible to forecast the effect of changed

effluents on the nearby sediments. At station B-0 which is located at the upcoast (NW) end of the diffuser the concentration of organic carbon in the upper 1 cm of sediment is now 1.7%; in 1983 (start of forecast period) it will be 1.8%, by 1984 it will be 1.5% and by 1988 the organic carbon level will be 1.3%. The last number represents equilibrium, which means that all the changes have occurred and that inflow and outflow of organic carbon is the same.

At that same site the change in copper concentration in the sediment was also forecast. At present the value is 60 ppm (mg/kg). By 1983 this will increase to about 65 ppm; by 1984 it will decline to 40 ppm and by 1988 it will reach equilibrium at about 22ppm. (The range of copper found at natural sites in 60 m depth is 2.8 to 40 ppm with a median value of 7 ppm). Metals in animals will decrease proportionately.

The Infaunal Index background in the Orange County area is about 75. At present the total distance from the discharge point to the background in both directions along the contour is 8 km. Within 5 years of the change the distance will be less than 500 m and conditions very close to background will exist around the discharge point.

The excess standing crop of benthic infauna will be reduced from 550 tons in 1983 to 110 tons in 1988 and there will be some slight decline in the abundance of bottom fish and some larger invertebrates near the outfall terminus.

Los Angeles County

The simulation model of sediments forecasts that at stations 6C to 7C the organic carbon concentrations will be 12.6% in 1983. By 1984 it will decline to 11.0%; by 1988 it will be 7.6% and eventually it will reach 4.7% (1993). This is relative to the natural range of 0.7 to 5.0% at coastal control stations.

Using a similar model, DDT in surface sediments at stations 6C to 7C will have a concentration of 8.5 ppm (mg/dry kg) by 1983 relative to about 43 ppm at present. However, in 1983 the maximum surface concentration will have migrated down slope from the present maximum at 200' to a depth of 900 ft where it will be 64 ppm. By 1993 the concentrations at 200' and 900' will be 2.6 and 22.0 mg/dry kg respectively. The highest levels of DDT measured in Dover sole and white croaker are now about 8.0 ppm; by 1983 this will fall to 5 ppm. PCB in animals will be reduced at the same rate; its level is about one-tenth that of DDT.

A forecast, based on the total distance from this outfall (both upcoast and downcoast) to background Faunal Index conditions, begins with the present situation. It is a total of 48 km to a background Infaunal Index of 80 (although we acknowledge that this is confused somewhat by the L.A. City discharges). After 20 years under the changed conditions it will be about 14 km in both directions along the coast from the discharge point to a background of 80 (roughly 4 km downcoast and 10 km upcoast).

The reduction in suspended solids emission will, in 5 years, reduce the excess standing crop of benthic organisms from 13,390 at present (and in 1983) to 600 tons in 5 years. Larger

echinoderms should return. Fin erosion will still occur in bottom fish but the prevalence will be substantially lower than now and will occur independantly of changes in solids emissions.

Los Angeles City

No substantial change in the 7-mile effluent is proposed by the LA/OMA plan. Thus we have no forecast except to say that the region around that discharge point seems to have been stable for a long time and it probably will not change.

At the 5-mile outfall the estimated present total distance to the Infaunal Index background (80+) is 24 km (there is some uncertainty because of the unknown influence of the L.A. County outfall). We forecast that within 10 years after the changeover that distance will be less than one kilometer.

In Santa Monica Bay we project that the proposed reduction in solids emission from the 5-mile outfall will be accompanied by a reduction in the excess standing crop of invertebrates from 4660 tons at present to 1000 tons in five years.

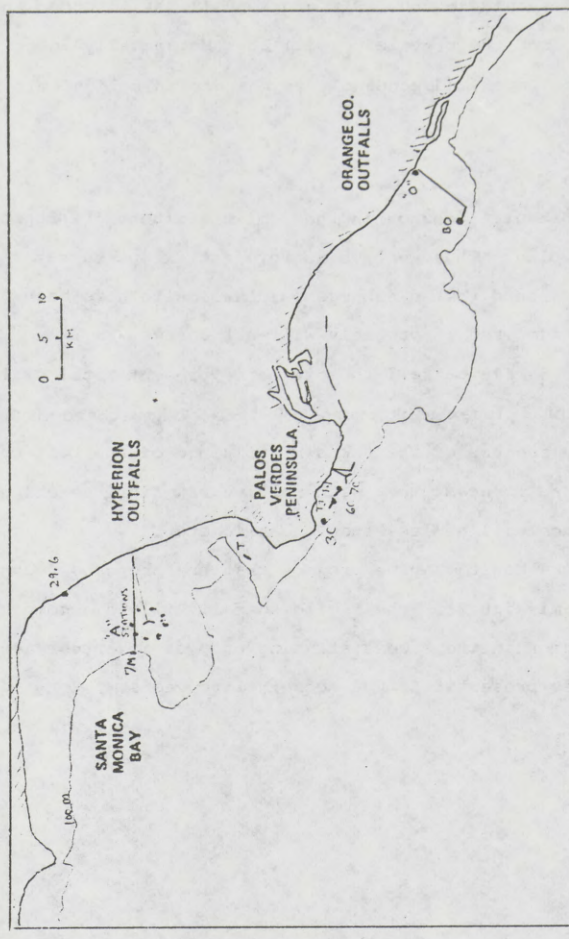


Figure 1. LA/OMA coastal area (Los Angeles and northern Orange County) showing existing discharges and approximate locations of stations mentioned in text and table.

Table 1. Examples of metals and chlorinated hydrocarbon forecast

	Median Back- ground level	Orange County Station B0-B5				Los Angeles County Station 6C-3C			
		Pre Change 1977	Start 1983	1 yr. 1984	5 yr. 1988	Pre Change 1977	Start 1983	1 yr. 1984	5 yr. 1988
Chlorinated hydrocarbons mg/kg									
Sediments									
" DDT	<0.01	0.01				13	7.7	7.0	4.7
" PCB	<0.01	0.1				0.8	0.5	0.4	0.3
Flatfish muscle DDT	0.03	0.05				8.1	5.0	4.5	3.0
" PCB	0.01	0.1				0.8	0.5	0.4	0.3
Crab muscle DDT	0.01	-				2.1	1.3	1.2	0.78
" PCB	0.03	-				0.17	0.10	0.09	0.06
Excess Metals in Sediment mg/kg									
Silver	0.3	0.2	0.2	0.16	0.12	16	10	9.7	8.8
Cadmium	0.2	1.2	1.2	0.72	0.26	32	16	15	13
Chromium	23.0	17	17	13	8.5	1050	620	580	460
Copper	7.0	29	29	18	8.3	580	440	410	320
Scallop muscle									
Silver	0.006					0.004	0.003	0.003	0.003
Cadmium	0.33					0.43	0.22	0.20	0.18
Chromium	0.03					0.24	0.14	0.14	0.11
Copper	0.11					0.15	0.11	0.11	0.08
									7.0
									8.2
									220
									140

Table 2. Forecasts based on biological measurements and mathematical model

	Orange County Station B0-B5					Los Angeles County Station 6C-3C					
	Natural Back- ground range	Pre Change 1977	Start 1983	1 yr. 1984	5 yr. 1988	1993	Pre Change	Start 1983	1 yr. 1984	5 yr. 1988	Eventual 1993
% Organic carbon (large particles removed)	0.5-2.0	1.7	1.8	1.5	1.3	1.3	12.6	12.6	11.0	8.0	6.5
Copper ppm	2.8-40.0	60	65	40	22	21.2			10.5	7.5	6.0
DDT ppm	0	<0.05					43	8.5	7.1	4.3	1.0
Infaunal Index total lineal distance to background level (both sides of pipe)	75-80+	8km	8km		<0.5		48km	48km			14 km
Solids discharge Metric tons/yr		25,000	(32,300) 8,940	8,940	8,940		13,800	19,900			
Excess stan- ding crop of benthic organisms metric tons	70-100 g/m ²	549	848	280	110	89	13,392	13,392	5,000	600	450
Liver somatic index (Dover sole)	0.7-1.0	1.5					2.2-2.6			>1.5	
% Prevalence of fin erosion in Dover sole	0						45	16	14	9	

FORECASTS

- 1) Changes in the bottom near Whites Point and Orange County as determined by a mathematical model using data on organic carbon, DDT, and copper.
Dr. Terry Hendricks

We have attempted to forecast the changes that may be expected to occur in the sediments around the Whites Point and Orange County outfalls (as the result of changing effluent quality) by developing a mathematical model to simulate physical processes which may affect the movement and fates of effluent and natural particulates. The results of this model indicate that the maximum concentrations of organic carbon in the surface sediments at these two sites in 1977 are 12.6 percent at Whites Point and 1.7 percent at Orange County. The maximum concentration at Whites Point is not predicted to increase during the period from 1977 to 1983. At Orange County, there will be a slight increase to 1.8 percent, reflecting the increase in flow to 215 MGD by that date. These predictions assume that the effluent characteristics existing in 1976 will continue unchanged until 1983.

Following conversion to the baseline alternative treatment in 1983, the maximum concentrations of organic carbon in the surface sediments (the top 1 to 2 gm/cm² of material) at Whites Point will decline to 11 percent in 1984; 8 percent in 1988; and 6.5 percent in 1993. The final (equilibrium) value will occur later and be about 4.7 percent. The areal patterns of the organic carbon concentrations in the surface sediments around the Whites Point outfall (with an "idealized" coast) for 1983, 1984, and 1988 are shown in Figures 1 a, b, c. The corresponding maximum

organic carbon concentrations at Orange County are 1.5 percent (1984) and 1.3 percent (188, 1993, equilibrium).

If particle size is reduced by future treatment techniques, particles will settle slower as no increased aggregation also results from the treatment. If the settling velocity distribution (SVD) is reduced (hypothesized curve, Figure 2), the area over which the particles are dispersed prior to reaching the bottom will increase. Additional processing of suspended solids in the future (full secondary treatment) likely will reduce the SVD compared to previous measurements which have been made.

For the Whites Point area we made a simulation for a hypothetical distribution of settling velocities (see Figure 2) which corresponds to a removal of most of the rapidly settling particulates. This change had only a small effect on the rate of decrease, but reduced the equilibrium concentration for organic carbon from 4.7 percent to 2.8 percent. Most of the effluent particles which settle near to (within 10 km) an outfall have settling velocities between 1 and 10^{-3} cm/sec.

The suspended solids which are discharged are assumed not to change mass through such processes as dissolution, which would lower particle mass, or sorption, which would increase particle mass. Also, biological scavenging and/or particle agglomeration will result in fewer numbers of larger, more massive particles. The extent to which these processes occur is not known, but the assumption is probably a reasonable first approximation. Also, previous measurements of SVD have not duplicated realistically the proper dilution or discharge conditions, the nature of

effluent (primary/secondary ratio), or the effect of natural particles in the ocean. Most previous measurements show SVD which are too fast.

Predictions of the total DDT (at Whites Point) and copper (at Orange County) concentrations in the sediments were also carried out concurrently with the organic carbon simulations. The peak total DDT concentration in the surface sediments at Whites Point is estimated to be between 340 and 400 mg/dry kg, depending on the assumptions made about the concentration on effluent particulates prior to 1970. This peak value would have occurred at station 6C or 7C, at the 60 m depth, sometime between 1965 and 1970. After source control was initiated in 1970, the surface concentrations are predicted to decline to about 43 mg/dry kg¹ by 1977.

By 1983, at stations 6C-7C, the surface concentrations are predicted to decline to 8.5 mg/dry kg. The highest surface concentration of total DDT, however, is no longer at the 60 m depth, but at the 275 m (max. model depth) where the concentration at stations 6-7 would be about 64 mg/dry kg. By 1993, the surface sediment values at the 60 m and 275 m depths would be 1.0 and 15 mg/dry kg, respectively, based on a background concentration of 0 mg/dry kg. These declines in surface organic carbon and DDT are illustrated in Figures 3 a,b.

1 Neglecting the possible effects of a transient population of Listriolobus pelodes which may have resulted in a decreased rate of reduction between 1975 and 1977. As a result, the surface concentrations may occur ~2 years later than predicted.

It might be noted that the reductions in both the organic carbon and total DDT concentration in the surface sediments occur primarily as the result of burial rather than by removal from the outfall area. For example, the profiles of organic carbon and DDT in the sediments at Whites Point stations 6C- 7C, for the years 1970, 1983, and 1993 are shown in Figures 4 a, b, c. Because relatively high concentrations still exist below the surface, the occurrence of large-amplitude, long-period swell for an extended period of time, or the appearance of benthic organisms which mix the sediments to considerable depth, could substantially alter the rate of change (but not the equilibrium values).

Figures 5 a, b show the change in time of the surface sediment concentrations of organic carbon and copper at the Orange County outfall station B-0 (upcoast end of the diffuser).

The conceptual approach to the predictive model is illustrated in Figure 6, which represents a typical onshore/offshore transect in the outfall area. The wastefield moves upcoast and downcoast under the influence of the ocean currents, with the alongshore distribution of settled effluent particulates assumed to be adequately predicted by the earlier SCCWRP dispersion model (SCCWRP, 1975).

The effluent particulates are mixed with natural particulates from two sources-- (1) deposition from the water column, and (2) deposition of resuspended particulates from adjacent areas. We assume that the speeds required to resuspend the sediments depend on the organic carbon (or volatile solids) content of the

sediments, as reported in SCCWRP, 1976. It is further assumed that the source of near-bottom currents of sufficient strength to produce the resuspension is the passage of surface swells through the area, hence the likelihood of resuspension at a particular location will depend on the water depth as well as the amplitude and period of the swell. We hypothesized that the average amount of material resuspended during a year could be estimated by the fraction of that time that the near-bottom currents exceed the resuspension speed.

Limited current measurements near the bottom indicate that the weaker, but more persistent portion of the currents, which are responsible for the actual transport of the resuspended material, have a substantial offshore component. Since the concentration gradients of effluent-related materials in the sediments are much greater in the transverse direction than in the along-shore direction, it was assumed that the results of reworking of the sediments would be manifested primarily in the transverse direction and would result in a net offshore movement of the resuspended material.

As effluent-related, natural, and resuspended particulates are deposited, it was assumed that they are uniformly mixed with a portion of the surface sediments by benthic animals.

The concentration and deposition of effluent-influenced sediments under the combined influences of deposition and resuspension is then obtained by calculating the changes in adjacent cells along the transect, stepping along the transect from inshore to offshore. These calculations are repeatedly carried

out at sub-year intervals for the past and projected period of operation of the outfall.

The model is based on the hypothesis that the dilution of effluent particulates occur primarily as the result of resuspension of sediments by wave action, rather than by natural deposition or by the aggregation of natural and effluent particulates (these latter mechanisms do not appear to adequately describe the observed distributions or concentrations). Input data for the model was obtained from studies on organic carbon in the Whites Point effluent and sediments (Myers, 1974), a stochastic model of particulate sedimentations (SCCWRP, 1975), wave data collected off Torrey Pines beach (Pawka, 1976) and the history of the effluent quality and flow rates over the period of operation of the deep (200') outfalls. The model was developed for the Whites Point outfall area and then tested by comparing the observed and predicted organic carbon and DDT concentrations in the surface sediments, the rate of change in the DDT concentration of these sediments after source control was initiated and the vertical distribution of organic carbon in the sediments at one station (6C) near the Whites Point 90" outfall. The model prediction agreed remarkably well with the observed values (Figures 7-8).

Since equivalent input data was not available to adapt the model to the Orange County outfall, the model parameters were adjusted so that the model approximately reproduced the presently observed conditions; the calculations were then carried forward for the forecast period. Fortunately, each of the parameter changes was qualitatively in accord with the expected change

(i.e., the parameter increased or decreased as anticipated). Since the Whites Point simulation is derived from a more complete data base the predictions for this area should be more accurate than for Orange County.

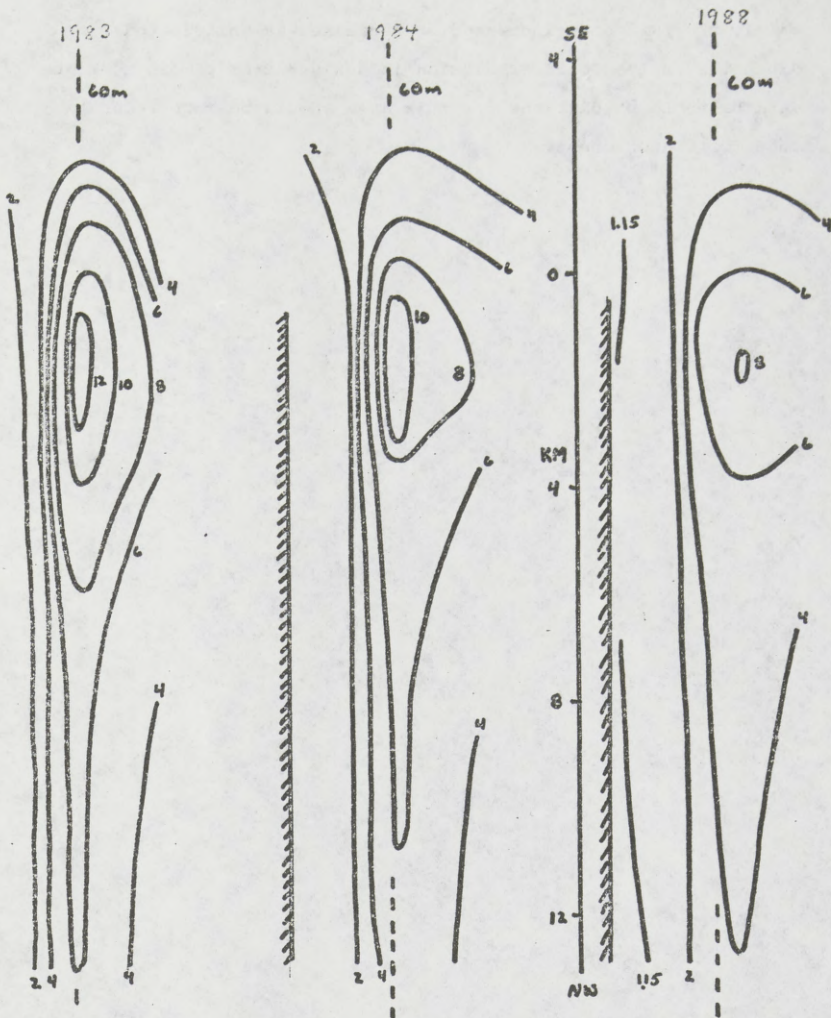


Figure 1. Contours of organic carbon concentrations in the surface sediments (upper 1-2 gm/cm² of material) around the Whites Point outfall for the years 1983(a); 1984(b); and 1988(c). The values are in percent and the coast and depth contours have been approximated by straight lines.

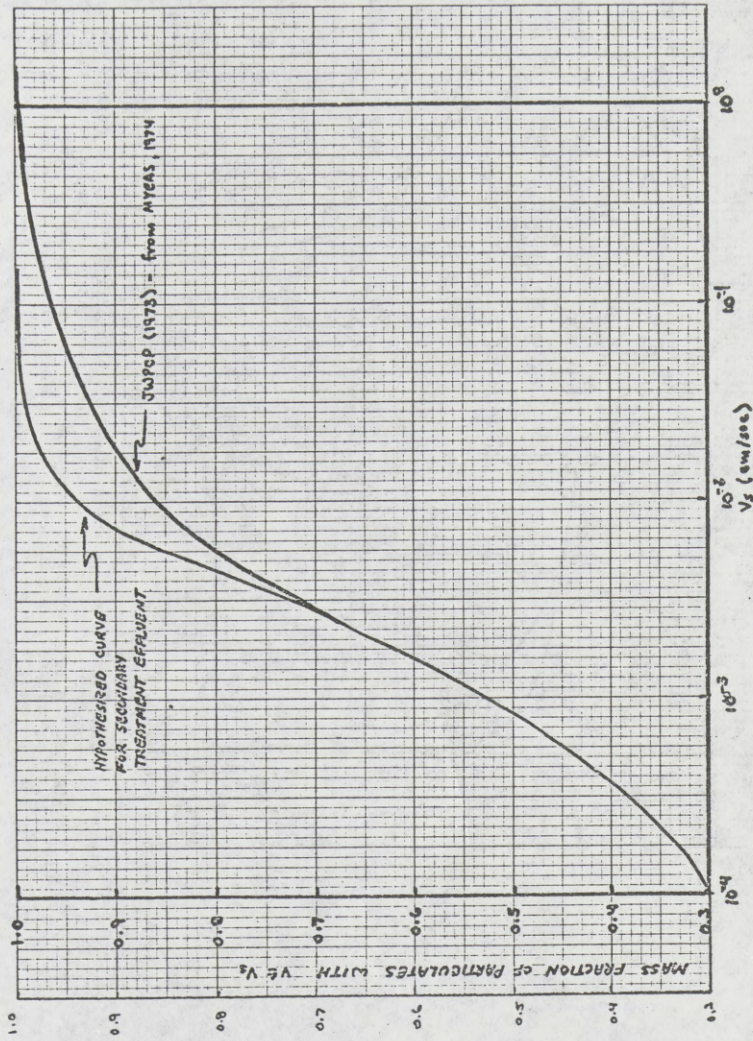


Figure 2. Distribution of Settling Velocities used in the Mathematical Model. The lower curve is from Myers (1974) measurements on a 1:1 sea water dilution of 1973 Whites Point effluent. The upper curve is a possible distribution after improved treatment.

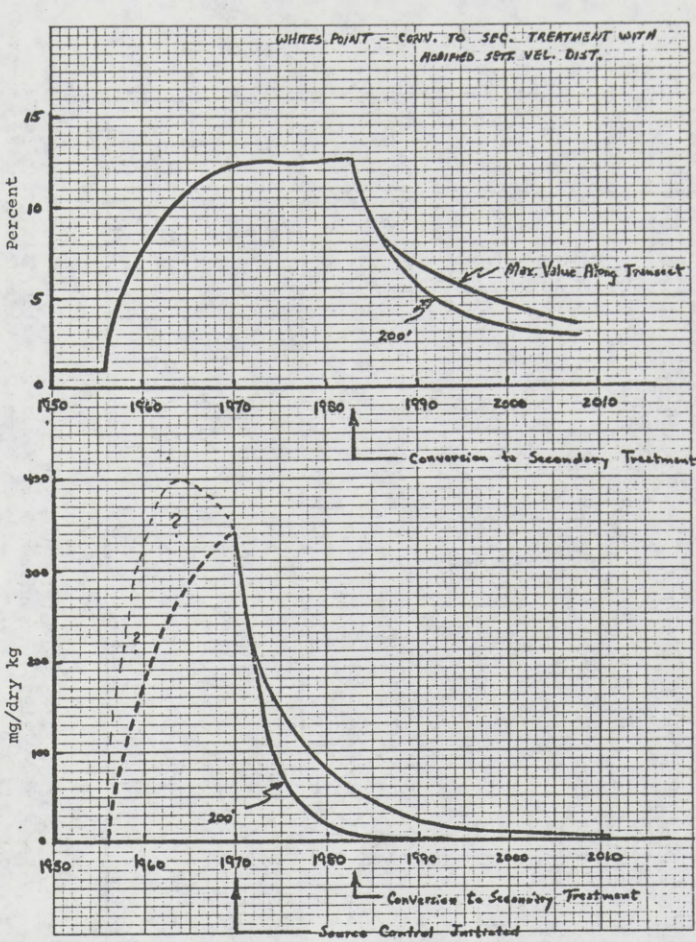


Figure 3. Time History of Surface Sediment Concentration of Organic Carbon (a) and total DDT (b) from 1950 to 2010. The lower curve is the value at station 6C - 7C at the 60 m depth; the upper curve, the max. value anywhere along this onshore/offshore transect. The effects from the shorter, earlier outfalls are neglected.

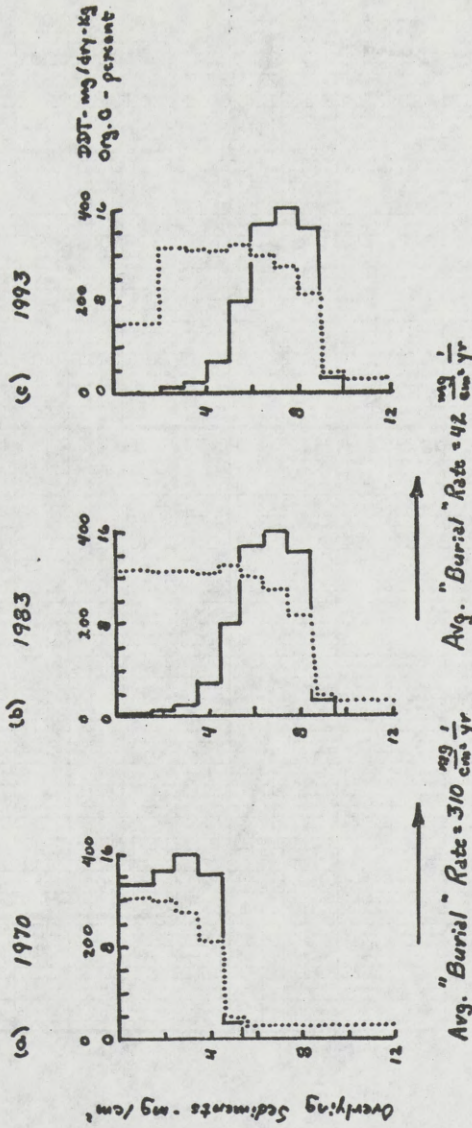


Figure 4. Vertical profiles of organic carbon (percent) and DDT (mg/dry kg) in the Whites Point sediments at stations 6C - 7C. The solid line represents DDT and the dotted line, organic carbon. The DDT values are for the assumption of a constant mass emission rate of 272 kg/day from 1956 to 1970. The depth is measured in terms of the mass of overlying material, i.e. gm/cm^2 . At an organic carbon concentration of about 12%, each gm/cm^2 corresponds to about 5 cm; at 1%, about 1 cm.

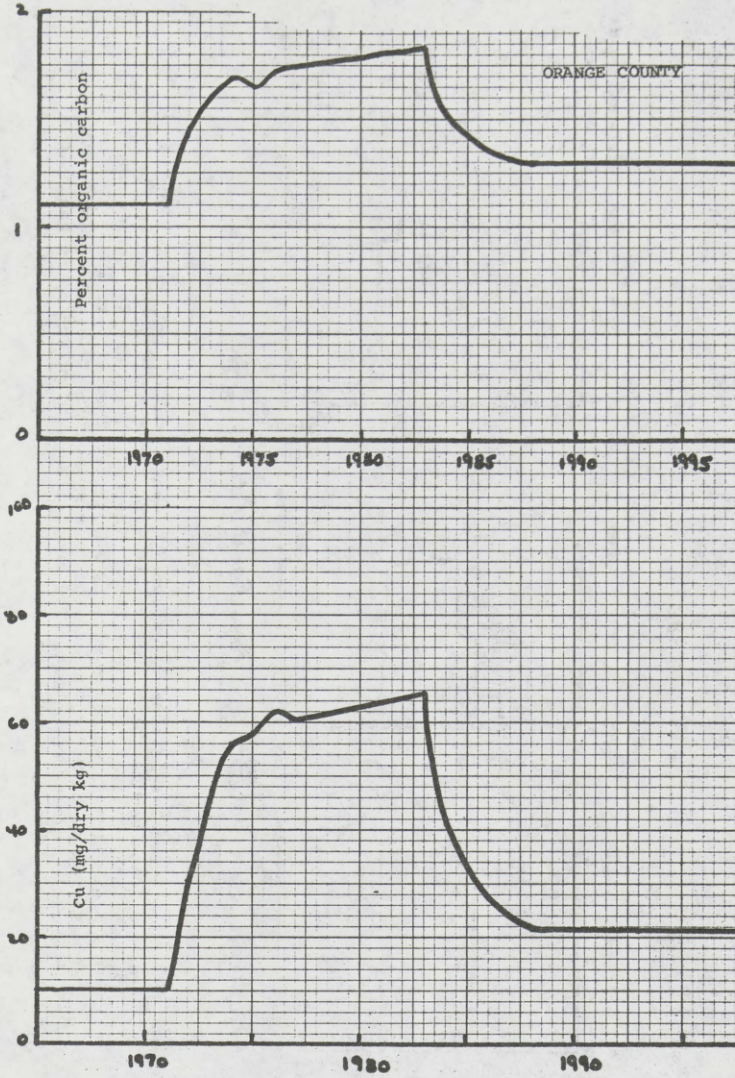


Figure 5. Time History of Surface Sediment Concentration of Organic Carbon (a) and copper (b) at station B-0 at the Orange Co. outfall. Organic carbon is expressed in percent; copper in mg/dry kg.

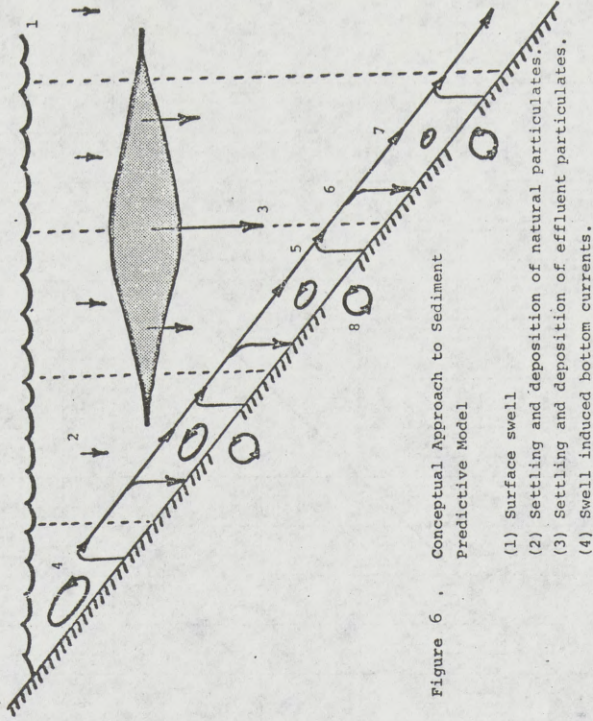


Figure 6 . Conceptual Approach to Sediment Predictive Model

- (1) Surface swell
- (2) Settling and deposition of natural particulates.
- (3) Settling and deposition of effluent particulates.
- (4) Swell induced bottom currents.
- (5) Resuspension of bottom sediments.
- (6) Deposition of resuspended sediments.
- (7) Net offshore movement of resuspended sediments.
- (8) Bioturbation of near-surface sediments.

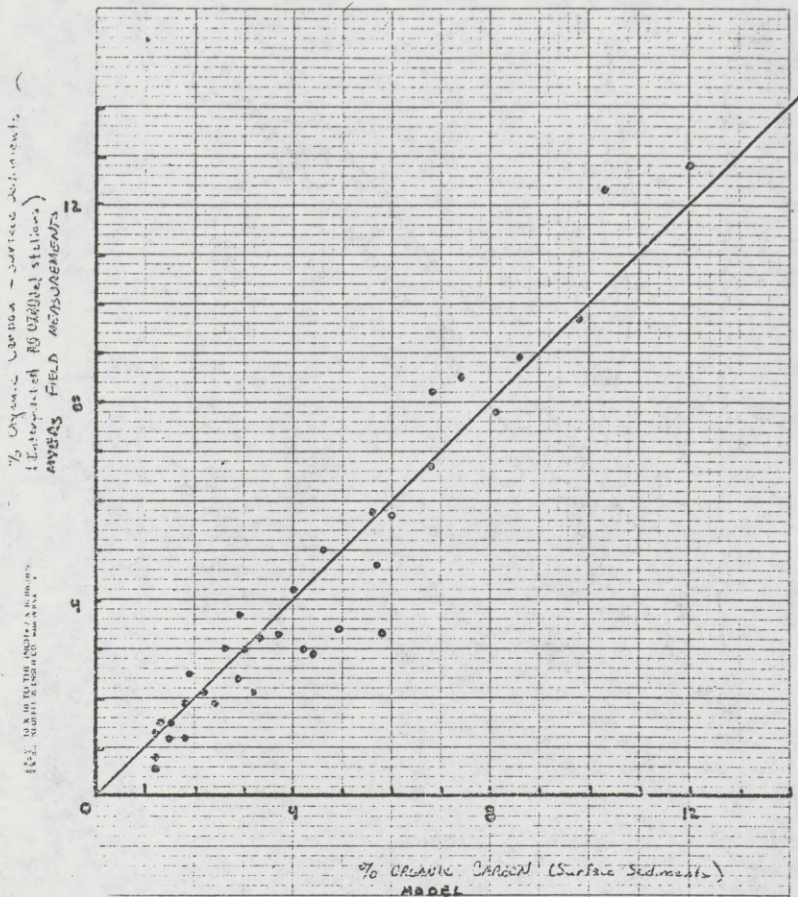


Figure 7. Comparison of model predicted values and Meyer's measurements of organic carbon in surface sediments.

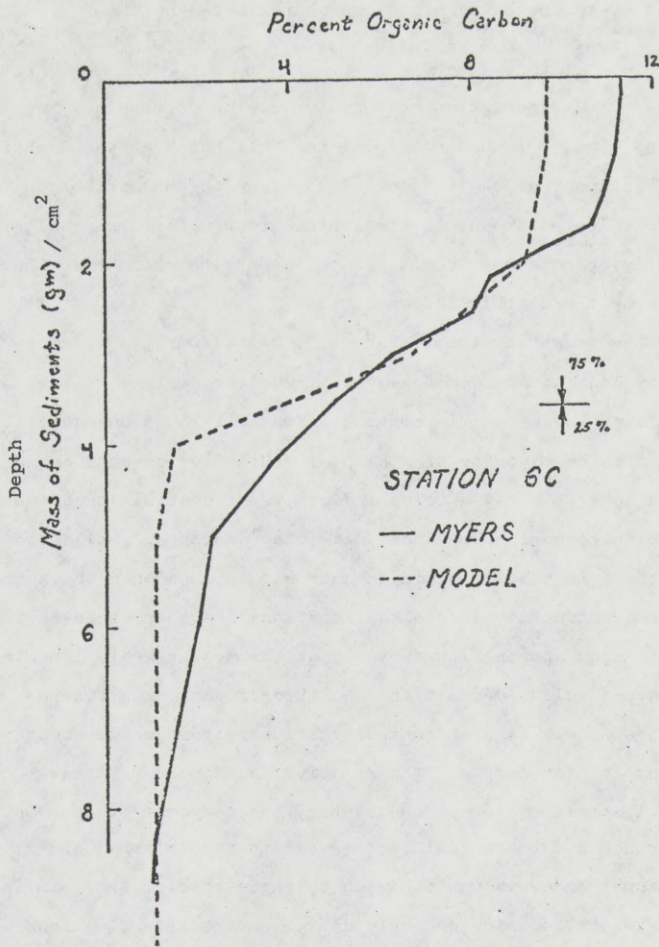


Figure 8. Comparison of model predicted values and Myer's measurements of organic carbon with depth.

2. Changes in indicator organisms as reflected by the
Infaunal Index. Jack Word

This is a description of a newly developed technique for assessing changes in bottom conditions. It has been shown that benthic infauna respond to each of the four LA/OMA discharges. Therefore, if the amount of these discharged materials is significantly changed one should see corresponding changes in the response by the benthic infauna.

We are measuring these changes by using four graded categories of consistent response by 25 invertebrate taxa (Table 1a). (The abundance of these taxa in control or outfall locations generally account for the majority of a sample). Briefly, on approaching an outfall certain key species indicative of control locations begin to decrease in abundance until they disappear, while two other groups of species begin to increase in abundance above the normal concentrations in control locations and then decrease in abundance upon approaching those locations most heavily impacted by increased solids deposition. At these locations a fourth group of species, rare at control stations, increase in abundance to extremely high levels. The relative abundances of these groups of species allow us to quantify the response at each outfall through a mathematical formula called the Infaunal Index. The Infaunal Index values depicted by these species show similar trends at each location and only differ in the affected areas. We assume that waste particulates are the primary cause of these patterns and that we can effectively compare the amount of solids discharged to the distances of similar Infaunal Index values. We

assume that these changes are primarily related to properties of these particulates other than the toxicity created by the attached chlorinated hydrocarbons, metals, viruses, and bacteria. This then allows us to make direct extrapolations for a larger outfall discharging a decreased solids load by comparisons with an outfall discharging at that load now.

The Present Situation

The present situation in the Los Angeles-Orange County areas have several complications that must be accounted for prior to making our predictions. First our calculations show that "control" locations are not present within the area from just north of the center of Santa Monica Bay to just south of Newport Bay (see chart, Figure 1). This area appears to be affected by some broader scale phenomenon in addition to the outfall discharges. Some of the possible causes may be the Los Angeles-Long Beach Harbors, shipping activities, Newport Bay and Harbor area fallout in addition to the outfalls. Furthermore the impacts of the Los Angeles County and Los Angeles City outfalls appear to blend together in the southern end of Santa Monica Bay. A third problem, is the presence of a large, apparently transient invertebrate (Listriolobus pelodes) whose patterns of abundance off Palos Verdes since the winter of 1973 has paralleled many improvements in the benthos especially the decrease of H_2S smelling sediment, changes in certain faunal communities and Faunal Index numbers. It is very likely that Listriolobus pelodes (an animal now disappearing from Palos Verdes) played a very significant but only transient part

in reaeration of the sediment through extensive bioturbation allowing more sensitive species to colonize the area for what may only be a brief period of time.

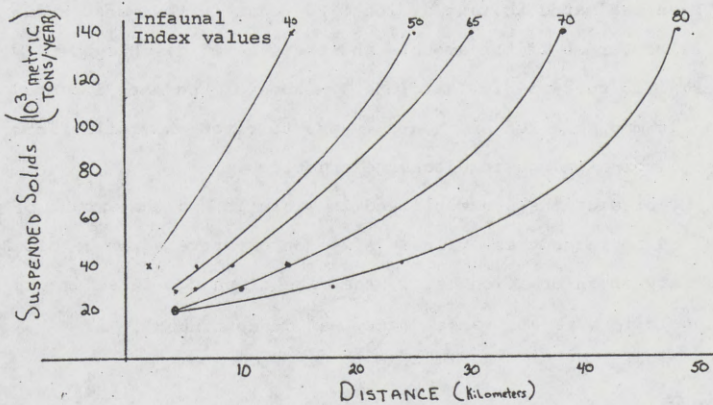
Since 1973 the total amounts of suspended solids discharged each year has risen slightly from 128,000 metric tons/year to 138,000 metric tons/year at the end of 1976. For the purpose of this report it is assumed that prior to the recruitment episode of Listriolobus pelodes, the impact on bottom conditions are the least that would be expected by discharging in excess of 130,000 metric tons/year. The Faunal Index for these conditions (Summer, 1973) was calculated and these values are what will be used as the present basis for this particular area. At no location in the entire sampling grid was a faunal index value of greater than 60 obtained. However, sampling done during 1957(58) showed Faunal Index values in the vicinity of 80 at the northern end of the sampling grid. Recent information (60 m synoptic survey) have shown that natural control locations have a Faunal Index in excess of 80. At depths of 60 m a Faunal Index value indicative of control levels was not found upcoast until a region offshore from Venice, a distance of approximately 4 nautical miles from the 5-mile discharge in Santa Monica Bay. In Santa Monica Bay it is difficult to tell where the affects of one discharge ends and the other begins; however, it does appear that JWPCP's discharge has affects within this bay.

The effects around the discharge location off Huntington Beach are much less extensive. However, the effects are added to a benthos already impacted by what is believed to be a

large-scale urban impact in San Pedro Bay. Twenty years ago (1957/58) this area was typified by Infaunal Index values in the same range as now seen 2-3 km upcoast from the Orange County discharge. It has therefore not been feasible to distinguish the maximum impact around this discharge from the overall lower index values in this area. We can however distinguish the impacts that are nearer the discharge location.

Urban effects were looked for around the San Diego-Point Loma area by also comparing present data to those collected in 1957(58). Control values were seen at the discharge location prior to the pipe being placed there and comparable stations are seen to be affected 2.5 - 3.0 km upcoast from the discharge location, while stations unaffected by the outfall remained the same.

Forecast Based upon the previous assumptions a prediction can be made by comparing the discharge of suspended solids to the lineal distance (both upcoast and downcoast) of impact at a certain Infaunal Index value of the following figure.



Based upon this figure, when the discharge rate off Palos Verdes is 19,900 metric tons/year rather than 138,900 metric tons/year and if the settling velocities are as they are now, the Infaunal Index score of 80 (Control values) would be found at 5 km (lineal distance) rather than the present predicted value of 48 km (lineal distance). If the settling rates of particulates are as estimated, these values are probably fairly good predictions of the distance of various levels of impact starting at a time without any previous accumulations of deposited material or at some point in the future when these accumulations are buried by natural sediments or moved away by currents. We have observed (60 meter survey) that stations with a high COD chemical oxygen demand in the sediment buried beneath a 1-2 cm layer of background COD values show a natural or control community with Infaunal Index values in excess of 80. It has therefore been assumed that burial of contaminated outfall material by natural deposits to a depth of 2 cm will result in virtual exclusion of this deeper material from affecting control communities of organisms. The length of time required to obtain this deposition is unknown but has been estimated to take at least 20 years in the worst areas off Palos Verdes if the amounts and the size of discharged material is decreased. Therefore, in some of the more impacted areas it may take longer than 10 years to reach an equilibrium point after a change in discharge practices.

My predictions are contained in Table 1b and the amount of time required to reach these values is my conservative estimate based upon a variety of information (e.g., the rate of change in sediments after the one mile pipe at Orange County was discontinued).

TABLE 1a
TAXA FOR CALCULATION OF FAUNAL INDEX NUMBERS

Group 1 - Suspension Feeders (pristine area)	
<u>Phoronis</u> spp.	Phoronid
<u>Amphiodia</u> spp.	Brittle star
<u>Sthenelenella uniformis</u>	Worm
<u>Ampelisca</u> spp.	Amphipod
<u>Paraphoxus</u> spp.	"
<u>Heterophoxus oculatus</u>	"
<u>Metaphoxus frequens</u>	"
Group 2 - Mixture of Feeding Strategies	
<u>Mediomastus</u> spp.	Worm
<u>Myriochele</u> spp.	"
<u>Tharyx</u> spp.	"
<u>Axinopsida serricata</u>	Clam
<u>Mysella</u> spp.	"
<u>Photis</u> spp.	Amphipod
<u>Euphilomedes</u>	Ostracod
Group 3 - Deposit Feeders, mainly molluscs	
<u>Parvilucina tenuisculpta</u>	Clam
<u>Macoma carlottensis</u>	"
<u>Bittium</u> spp.	Gastropod
<u>Spiochaetopterus costarum</u>	Worm
Group 4 - Deposit Feeders, mainly worms (outfall area)	
<u>Armandia bioculata</u>	Worm
<u>Shistomerincois longicornis</u> (= <u>Stauronereis rudolphi</u>)	"
<u>Ophryotrocha</u> sp.	"
<u>Oligochaeta</u> , UI	"
<u>Capitella capitata</u>	"
<u>Dorvilleidae</u> , UI	"
<u>Stenothoidae</u> , UI	Amphipod
<u>Solemya panamensis</u>	Clam

$$\text{Infaunal Index} = 100 - 33.3 \left(\frac{n_2 + 2n_3 + 3n_4}{n_1 + n_2 + n_3 + n_4} \right)$$

where n = the number of animals counted in a sample
from the appropriate group.

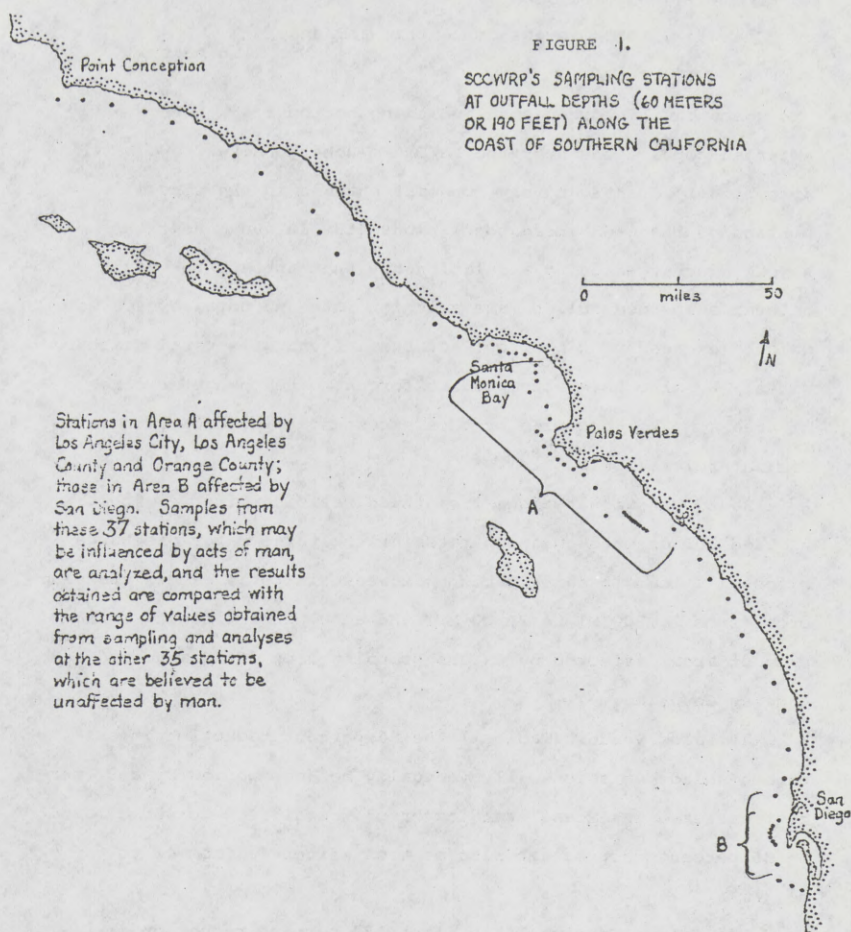
(Extracted from a forthcoming paper by Jack Q. Word)

Table 1b. Distances to normal Infaunal Index numbers.

	Background value	Present (lineal Distance) Distance to background**	Predicted Distance to background (after Switch)	Time
Point Loma	80+	8 km	< 500 m	within 5 years
Orange County	75	8 km	< 500 m	within 5 years
JWPCP	80	48 km*	5 km	greater than 20 years
Hyperion 5-mile	80+	24 km	< 1 km	within 10 years

* extrapolated

** in both directions (tip to tip)



3. Changes in the biomass of benthic infauna.

Dr. Alan Mearns

Some benthic organisms, including bottom fish, have greatly enlarged populations near the LA/OMA discharge sites. We have attempted to quantitatively forecast changes in the size of a portion of these enhanced populations (the infauna) near the LA/OMA discharges using a relationship that appears to exist between suspended solids mass emission rate and total excess wet weight (excess standing crop) of the infauna at several discharge sites. We also have attempted to forecast the change in size of area (sq. km) occupied by this excess standing crop using a similar relationship.

Based on calculations from these relationships we expect reduced solids mass emission rates at the three major discharge sites will lead to an 87 percent decrease in total excess standing crop (from 19,900 MT to 2,500 MT) and a 40 percent decrease in size of areas affected by excess standing crop off Orange and Los Angeles Counties.

At Palos Verdes (Table 1) the 86 percent reduction in suspended solids emission will eventually be accompanied by a 97 percent decrease in excess standing crop (from 13,400 to 450 MT) and an 85 percent decrease in size of area affected (from 41 to 6 sq. km).

Off Orange County (Table 1) the 72 percent reduction in solids emissions will be accompanied by a 90 percent decrease in excess standing crop (from 850 to 90 MT) and a 72 percent decrease in size of area occupied by that excess (from 11.1 sq km

Table 1. Changes in suspended solids mass emission rates, excess standing crop of infauna, and size of area affected by excess standing crop at four LA/OMA coastal discharge sites.

	Pre change (1975)	1983	1984	1988	Final
PALOS VERDES					
Solids, MER, MT/yr	138,000	138,000	19,900	19,900	19,900
Excess Standing Crop, MT.	13,390	13,392	5,000	600	450
Area Affected, sq. km	41	41	26	8	6
ORANGE COUNTY					
Solids, MER, MT/yr	25,200	32,300*	8,940	8,940	8,940
Excess Standing Crop, MT	550	848*	280	110	89
Area Affected, sq km	9.1	11.6	7	4	3.3
HYPERION 5-MILE					
Solids, MER, MT/yr	40,460	38,300	15,100	15,100	15,100
Excess Standing Crop, MT	4,660	4,661	2,700	1,000	914
Area Affected, sq km	23	23	17	10	9.2

* Projected suspended solids MER considerably larger than during 1975 (25,500 MT/yr) when standing crop actually measured.

projected for 1982 to 3.3 sq km projected for after 1988).

In Santa Monica Bay (Table 1) we project that the 61 percent reduction in solids mass emission rate at the 5-mile outfall will be accompanied by an 80 percent reduction in excess standing crop (from about 4700 to 900 MT) and a 60 percent reduction in size of area affected by excess biomass (from 23 to 9 sq km). There will be no measurable change in either size of excess standing crop or size of area affected near the Hyperion 7-mile outfall where we estimate an excess standing crop occurs over an area estimated to be under 11 sq km (Table 1).

Approach

Relation between Benthic Biomass and Suspended Solids Emissions

We arrived at these figures by carefully reexamining the relationship between excess benthic standing crop and solids mass emissions rates described in Task II (Section III.C.3. p. 148 and Figure III.C.3.g). Additional independent estimates of size of areas affected by high biomass were made by contouring past and more recent biomass (g/m^2) data from monitoring surveys. Median values of excess standing crop and size of areas influenced by that excess were plotted against suspended solids mass emission rates and best-fit regression lines generated for the log-log plots (Figures 1 and 2). Equations for the lines were transformed so that the percent decrease in excess standing crop and size of area affected could be calculated directly from actual recent measurements (this obviated reliance on the best

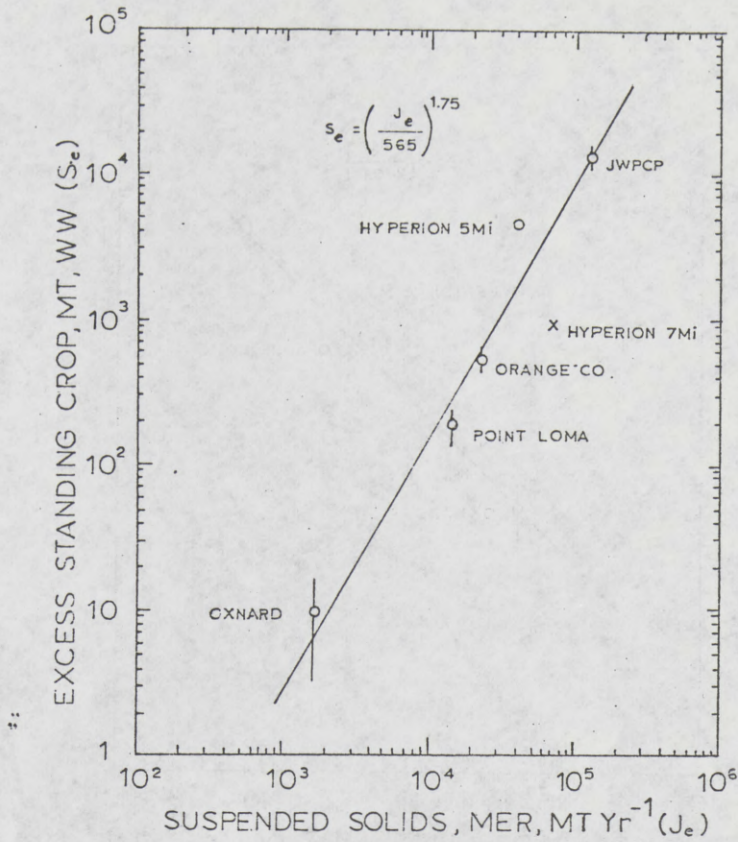


Figure 1. Relationship between suspended solids mass emission rates (J_e) and excess standing crop of benthic infauna (S_e) at six southern California ocean discharge sites. Open circle and bar represents median and range of estimates of standing crop; x represents standing crop near the Hyperion 7-mile sludge outfall (excluded from regression line).

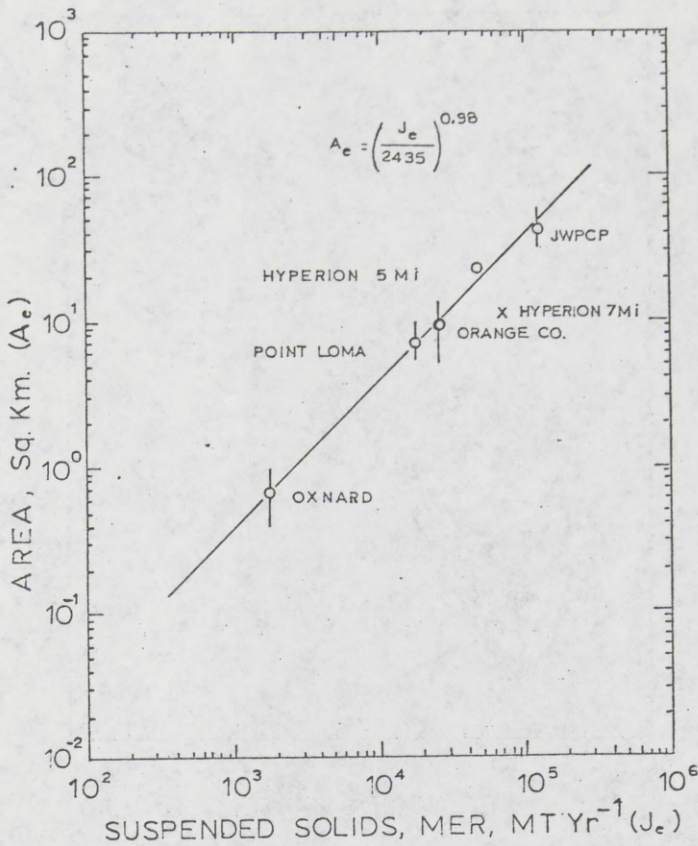


Figure 2. Relationship between suspended solids mass emission rates (J_e) and area occupied by excess standing crop (A_e) at six southern California ocean discharge sites. Open circle and bar represents median and range of estimates of area; x represents estimate of size of affected area near the Hyperion 7-mile sludge outfall (excluded from regression line).

fit line itself since it does not accurately forecast values that deviate from it substantially).

Past experience at an abandoned shallow water (20 m) outfall site (Orange County) suggested that the infauna can respond in a matter of months to termination of discharge. Recovery to normal diversity and abundance at that site was nearly completed within a year of termination of discharge. In deeper water, I postulate similar changes may take three times as long, i.e. that the infauna would be one-third of their way toward new equilibrium conditions at the end of the first year of the reduced emission rate and some 90% of the way (on a log basis) after five years. The central two columns in Table 1 cite the condition we expect after one year (1984) and five years (1988).

Assumptions and Uncertainties

Standing crop is simply a convenient way to express estimates of total population size of macrobenthic invertebrates in a given area in terms of wet weight. The term excess standing crop means an amount that occurs in excess of what would normally be expected.

Excess standing crops of macrobenthic invertebrates occur near large municipal discharge sites. The major assumption in this analysis is that this excess has been produced directly or indirectly by a assimilation of a portion of the discharged material, (suspended solids) reaching the bottom within the area surveyed. A second assumption is that there is a direct quantitative

relationship between the amount of solids discharged and the amount of excess macrobenthic biomass produced (such as suggested in Figures 1 and 2). A third assumption is that the standing crop can be adequately estimated by calculation from measurements of benthic biomass (g/m^2) made at a number of stations surrounding a discharge, and that existing data includes measurements of both normal background biomass as well as an equitable sampling of the area where abnormally high biomass occurs.

The uncertainties in this analysis are several fold. First, it is possible that the increased infauna is deriving its nutrition directly or indirectly from sources other than discharged suspended solids (for example, dissolved sewage-origin materials aggregating with natural oceanic material). If so, causative materials may not be removed through reduction in waste solids and the changes in the infauna will be less than projected.

Only a few species contribute to most of the excess standing crops, including several species of clams (e.g., Parvilucina tenuisculpta) and, off Palos Verdes, the echiuroid Listriolobus peloides. Shells are included in the excess but should not alter the results if their contribution is similar at all sites.

None of the past benthic surveys have been designed to estimate total population sizes; some grids have only a few sites useful for characterizing affected populations so the estimates of excess standing crops may be too high or too low (Hyperion 5- and 7-mile, Orange County and Oxnard outfalls). Other surveys indicate that the size of some benthic populations has been underestimated because they appear to extend beyond the confines of survey grids

(Palos Verdes, Orange County, Point Loma). In addition, effects of the Hyperion 5-mile and 7-mile outfalls appear to overlap; choice of a biological boundary between them was arbitrary, resulting in what we believe is an over-estimate of the size of area affected by the 7-mile sludge outfall.

Finally, despite what we consider an overestimate in the size of area affected by excess biomass at the 7-mile outfall, even the overestimate effect (984 MT excess standing crop produced by 56,000 MT, Table 1, bottom column 1) is far below what is expected from the regression line calculated for the other five sites used (Figures 1 and 2). The 7-mile sludge has an extremely low ratio of BOD to suspended solids concentration (0.24) compared to other outfalls (0.8 to 2.5). One explanation may be that the nutrient value of solids from this sludge is too low to produce the effect expected in the basis of solids alone or that the material settles too quickly and buries the molluscs which are only slightly mobile.

4. Changes in epibenthic Invertebrates.

Jack Word

A number of large invertebrates form conspicuous and important assemblages on the soft bottom areas of the mainland shelf. Populations of certain types of trawl captured invertebrates have been affected by the LA/OMA discharges. In general, those species that are increased in abundance near outfall sites have been studied more and are better understood than those species avoiding the sites. Thus our predictions will be confined to those species which are better understood but, it should be kept in mind that not all species will respond as indicated.

The species selected for this analysis are generally large, mobile, and fairly long lived. The age at which a species matures and its longevity are important but relatively unknown parameters that will definitely affect the rate of their response to changes in discharge practices. This important parameter and the hypothesis that the species selected for study will not respond to changes in discharge practices until after the infauna has been modified are prerequisites for determining the rate of their change in abundance. The abundance of five selected species of invertebrates were determined at control locations and compared to the stations at each outfall where they were most abundant. Changes in patterns of the infauna after a major event (e.g., storms, cessation of discharge, and disappearance of a species which controlled physical/chemical parameters in the sediments) have taken 3 months to one year before becoming observable. I have therefore assumed conservatively that there

will be no change at the end of one year after the initiation of changes in discharge practices. Based upon the theoretical depositional model made by T. Hendricks I am assuming that after 10-20 years the present sediments will be buried to a depth of 2 cm at each of the outfall areas. At this depth in background sediments we have found (60 meter survey station C31) that contaminated materials in deeper sediments do not seem to affect the communities of infauna dwelling there and we assume it will also not affect the larger trawl-caught invertebrates.

Therefore, after 10 years of reduced discharge I have assumed that the surface sediments will primarily be of this newer type and not a combination of the older sediments and the new. I am also assuming that this material can be considered roughly the same as that which is coming from a pipe discharging at an equivalent rate (e.g., no significant change in the settling rates of particulates).

The predictions are contained in Table 1 and are educated guesses based upon extensive trawling near and far away from outfalls. In general the abundance of the species selected will decrease as the amount of discharged material decreases. However, the abundances of certain of these species will increase off Palos Verdes while others will decrease. I believe the reason for this difference off Palos Verdes is that there has either been an excessive accumulation of organic material in the sediments or that the absence of echinoderms is due to some toxicant specific to Palos Verdes (e.g., DDT). Therefore, as the present sediments or contaminants are buried beneath newer accumulations of less toxic materials depositing at a slower rate we should see an increase in the abundance of the discharge oriented species.

Predicted Response of Selected Major Trawl-caught Invertebrates
Abundance/10 minute Trawl (24' otter trawl)

	Control Abundance	LACOSAN			Hyperion			ORCOSAN		
		P*	1-yr	5-yr	10-yr	P	1-yr	5-yr	10-yr	P
<u>Pleurobranchaea</u> <u>californica</u> (Seahare)	1	95	N.C.**	40.	5	5	N.C.	3	2	<1
<u>Parastichopus</u> <u>californicus</u> (Sea Cucumber)	20	0	N.C.	10	25	60	N.C.	40	25	25
<u>Astropecten</u> <u>verrilli</u> (Sea Star)	<10	0	N.C.	5	20	550	N.C.	200	100	25
<u>Sicyonia ingentis</u> (Ridgeback Prawn)	25	600	N.C.	300	100	450	N.C.	200	100	100
<u>Lytechinus anamesus</u> (Sea Urchin)	<50	0	N.C.	50	100	400	N.C.	200	100	100

* P = Present

** N.C. = No Change

5. Changes in the abundance of bottom fish.

Dr. Alan Mearns

The abundance and variety of benthic fishes is different at LA/OMA outfall sites than away from them.

At depths of 35 to 200 meters, we expect there will be increased abundances of certain species within several years following reduction in solids emissions. Population of tongue sole (Symphurus atricauda), yellowchin sculpin (Icelinus quadriserratus), and Pacific sanddabs (Citharichthys sordidus) should increase off Palos Verdes and near the Hyperion outfalls. Relative abundances of speckled sanddabs (Citharichthys stigmaeus) will increase in shallower waters off Palos Verdes.

Within the same depth range there will be major (at least 90 percent) reduction in the abundance of Dover sole (Microstomus pacificus) off Palos Verdes and smaller reduction in catches of Dover sole and English sole (Parophrys vetulus) in Santa Monica Bay and off Orange County at stations closest to the outfalls within several years following reduction in solids emission. Decreased abundances will primarily reflect decreased survival of juvenile (Young-of-the-year) Dover sole off Palos Verdes.

Overall, abundances of bottom fish will decrease at all sites but the decreases will be difficult to measure off Orange County and in Santa Monica Bay. Year-to-year natural variations in recruitment and abundance of bottom fish will continue to mask long-term trends for most other species.

6. Changes in fish health (tumors, fin erosion, liver condition)
Marjorie Sherwood

Tumors

a. Skin Tumors in Flatfish

External tumors have been observed in local Dover sole (Microstomus pacificus) populations for many years. Unlike fin erosion, this tumor disease does not appear to be related to single municipal wastewater discharge sites or to other discrete sources of pollutants. Skin tumors are present in young Dover sole from a wide geographic area, which includes Baja and southern California, and the disease is quite similar to that which affects other flatfishes of the same family (Pleuronectidae) as far north as Bristol Bay, Alaska. The lack of association of the disease with specific waste discharge conditions coupled with its apparent relation to the life cycle of the Dover sole suggest that decreased solids mass emission rates will not reduce the prevalence of the disease in fish of a given age class. However, the prevalence of tumor-bearing fishes in trawl catches may decrease if the survival of young Dover sole decreases. As noted elsewhere, lower total abundances of Dover sole are forecast for Palos Verdes. Tumor-bearing Dover sole will continue to be found throughout the Bight.

b. Lip Tumors in White Croaker

White Croaker with lip papillomas were observed in Santa Monica Bay by Russell and Kotin 1957 and by the California Department of Fish and Game and the City of Los Angeles during the 1957-63 trawl surveys. The tumors were described as non-malignant and possibly a response to an environmental irritant.

The overall frequency of the disease in this species as reported by Russell and Kotin was 10 of 353 specimens in Santa Monica Bay and none of 1116 specimens at a control site 50 miles away. The location of the control site was not specified.

Since 1970, the overall prevalence of the disease calculated on an annual basis has been less than 1% in Santa Monica Bay and on the Palos Verdes shelf and less than 5% in San Pedro Bay. The southernmost reported occurrence of this condition was off Camp Pendleton in San Diego County.

White croaker often appear to congregate in the more shallow areas of waste discharge. In San Pedro Bay, the percentages of specimens with lip papillomas showed a similar magnitude and variability in surveys taken before and after a switch in depth of discharge from 20 to 60 m. Because of these data and the relatively wide coastal distribution of the condition, the lip papilloma disease does not appear to be related to the discharge of municipal wastewaters.

The lack of a definite association of this disease with waste discharges coupled with an apparent long-term decrease in prevalence unrelated to past mass emission rates of suspended solids, suggest that new reductions in solids will not result in changes in the prevalence of this disease.

Fin erosion

Present situation. Between 1972 and 1976, fin erosion was observed in at least 33 of 151 bottom fish species collected in southern California otter trawl surveys. The Dover sole, rex sole, slender sole, greenstriped rockfish, and vermilion rockfish were five of the most frequently affected species for which prevalences were highest on the Palos Verdes shelf. For example, 39% of the Dover sole on the shelf were affected while prevalences to the north and south were at least one order of magnitude lower--Santa Monica Bay (3.5%), south San Pedro Bay (2.0%), Dana Point (0.67%).

Prevalence data in conjunction with measurements of total DDT in tissues suggest that Dover sole with fin erosion collected near the Orange County discharge site and probably at locations further south were migrants from the Palos Verdes shelf. Less frequent monitoring data and close proximity to the area of high prevalence make it more difficult to determine the origin of Dover sole with eroded fins in Santa Monica Bay.

Prevalence data are influenced by migrations of larger specimens and by recruitment of smaller specimens. Although overall disease frequencies in Dover sole and rex sole on the Palos Verdes shelf appear to be decreasing, the disease is still developing in recently settled Dover sole, i.e. those less than 120 mm SL (Figures 1 and 2).

Fin erosion appears to be the result of exposure to contaminated sediments (Sherwood and Mearns, 1977). A recent comparison of trace contaminants in fishes with fin erosion from

Figure 1. Prevalence of fin erosion in Dover sole and rex sole from nine stations on the Palos Verdes shelf, 1972-77.

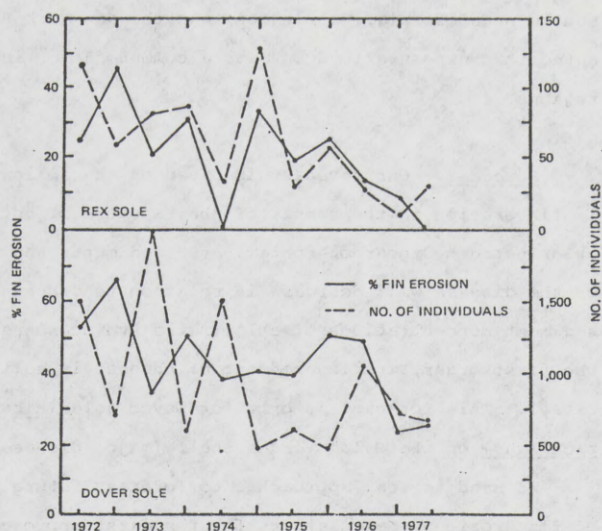
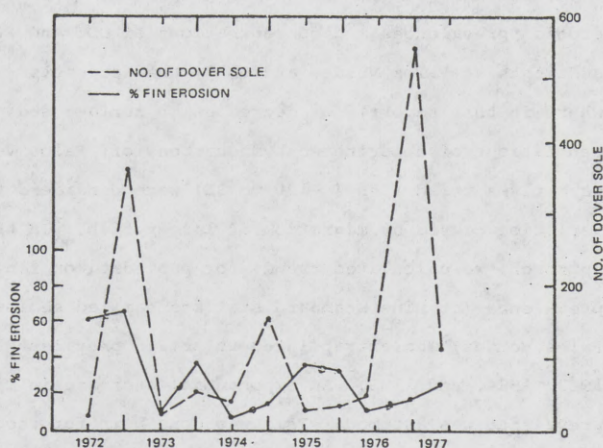


Figure 2. Prevalence of fin erosion in Dover sole less than 120 mm, SL, collected at nine stations on the Palos Verdes shelf, 1972-77.



southern California, Washington, and the New York Bight, indicated that exposure to PCB's was a common factor in all three regions.

Forecast. Our forecast is based on the following assumptions:

1) fin erosion is the result of the exposure of bottom fish to chlorinated hydrocarbon-contaminated sediments and 2) prevalence of the disease will decrease in relation to decreases in surface sediment concentrations of chlorinated hydrocarbons (which, for the first order, are independent of changes in solids emission rates). This forecast is only for Dover sole (Microstomus pacificus) on the Palos Verdes shelf (major disease epicenter).

We used several approaches to forecast future prevalences of fin erosion. Calculations for the first approach were based on 1) an extrapolation of the geographic relationship between fin erosion prevalences and concentrations of DDT and PCB in surface sediments at Palos Verdes and on 2) the forecasts (cited elsewhere in this report) for decreases in surface sediment concentrations of chlorinated hydrocarbons off Palos Verdes. Only recently-settled fish (<120 mm SL) were considered to reduce variation caused by migration of larger fish. In the second approach, we calculated trends for past data on fin erosion prevalence (at nine standard stations sampled semi-annually off Palos Verdes) and extrapolated to obtain prevalences expected in 1983, 1984, and 1988. An exponential decrease in fin erosion prevalence was assumed. This was done both for recently-settled individuals (<120 mm SL) and for all Dover sole in the catches.

As shown in Table 1, we expect prevalence of fin erosion in Dover sole off Palos Verdes to continue to decline, but we do not expect a zero incidence by 1988. In general, we believe that overall prevalence and prevalence in young fish will be less than 16 percent in 1983, less than 14 percent in 1984, and less than 9 percent in 1988, with or without the reduction in solids mass emission rates.

Table 1. Present (1975) and predicted levels of DDT and PCB's in surface sediments at Palos Verdes and of prevalence of fin erosion in Dover sole at Palos Verdes.

		1975	1983	1984	1988
Maximum values					
DDT	} in sediments mg/kg dry	130	59	54	36
PCB		10	4.5	4.1	2.7
% Fin erosion					
1. Fish < 120 mm SL					
	first method ¹	< 45%	< 8%	< 7%	< 5%
2. Fish < 120 mm SL					
	second method ²	26%	7%	6%	3%
3. All Sizes					
	second method ²	45%	16%	14%	9%

-
1. Estimated from known relationships between fin erosion prevalence and sediment DDT and PCB levels and forecasts of future concentrations (top two rows)
 2. Estimated by extrapolating trends observed in existing data on fin erosion prevalence at 9 stations sampled semi-annually at Palos Verdes, 1972-1977

Liver condition

Present situation. In fishes, increases in liver size and fat content, and changes in liver cell structure can be sensitive indicators of the presence of certain types of environmental contaminants. The degree of exposure is reflected both in the magnitude of the response in each individual as well as in the percentage of individuals affected.

Median values of liver-somatic index (the ratio of liver weight to body weight multiplied by 100) ranged from 0.7 - 1.0 in apparently healthy Dover sole from central California, Dana Point and Catalina Island to as high as 2.6 at one site off Palos Verdes; values in specimens without fin erosion from San Pedro and Santa Monica Bays were approximately 70 percent of that at Palos Verdes (Table 1). Liver size, fat content, and disruption of cell structure all appear to be related in this species (Pierce et al. 1977 and Sherwood et al. 1978).

Although liver size and fat content are affected by factors such as diet, reproductive condition, and disease, they also appear to change in relation to exposure to chlorinated hydrocarbons (Sherwood et al. 1978). A comparison of liver size and fat content with chlorinated hydrocarbons in muscle tissue of Dover sole from one station on the Palos Verdes shelf and one off Dana Point suggests that if total DDT in muscle is greater than 2 ppm, wet weight, and total PCB is greater than 0.1 ppm, wet weight, in Dover sole liver structure and function have probably

been altered.

Forecast. Our forecast of changes in liver condition is based on the following assumptions: 1. The relationship between chlorinated hydrocarbon levels and liver condition described by Sherwood et al. 1978 is a causal one, 2) other contaminants which affect liver condition, such as petroleum hydrocarbons, are insignificant with respect to chlorinated hydrocarbons in sediments near the outfalls; 3) chlorinated hydrocarbon forecasts are accurate; 4) migration of specimens from the Palos Verdes shelf will affect conditions to the north and south, and 4) recovery of fish health as measured by liver condition is independent of changes in mass emission rates of wastewater solids.

Using the following projected median values for chlorinated hydrocarbons (mg/kg wet weight) in the muscle tissue of Dover sole:

	1975	1983	1984	1988
DDT	11.0	5.0	4.5	3.0
PCB	1.1	0.50	0.45	0.30

we believe that in 1988 the median LSI value for Palos Verdes Dover sole will still be 1.5 or above -- higher than the values presently measured in Dana Point specimens. Median LSI values in Dover sole from San Pedro and Santa Monica Bays, should approach background levels.

Table 1 . Liver-somatic index (LSI) in Dover sole from central and southern California.

	Collection Date and Source	LSI median (range)	N	Range Specimen Total Weights (gm)
Monterey Bay	1975 G.Caillet, Moss Landing Marine Laboratory	0.7 (0.4-1.0)	15	74.7- 321.3
Santa Monica Bay	1972-74 SCCWRP	1.6 (0.5-2.2)	14	48.7- 291.3
Palos Verdes T0	1977 CSDLAC	1.4 (1.0-2.2)	10	44.8- 113.0
T4	1977 CSDLAC	2.3 (1.8-3.3)	10	45.9- 97.6
T3 no erosion	1976 SCCWRP	2.2 (0.9-3.0)	12	64.8- 100.0
T3 fin erosion	1976 SCCWRP	2.6 (1.6-3.8)	12	75.5- 101.4
San Pedro Bay				
no erosion	1972-74 SCCWRP	1.6 (0.7-2.9)	56	15.3- 273.0
fin erosion	1972-74 SCCWRP	2.4 (2.2-3.9)	9	31.9- 129.7
Dana Point	1976 SCCWRP	0.8 (0.6-1.2)	12	63.3- 106.8
Catalina Island	1972-74 SCCWRP	1.0 (0.2-1.6)	29	18.7- 111.4

7. Changes in water column and plankton (dissolved oxygen, phytoplankton, zooplankton) Dr. Alan Mearns

Dissolved Oxygen

Dissolved oxygen concentrations at any depth near LA/OMA discharge sites are not depressed by more than 10 percent background conditions. Existing depressions (which occur mainly near the bottom) may be due to entrainment of deeper water or, less likely, to effluent BOD (either dissolved or particulates) or phytoplankton, or uptake by bottom sediments.

Accordingly, we predict there will be no measurable increase in water column dissolved oxygen concentrations as a result of reduction in solids mass emission rates.

Phytoplankton

Phytoplankton as measured by chlorophyll and primary productivity is occasionally enhanced at all LA/OMA outfall sites. Existing evidence suggests that production is limited because the sewage plumes, which contain dissolved nitrogen required by phytoplankton, generally remain below the mixed layer most of the year; a second limiting factor may be the presence of materials toxic to phytoplankton in the JWPCP effluent.

Accordingly, we predict there will be no demonstrable decrease in phytoplankton at the three main dischargers. There may be increased blooms, however, if certain conditions are met. these include (1) reduction in effluent toxicity and (2) increased light penetration due to solids removal. The site most likely to meet these criteria is Palos Verdes, but a more penetrating

analysis of dissolved nitrogen emissions is required to quantify such a forecast.

To our knowledge no one has attempted to examine whether or not any relation exists between solids mass emission rates and occurrence or extent of red tides. Red tides will continue to occur naturally and unpredictable in years to come.

Zooplankton

Zooplankton abundance, as measured by zooplankton volumes, do not appear to be stimulated or decreased by present solids emissions; this lack of association is due in part to a lack of appropriate data. Zooplankton volumes were reduced significantly in Santa Monica Bay when emission were diverted from shallow nearshore discharge to deep water discharge.

Accordingly we predict there will be no further demonstrable decrease in zooplankton volumes when solids emissions are reduced. However, because zooplankton abundances may be related to phytoplankton production and because there is a possibility of increased phytoplankton growth at some sites, there may be slight increases in zooplankton abundances. Large year-to-year changes in zooplankton abundances and in zooplankton composition will continue to occur naturally and unpredictably.

8. Changes in sport and commercial fish catches.

Dr. Alan Mearns

Sportfish

Although sportfish landings near LA/OMA waste discharge sites are higher than elsewhere along the coast there is no conclusive evidence that the landings or the catch per unit effort or total landings are connected with solids emissions. Near outfalls, increased catches may be associated with the artificial habitats provided by the outfalls. Accordingly, we predict no measurable change in catch per unit effort or in total landings or sportfish associated with reduction in solids emission rates.

There is some evidence that sport catch composition is different near the LA/OMA discharge site than at more distant sites. Reductions in catches of white croaker (kingfish, Geryonemus lineatus) (and perhaps other bottom-feeding sportfish) may be expected off Palos Verdes and in Santa Monica Bay since the biomass of benthic organisms (their food) is predicted to decrease. As noted elsewhere, levels of trace metals in fin fish will not change, while there will be some reduction in metals in shellfish at Palos Verdes. Levels of chlorinated hydrocarbons in sportfish and shellfish will continue to decrease.

Sportfish catches and catch composition will continue to demonstrate year-to-year changes due to natural changes in water temperature, recruitment success and other large-scale factors that affect survival of fish.

Commercial fish

Commercial fish landings near LA/OMA discharges are higher than elsewhere along the coast, but there is no evidence that the catches are related to solids emission per se. Large schools of anchovy are occasionally observed near discharges off Palos Verdes and in Santa Monica Bay and observers speculate they may be feeding on sewage particles.

Accordingly, we predict there will be no measurable change in total commercial fish catches and landings that can be attributed to reduction in solids mass emission rates. Schools of anchovy, and of fish which feed on them (mackerel, bonito, barracuda, yellowtail queenfish) may occur less frequently near discharge sites off Palos Verdes and in Santa Monica Bay.

Commercial fish landings will continue to demonstrate year-to-year variations depending on natural events not connected with solids discharges. Sardines and Pacific mackerel may return in abundance, and anchovy decline, at some distant date depending on natural events and pelagic fishery management practices.

9. Changes in nearshore bacterial levels.

Henry Schafer

Implementation of secondary treatment under the baseline alternative will result in a one to two order of magnitude decrease in the number of coliform bacteria discharge through Hyperion's 5-mile outfall, JWPCP outfalls and the Orange County outfall, based on data from Morris, Mearns and Kim (Task II, Table IA2a and Hyperion monitoring data. This should cause a one to two order of magnitude drop in Most Probable Number (MPN) of bacteria in the nearshore and shore stations monitored by LA/OMA dischargers.

Large numbers of coliforms are present in effluents, however most concern and regulations are focused on the nearshore and shore areas.

Hyperion and Orange County do not chlorinate their effluents during normal operations so that changing to secondary treatment is assumed to reduce the nearshore and beach MPNs by one to two orders of magnitude.

L.A. County's JWPCP used about 2,000 tons of chlorine between June 1976 and June 1977 to successfully meet most state bacteria standards. Predicting bactericidal changes is however complicated by the assumed discharge of centrate (14 metric dry tons/day) with the effluent. If the centrate is concentrated with more than 1,500 mg/l solids the centrate will account for less than one percent of the flow. If JWPCP centrate has a similar concentration of bacteria as Hyperion's seven-mile outfall (6×10^7) it should not prevent a one to two orders of magnitude reduction in coliform bacteria.

Forecast of compliance with State bacteria standards.

1. Santa Monica Bay.

Offshore monitoring of Santa Monica at various depths up to 42 meters has shown little or no influence of the seven mile outfall on the water column bacteria. With little change predicted in flow or mass emissions the seven mile outfall is expected to continue to have little effect on the nearshore and beach bacteria counts.

With one exception, the Santa Monica Bay nearshore areas has consistently met all coliform standards. For example, only one station exceeded any standard during 1976. That station (beach station number 29.6) exceeded the requirement listed as # 2 (Table 1) fifteen percent of the time, however the Pico Blvd. storm drain is suspected as the source of bacterial contamination. Thus, there is little room for improving Santa Monica Bay's compliance record with State Regulations.

2. Orange County

Orange County Beach and nearshore waters usually meet state requirement, however, some shore stations do not regularly meet the requirement listed as # 5 on Table .

In 1976 all nearshore stations met state requirements except 10 or the twenty shore stations exceeded standard # 3, Table 1 in one to seven month of the year. The cause of this contamination has not been determined. However, if the present sewage discharge is the source and emissions were reduced by

a factor of 10 a maximum of four stations would have exceeded these limits and only one station (Station 0 next to the mouth of the Santa Ana River) would have exceeded the requirements for more than one month.

It is necessary to conduct a more extensive survey to determine what contribution, if any, the offshore outfall makes on these shore stations bacterial counts.

3. Palos Verdes

The Palos Verdes Peninsula has regularly met bacteric standards since about June 1976. Shore stations have met requirements while nearshore stations have exceeded standard # 2 Table 1 for one to two months by 1-2 percent. Presumably the present discharge is responsible for this contamination although discharges from Marineland and storm runoff have been shown to be sources of coliform bacteria.

If the baseline alternative reduces the coliform counts by a factor of ten all stations should comply with all standards. It would be difficult to predict how much chlorine could be reduced, since we do not know how chlorination affected these past measurements.

Chlorine can be reduced.

Uncertainties

Although other sources of coliform bacteria have been identified (storm drains, rivers, creeks, drainage channels, surface runoff, etc.) the extent to which these sources contaminate nearshore areas is uncertain.

Table 1. Summary of State Regional Water Quality Control Board's Standards for Most Probable Number (MPN) bacteria counts in the LA/OMA Region and the locations they specifically apply to.

Shore Stations

1. The median MPN shall be $\leq 70/100$ ml for any 6 months period.
Palos Verdes, Santa Monica, Orange County.
2. Not more than 10 percent of the samples shall have an MPN over $330(230)/100$ mls for a six month period. Palos Verdes, Santa Monica.
3. Not more than 10 percent of the samples shall have an MPN over $230/100$ mls in a thirty day period. Orange County.
4. Not more than 20 percent of the samples over $1,000/100$ ml in a thirty day period. Palos Verdes, Santa Monica, Orange County (3 stations).
5. No sample shall exceed $10,000/100$ ml when verified within 48 hours. Palos Verdes, Santa Monica Bay, Orange County.

Nearshore Stations

1. The median MPN shall be $\leq 70/100$ mls in a six month period.
Palos Verdes.
2. Not more than 10% of the samples shall be over $330/100$ mls in a six month period. Palos Verdes.
3. Not more than 20% of the samples shall be over $1,000/100$ mls in any thirty day period. Palos Verdes, Santa Monica, Orange County.
4. No sample shall exceed $10,000/100$ mls when verified within 48 hours. Santa Monica, Orange County.

10. Changes in chlorinated hydrocarbons and metals.

Dr. David Young

In order to predict changes expected in levels of chlorinated hydrocarbon and trace metal contamination in the LA/OMA discharge zones following the 1983 changes in treatment, we have utilized recently reported monitoring data to estimate the response times of these ecosystems to step-function decreases in dominant inputs. Monthly measurement of total DDT sediment concentrations conducted by CSDLAC since mid-1974 at JWPCP benthic stations 6C and 3C (located 2 km and 7 km northwest of the JWPCP discharge point) suggest that these values are decreasing with a half-time on the order of 7 years (Figure 1). Analysis of time-series measurements by SCCWRP and CSDLAC on Dover sole (Figure 2), black perch, kelp bass and intertidal mussels (Figure 3) collected off Palos Verdes Peninsula since 1972 yields a median half-time for total DDT of 8 years:

<u>Organism</u>	<u>Data Source</u>	<u>Data Interval</u>	<u>Half life in years</u>
Dover Sole	SCCWRP	1972-76	7
Dover Sole	CSDLAC	1972-76	>16
Black Perch	CSDLAC	1972-77	4
Kelp Bass	CSDLAC	1972-77	13
Mussels	SCCWRP	1972-76	8

The available data indicate that the JWPCP emissions of DDT residues dropped from as much as 100 m tons (600 lb/day) in 1970 to less than 4 m tons in 1973; this constituted a virtual step-function decrease by at least a factor of 10 near the

beginning of the half-time study period (1972-1977). Thus, the DDT response characteristics of the Palos Verdes ecosystem (sediments, organisms) observed over this period are believed to effectively approximate those of the "minimal DDT discharge" condition, and are the best model for what is expected to occur over the next decade (the extent of this forecast). Although the picture is less clear for PCB. Numerous studies by the Project since 1972 have demonstrated an approximate parallel behavior between total DDT and PCB 1254 (the dominant component of total PCB in sediments and organisms) off Palos Verdes Peninsula. Thus, lacking firmer data we believe that both DDT and PCB levels in sediments and organisms from this region will continue to decrease exponentially with an approximate 7 year half-time at least until 1988, irrespective of future emission reductions. Application of this assumption to results of a seafood survey conducted in or around 1975 yields the projected levels listed in Table 1 (the values for Dover sole were used in our forecast of changes in fish health).

Six metals were analyzed by CSDLAC in the JWPCP 6C-3C sediments time-series collections. After correcting for natural concentrations, the "excess concentration" values also appear to be decreasing exponentially, with the following half-times: Cd - 5yr; Cr- 7 yr; Cu- 13 yr; Ni- 13 yr; Pb- 6 yr; Zn- 5 yr (Figure 4). To obtain our projections we first extrapolated these trends to January 1983. At that time the changes in treatment are predicted by LA/OMA to result in order of magnitude reductions in emission of these metals. Thus, we have assumed that the

"response" of the sediment metal excess concentrations at stations 6C and 3C to this step-function decrease in input will be similar to that observed for DDT and PCB following the approximate step-function decrease in those inputs during the early 1970's.

To account for the fact that the measured metal excess concentrations on the 6C-3C sediments are lower than those estimated for the JWPCP effluent particulates, for each metal we calculated an effective dilution factor (which also incorporates any desorption prior to deposition at 6C - 3C). These factors were then utilized along with the 1983 LA/OMA metals and solids emission estimates to obtain predicted values for the new equilibrium excess concentration values in the 6C - 3C region. The projected 1983 values were assumed to approach this new equilibrium exponentially with a half-time of 7 years. Corresponding median 6C - 3C excess concentration values as a function of time are compared to estimated natural sediment concentrations in Table 2.

Because time-series data for metals in animals from Palos Verdes Peninsula are lacking, and above-normal concentrations are found principally in deposit and filter feeders, we have assumed that excess concentrations observed there in or around 1975 will decrease at the same rates predicted for the 6C - 3C sediments. The results are listed in Table 3.

SCCWRP studies have shown that PCB emissions via the OCSO outfall have decreased by an order of magnitude since 1972. (DDT inputs have been negligible). Monitoring data indicate that median PCB concentrations in surficial sediments near the OCSO

diffuser (B0-B5) have decreased rapidly since 1974, with a half-time on the order of 1 year (Figure 5), 1977 values generally were below 0.1 mg/dry kg. Average PCB muscle tissue concentrations reported by OCSD in speckled sanddabs trawled quarterly from the end of the outfall have decreased at a similar rate, and by the end of 1976 had fallen below 0.1 mg/wet kg.

SCCWRP analysis of OCSD monitoring data also suggests that sediment metal concentrations in a 10.6 sq km zone around the outfall diffuser have reached approximate equilibrium (Figure 6). Excess concentration values for sediments and a benthic clam and worm collected within a few kilometers of the discharge in 1977 have been obtained from this program. (Total concentrations are listed in Task 2 Report: Table III B 1a and III C 5f, respectively). It is assumed that the levels will persist essentially unchanged until 1983, when the OCSD metals emissions, like those for JWPCP, will undergo an order of magnitude reduction. Therefore we have utilized the same procedure described above for JWPCP metals, under the assumption that the new OCSD equilibrium levels will be approached exponentially with the 1 year estimated half-time observed for PCB. Resulting forecasts are presented in Table 4.

The SCCWRP 1971 survey of chlorinated hydrocarbons in bottom sediments around the terminus of Hyperion's 7-mile outfall revealed a relatively low maximum concentration of total DDT (2 mg/dry kg) compared to more than 200 mg/dry kg in the JWPCP discharge zone). In contrast, the maximum PCB concentration in the 7-mile zone (12 mg/dry kg) was similar to that measured off Palos Verdes Peninsula. Since the early 1970's PCB emissions via this

outfall have decreased by an order of magnitude, but there has been no clear decrease in corresponding contamination of surficial sediments. The median concentration of total PCB measured in five samples collected from a 4 sq km zone off the outfall terminus in 1971-72 was 0.5 mg/dry kg (range 0.2-12); the corresponding values for thirty-five samples collected there in 1976 were 0.8 mg/dry kg (range = 0.1-5). Similarly, over a three-year interval there were only secondary changes in PCB levels in muscle tissue of Dover sole from this area; 1971-72 and 1974-75 median values were 2.2 (0.8 - 2.8) and 2.0 (1.0 - 2.3) mg/wet kg, respectively. No significant changes are expected in PCB emissions resulting from the 1983 change in treatment. These facts suggest that PCB levels will decrease only very gradually in the benthic environment off the 7-mile outfall.

Median excess concentrations (mg/dry kg) of trace metals in a 4 sq km zone off the end of the 7-mile outfall measured by SCCWRP in 1970-71 and again in 1976 are listed below.

<u>Metal</u>	<u>1970-71</u>	<u>1976</u>	<u>BG</u>
Ag	30	3.4	0.3
Cd	20	20	0.2
Cr	570	200	23
Cu	250	200	7
Ni	~6	24	14
Pb	95	85	5

With the exception of Ag, these data indicate only secondary changes in the degree of trace metal contamination of sediments in this zone. (Corresponding data for organisms are not available). Because only minor changes in metal emissions are predicted via this outfall in 1983, the levels of metals in bottom

sediments (or organisms) around the Hyperion 7-mile outfall are not predicted to change significantly after 1983.

A SCCWRP 1972 sediment survey revealed relatively low concentrations of total DDT and total PCB in the vicinity of the Hyperion 5-mile outfall diffusers; typical concentrations were 0.1 and 0.05 mg/dry kg, respectively. Subsequently, PCB MERS have decreased by an order of magnitude (the DDT sediment levels are thought to result from past JWPCP discharges). Data for organisms from this zone are not available; however, the above sediment values suggest that the 5-mile outfall is not causing significant PCB contamination of the local biota.

The Hyperion 5-mile discharge appears to have contributed to elevated trace metal concentrations in bottom sediments; median 1970 excess concentration values (mg/dry kg) for the eight "A" stations (located within about a 2 km radius of the diffusers) and estimate control values are listed below:

<u>Metal</u>	<u>Excess Concentration (above BG)</u>		<u>Median BG</u>
	<u>1972</u>	<u>Post-1983 equilibrium</u>	
Ag	3.4	2.3	0.3
Cd	2.0	0.41	0.2
Cr	100	25	23
Cu	35	10	7
Hg	0.2	0.067	0.04
Ni	4	2.7	14
Pb	22	9.3	5
Zn	83	39	37

No recent data for these stations have been located that would permit an evaluation of temporal changes in sediment concentrations, and corresponding contamination levels in organisms from this

region are unknown. However, median values for the new equilibrium excess metal concentrations expected in surficial sediments from the Hyperion 5-mile "A" stations have been calculated and are listed above.

Table 1. Projected median chlorinated hydrocarbon concentrations in JWPCP sediments (mg/dry kg) and muscle tissue of seafood species (mg/wet kg), from the SWPCP monitoring zone.

Sample/C.H.	Control	1975	1978	1983	1984	1988
Surface Sediment						
Total DDT	<0.01	17	13	7.7	7.0	4.7
Total PCB	<0.01	1.1	0.81	0.49	0.45	0.30
Dover Sole						
Total DDT	0.026	11	8.1	5.0	4.5	3.0
Total PCB	0.008	1.1	0.81	0.50	0.45	0.30
White Croaker						
Total DDT	-	11	8.1	5.0	4.5	3.0
Total PCB	-	1.0	0.74	0.45	0.41	0.28
Pacific Sanddab						
Total DDT	0.16	6.2	4.6	2.8	2.5	1.7
Total PCB	0.03	0.46	0.34	0.21	0.19	0.13
Black Perch						
Total DDT	0.06	4.6	3.4	2.1	1.9	1.3
Total PCB	-	-	-	-	-	-
Scorpion Fish						
Total DDT	0.22	4.2	3.1	1.9	1.7	1.2
Total PCB	0.06	0.44	0.32	0.20	0.18	0.12
Kelp Bass						
Total DDT	0.05	3.0	2.2	1.4	1.2	0.84
Total PCB	0.02	0.30	0.22	0.14	0.12	0.08
Pacific Bonito						
Total DDT	1.9	1.9	1.4	0.86	0.78	0.53
Total PCB	0.49	0.30	0.22	0.14	0.12	0.08
Yellow Crab						
Total DDT	0.01	2.8	2.1	1.3	1.2	0.78
Total PCB	0.04	0.23	0.17	0.10	0.09	0.06
Spiny Lobster						
Total DDT	0.009	1.0	0.74	0.45	0.41	0.28
Total PCB	0.014	0.079	0.058	0.036	0.032	0.022
Intertidal Mussels						
Total DDT	0.01	1.0	0.74	0.45	0.41	0.28
Total PCB	0.01	0.1	0.074	0.045	0.041	0.028
Rock Scallop						
Total DDT	0.03	0.26	0.19	0.12	0.11	0.072
Total PCB	0.003	0.014	0.010	0.0063	0.0057	0.0039

Table 2. Predicted median "Excess Concentration" values (mg/dry kg) for trace metals in surficial sediments (0-5 cm) from JWPCP benthic stations 6C and 3C. Background is median of range of values of 29 control stations.

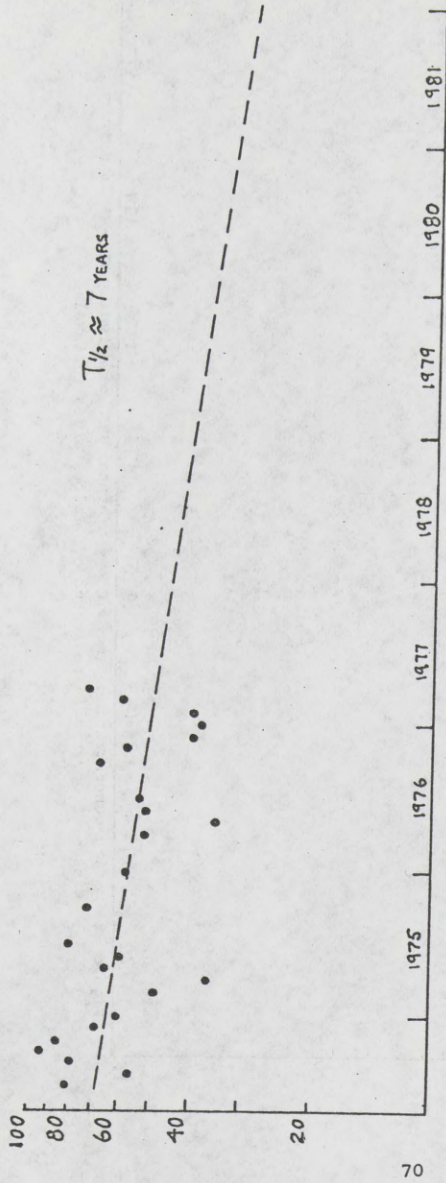
Metal	Sept. 75	Excess Concentration (Above BG)				Equilib.	BG
		Jan. 78	Jan. 83	Jan. 84	Jan. 88		
Ag	21	16	10	9.7	8.8	7.0	0.3
Cd	44	32	16	15	13	8.2	0.2
Cr	1,200	1,050	620	580	460	220	23
Cu	690	580	440	410	320	140	7
Hg	3.7	2.7	1.5	1.5	1.5	1.4	0.04
Ni	64	56	43	42	41	38	14
Pb	430	330	200	199	198	190	5
Zn	1,700	1,200	600	580	515	380	37

Table 3. Predicted "Excess Concentration", values (mg/wet kg) for trace metals in organisms from the JWPCP monitoring zone.

Tissue-Organism-Metal	Excess Concentration (Above BG)					BG	
	1975	1978	1983	1984	1988	Equilib.	
GONAD							
Mussel	Ag	~0.36	~0.17	~0.16	~0.15	~0.12	<0.14
	Cr	0.16	0.14	0.08	0.06	0.03	0.14
	Cu	7.3	6.1	4.7	3.4	1.5	2.3
Scallop	Ag	0.06	0.05	0.03	0.03	0.02	0.015
	Cr	1.8	1.6	0.93	0.69	0.33	0.38
	Cu	1.4	1.2	0.9	0.6	0.3	1.9
MUSCLE							
Mussel	Cu	0.7	0.6	0.4	0.3	0.1	2.5
	Hg	0.04	0.03	0.03	0.03	0.03	0.02
Scallop	Ag	0.016	0.012	0.008	0.007	0.002	0.006
	Cd	0.59	0.43	0.22	0.20	0.11	0.33
	Cr	0.28	0.24	0.14	0.14	0.05	0.03
	Cu	0.18	0.15	0.11	0.11	0.04	0.11
	Hg	0.032	0.023	0.013	0.013	0.012	0.024
	Ni	0.12	0.11	0.08	0.08	0.07	0.10
Abalone	Ag	0.02	0.02	0.01	0.01	0.007	<0.01
	Cr	0.90	0.79	0.46	0.43	0.16	0.10
	Hg	0.002	0.002	0.001	0.001	0.001	0.009
	Ni	0.48	0.42	0.32	0.32	0.28	0.20
	Zn	5.9	4.2	2.1	2.0	1.3	7.1
Prawn	Hg	0.034	0.025	0.014	0.014	0.013	0.046
Crab	Cr	0.04	0.04	0.02	0.02	0.01	0.04
	Ni	~0.22	~0.19	~0.15	~0.14	~0.13	<0.04
Lobster	Ag	0.04	0.03	0.02	0.02	0.007	0.0
	Cd	~0.01	~0.01	~0.01	~0.01	~0.00	<0.01

Table 4. Predicted "Excess Concentration" values (mg/dry kg) for trace metals in surficial sediments, the benthic clam *Parvillucina*, and the polychaete worm *Cistena* from 6 near diffuser stations (Orange County B0-B5) of the OCSD monitoring zone.

Class/Metal	Excess Concentration (Above BG)					Equilib.	BG
	Aug. 77	Jan. 83	Jan. 84	Jan. 88			
SEDIMENT:	Ag	0.2	0.2	0.16	0.13	0.13	0.3
	Cd	1.2	1.2	0.72	0.26	0.22	0.2
	Cr	17	17	13	8.5	8.2	23
	Cu	29	29	18	8.3	7.7	7
	Zn	19	19	18	18	18	37
CLAM:	Ag	-	-	-	-	-	44
	Cd	22	22	13	4.8	4.0	12
	Cr	5	5	3.8	2.3	2.2	5
	Cu	170	170	105	48	45	170
	Zn	60	60	57	57	57	240
WORM:	Ag	0.7	0.7	0.6	0.5	0.5	0.6
	Cd	0.5	0.5	0.3	0.1	0.1	4.9
	Cr	5.0	5.0	3.8	2.3	2.2	8.0
	Cu	55	55	34	16	14	42
	Zn	4	4	4	4	4	41



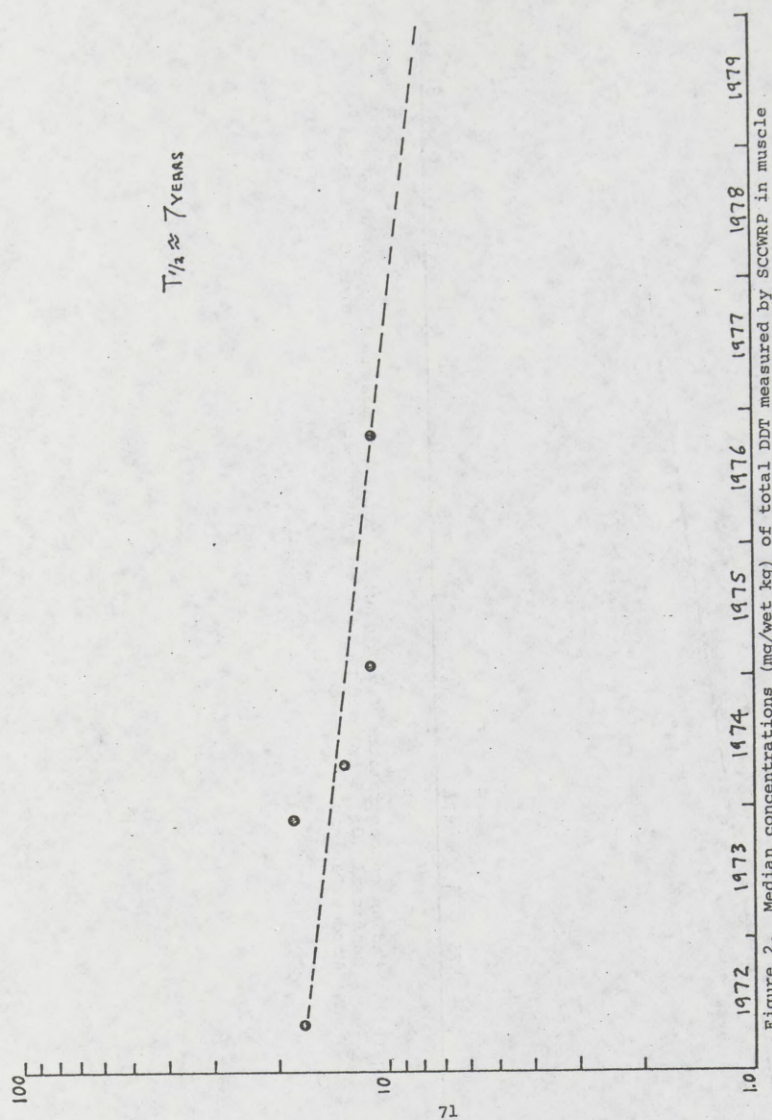


Figure 2. Median concentrations (mg/wet kg) of total DDT measured by SCWRP in muscle tissue of Dover sole collected off Palos Verdes Peninsula.

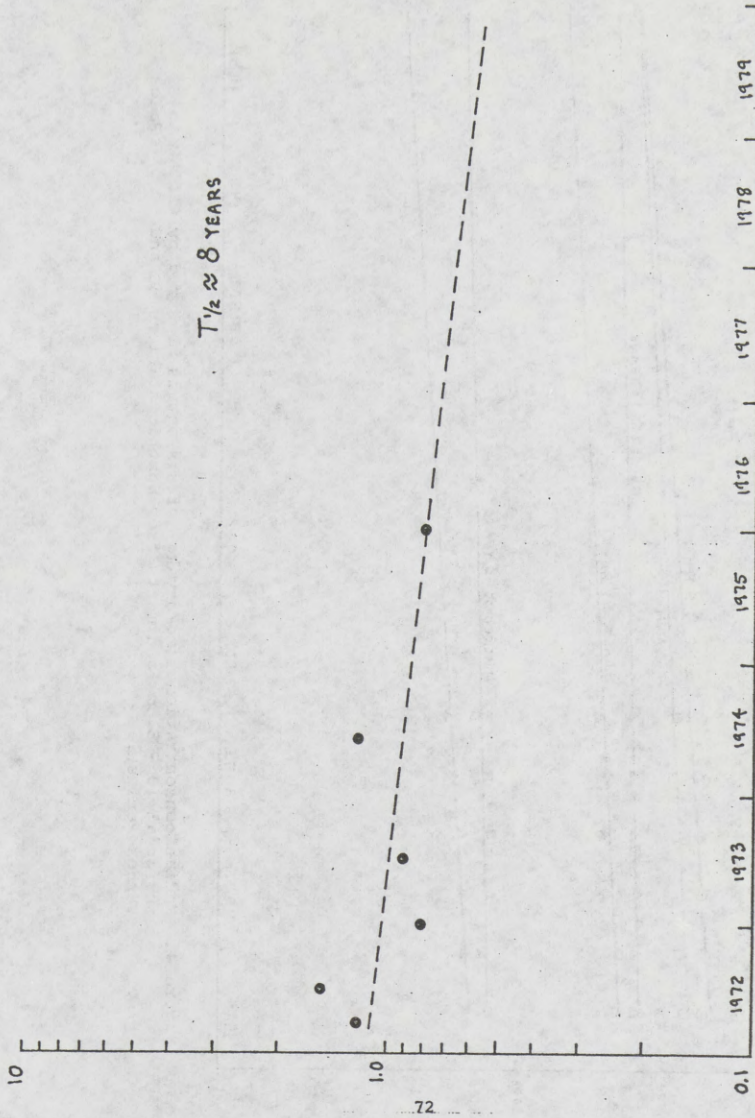


Figure 3. Concentrations (mg/wet kg) of total DDT measured by SCCWRP in soft tissues of intertidal mussels from Royal Palms Beach on Palos Verdes Peninsula.

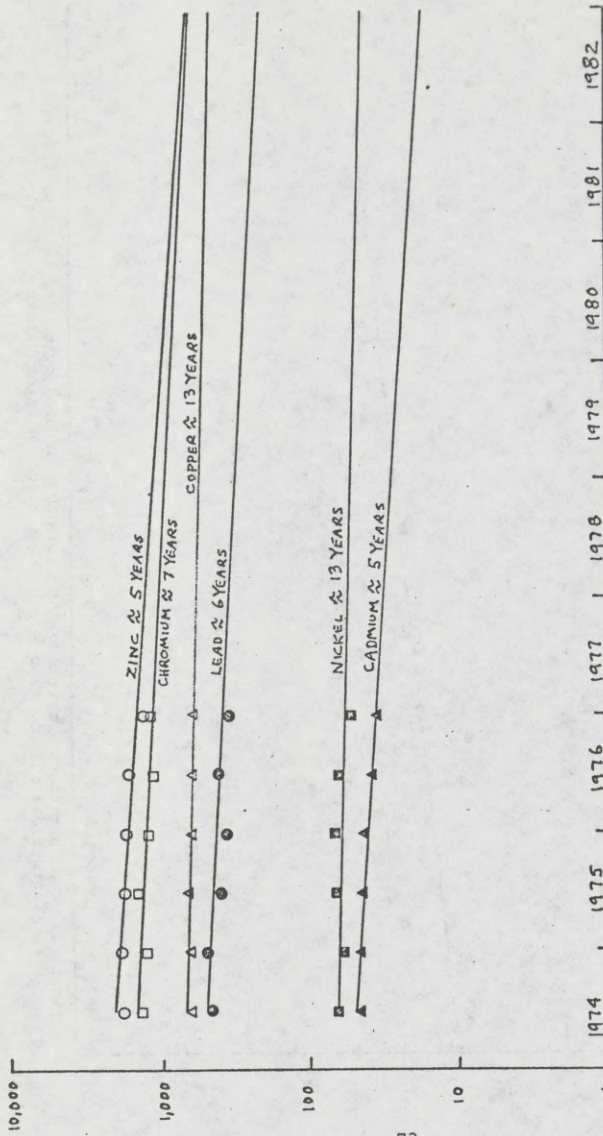


Figure 4. Median concentrations (mg/dry kg) of six metals measured by CSDLAC in surficial (0 - 5 cm) sediments from benthic stations 6C and 3C off Palos Verdes Peninsula.

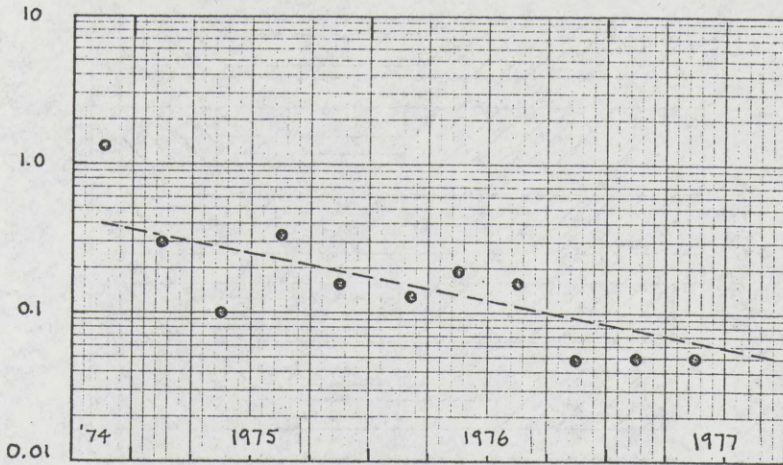


Figure 5. Median concentrations (mg/dry kg) of total PCB measured by OCSD in surficial sediments from benthic stations B0 - B5.

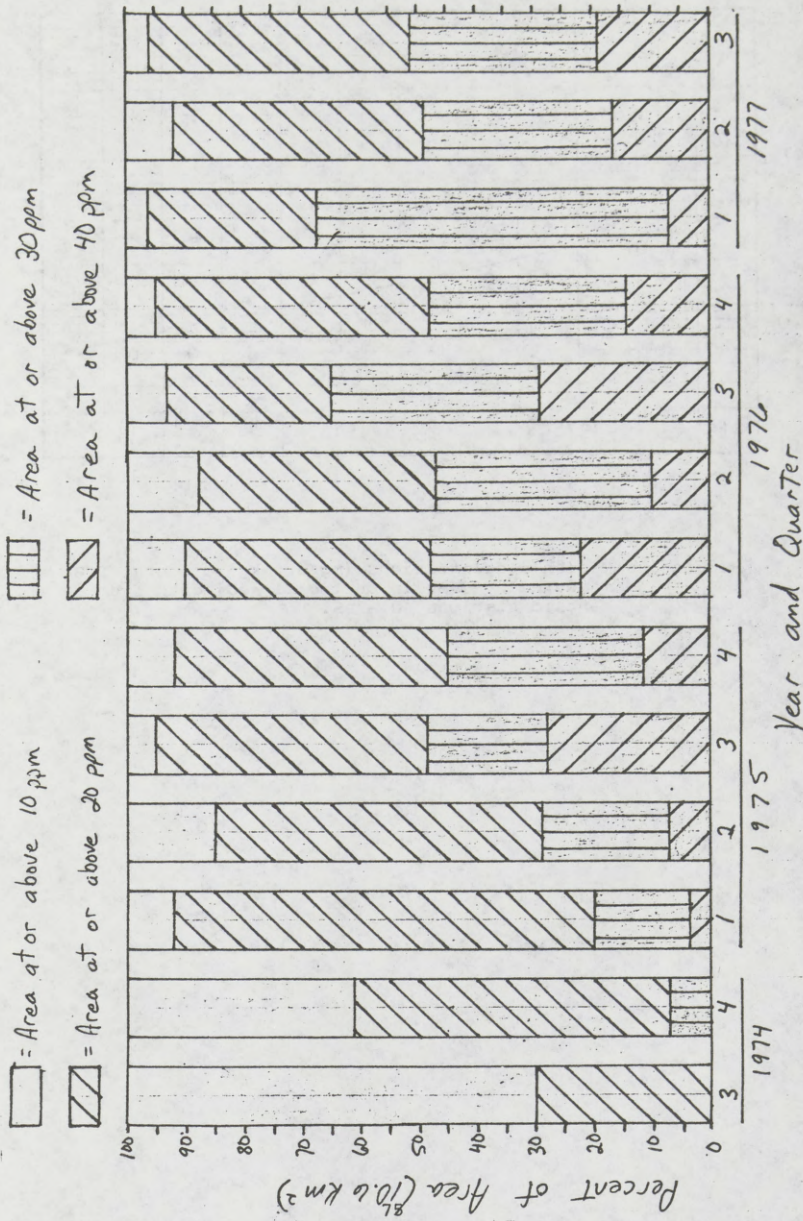


Figure 6. Percent of area (in a 10.6 sq km zone around the OCSD outfall diffuser) which has exceeded 10, 20, 30, and 40 mg/dry kg copper in surficial sediments, 1974-77.

APPENDIX A

REGIONAL WASTEWATER SOLIDS MANAGEMENT PROGRAM
LOS ANGELES/ORANGE COUNTY METROPOLITAN AREA

WRITE: LA/OMA PROJECT, P.O. BOX 4998, WHITTIER, CA 90607 TEL: (213) 699-7411

November 8, 1977

Willard Bascom, Director
Southern California Coastal Water
Research Project
1500 East Imperial Highway
El Segundo, California 90245

RECEIVED
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SOUTHERN CALIFORNIA
COASTAL WATER RESEARCH PROJECT

SLUDGE QUANTITIES AND CHARACTERISTICS UNDER THE
BASELINE "NO PROJECT" ALTERNATIVE

As discussed at the Marine Advisory Committee meeting on October 25, we have assembled the projected sludge quantities and characteristics under the Baseline "No Project" Alternative. Both Federal and State law require that a "no project" alternative be included as part of any long range, facilities planning. Applying the "no project" concept to the LA/OMA study has been complicated by the fact that interim solids processing facilities and secondary treatment facilities have been designed and, in some cases, construction has commenced. Obviously, the term "no project" does not strictly apply in the case of the LA/OMA study since many projects which will produce sludge, and others which will process it, are currently being implemented. Therefore, the term "baseline" has been adopted to describe this alternative and the following definition developed:

"For purposes of comparison, the baseline alternative will assume full secondary treatment to be implemented in stages on or before 1983. Credit will be given for all primary and waste activated solids processing facilities in place, under construction, or contracted for construction as of December, 1978. Sludges beyond those which can be processed in the latter facilities will be assumed to be discharged through existing outfall facilities for ocean disposal."

Application of this definition to the individual treatment plants has been complicated by the need to consider facilities likely to be committed by December, 1978. As this date grows nearer, the projections have been revised to reflect additional information and changing conditions. The data presented here represents our latest projection and is the same information which will be given to other LA/OMA consultants. Little if any change in this data is expected as evaluation of the baseline alternative proceeds in the next few months.

To provide some perspective on the sludge processing and ultimate disposition under the baseline alternative, process diagrams for each treatment plant have been enclosed as attachments 1, 2 and 3.

Summary sheets are enclosed (attachments 4, 5 and 6) which describe the projected effluent and sludge quantity and quality. Mass emission rates for various metals and chlorinated hydrocarbons are shown for both the wastewater and sludge components of the total discharge. Numerous assumptions and calculations were necessary in order to prepare these tables. Therefore, working sheets were prepared (included with attachments 4, 5 and 6) for each plant describing the approach and assumptions used in preparing the data contained in the summary sheets. Although the assumptions were numerous, we feel that the mass emission rates, particularly for metals, are reasonably good estimates of baseline discharges. For information purposes, a comparison of measured and projected characteristics for secondary effluent and digested sludge is presented in attachment 7. In general, the comparisons are quite favorable. The data for chlorinated hydrocarbons is somewhat tenuous because of the lack of suitable data. SCCWRP may have more recent information in this area. If so, we should discuss the information and revise the tables before proceeding further.

Please contact Tim Haug if you have any questions or revisions which you feel would be appropriate.

Bill Davis
Bill Davis
Project Manager

BD:RTH:mar

cc: Don Baumgartner
Jim Allen
Frank Dryden
Bob Horii
Dennis Reid
Lewis Schenazi
Kurt Wassermann
Russ Beckwith

Effluent Characteristics
Received from LA/OMA on 11-10-77

SUMMARY SHEET
BASELINE ALTERNATIVE
HYPERION

CONSTITUENTS	5-MILE EFFLUENT		7-MILE EFFLUENT
	MER	% SOL. ^{1/}	MER
Flow, mgd	365		^{4/}
SS, dtpd	45.6 ^{3/}		175 ^{2/}
% Volatile	78		65
<u>TRACE METALS (lb/day)</u>			
As	15.3	.87	8
Hg	1.5	34	3.9
Ag	20	46	42
Cd	12	0	48
Ni	368	92	108
Pb	37	51	68
Cr	137	0	581
Cu	146	0	559
Zn	300	46	627
<u>TRACE ORGANICS (lb/day)</u>			
DDT	0.06	50	0.1
PCE	0.7	70	0.73
TICH	0.8	69	0.83
Chlorinated Benzene	4	0	26.6

^{1/} Calculated % Soluble (see work sheet), values should be used with caution.

^{2/} Only 175 out of 335 dtpd of sludge would be discharged to the ocean

^{3/} Back calculated assuming 30 mg/l SS in effluent.

Effluent Characteristics
Received from LA/OMA on 11-10-77

SUMMARY SHEET

BASELINE ALTERNATIVE

JWPCP

CONSTITUENTS	SECOND. EFFLUENT		DIG. SLUDGE ^{2/}		COMBINED EFFLUENT MER
	MER	% Soluble ^{1/}	MER		
Flow, mgd	275		--		275
SS, dtpd.	34.4 ^{3/}		25 ^{4/}		60
% Volatile	78		57 ^{4/}		69
<u>TRACE METALS (lb/day)</u>					
Hg	0.8	66	0.19		1.0
Ag	9.6	72	2.1		11.7
Cd	10	48	3.9		13.9
Ni	608	96	18		626
Pb	203	74	38		241
Cr	211	41	90		301
Cu	138	47	53		191
Zn	774	71	163		937
<u>TRACE ORGANICS (lb/day)</u>					
DDT	0.6	35	0.28 ^{8/}		0.88
PCB	0.7	35	0.33 ^{8/}		1.03
TICH	1.3	35	0.61 ^{8/}		1.91
Chlorinated Benzene	13.5	65	3.5 ^{8/}		17

^{1/} Calculated % soluble (see work sheet), values should be used with caution.

^{2/} Digested Mixed primary and WAS, about 5% of total digested sludge.

^{3/} SS MER's were back calculated assumed a SS conc. of 30 mg/l in the effluent.

^{4/} Calculated, assuming volatilities of 50% and 71% for digested primary and WAS respectively, and a rough mass proportion of 2 to 1.

^{8/} Back calculated assuming mixed sludge concentrations.

Effluent Characteristics
Received from LA/OMA on 11-10-77

ATTACHMENT 6

SUMMARY SHEET
BASELINE ALTERNATIVE
OCSB

<u>CONSTITUENT</u>	<u>SECONDARY EFFLUENT</u>	
	<u>MER</u>	<u>% SOLUBLE ^{1/}</u>
Flow, mgd	215	
SS, dtpd	27 ^{2/}	
% Volatile	78	
<u>TRACE METALS (lb/day)</u>		
As	-	-
Hg	-	-
Ag	4	52)
Cd	10	14
Ni	182	93
Pb	85	58
Cr	51	4
Cu	117	14
Zn	261	53
<u>TRACE ORGANICS (lb/day)</u>		
DDT	0.06	82
PCB	4	92
TICH	4	91
Chlorinated		
Benzene	11.5	67

^{1/} Calculated % soluble (see work sheet), values should be used with caution.

^{2/} Back calculated assuming 30 mg/l SS in effluent.

Summary of Effluent Characteristics now (1976) and under Baseline Alternative starting in 1983.

Mass Emission Rates in LA/OMA Effluents

	JWPCP				Hyperion				OCSB			
	1976		1983		Five Mile		Seven Mile		1976		1976	
	1976	1983	1976	1983	1976	1983	1976	1983	1976	1983	1976	1983
Flow (MGD)	353	275	359	365	4.1	4	182	215				
(liters x 10 ⁶)	1,336	1,041	1,359	1,380	15.5	15.1	689	814				
Sus.Solids	138,900	19,900	38,300	15,100	56,200	58,000	32,300	8,940				
% Vol.												
Solids		69		78		65		78				
Trace metals												
(ton/yr)												
Silver	6.3	1.9	5	3.3	4.9	7.0	2.5	0.65				
Arsenic	3.4	-	5	2.5	1.6	1.3	-	-				
Cadmium	12.8	2.3	10	2.0	7.4	8.0	10	1.6				
Chromium	370	50	95	23	66	96	48	8.5				
Copper	200	32	85	24	95	93	91	19				
Mercury	0.7	0.2	0.75	0.25	0.56	0.65	-	-				
Nickel	157	100	90	61	21	18	35	30				
Lead	108	40	15	6.1	9.4	11	28	14				
Zinc	650	160	109	50	120	100	140	43				
Chlorinated												
Hydrocarbons												
(kg/yr)												
DDT	940	150	25	9.9	18	16	31	9.9				
PCB	1,300	170	110	120	120	120	990	660				
TCH		320		130		140		660				
Chlor.												
Benzenes		2,800		650	4,400			1,900				

Mr. ROBERTS. Let me introduce our next distinguished witness, Dr. John H. Ryther. He received his Ph. D. in marine biology from Harvard University in 1951. He is currently the senior scientist at the Woods Hole Oceanographic Institution in Woods Hole, Mass., near Cape Cod. It is a rather lovely summer area. He was formerly the chairman of the institute's department of biology.

Dr. Ryther has participated in the National Academy on Agriculture, and the National Academy of Science. He has been a consultant for the National Science Foundation, the National Institutes of Health, the U.S. Navy, and the U.S. Department of the Interior.

He is also a past president of the Bermuda Biological Station, and a former Commissioner of the Marine Mammal Commission, as well as a member of President Kennedy's Science Advisory Committee.

Dr. Ryther, we are delighted to have you here, sir.

TESTIMONY OF PROF. JOHN H. RYTHER, SENIOR SCIENTIST, WOODS HOLE OCEANOGRAPHIC INSTITUTE

Dr. RYTHER. Thank you, Mr. Chairman.

To that biography, I might add a couple of things relevant to this hearing. One is that I have done work over the past decade or so on effects of pollutants in waste-water discharges on marine ecology, and marine ecosystems in general. The other, similarly related subject that I have been working on more recently is the utilization of waste water as a source of nutrients for actually growing aquatic organisms, both in the freshwater and marine environment, as a source of fertilizers in aquaculture systems, which would combine the function of removing the nutrients, a sort of tertiary sewage treatment, and growing useful crops of organisms in the process.

So I have been looking very much on waste-water as a resource in this respect, and I still like to consider it in that way.

One other thing I might mention is that I am also on the consulting board of Dr. Bascom's group, and I hereby subscribe to the things that he has just said.

I have a prepared statement here, which I would like to read.

My name is John H. Ryther. I am a senior scientist at the Woods Hole Oceanographic Institution, Woods Hole, Mass., where I have carried out research in the fields of biological oceanography and marine ecology since 1951. My areas of specialization are biological productivity of the sea, marine aquaculture, waste recycling, and effects of pollution on marine ecosystems. I have been directly involved in several studies of the effects of waste-water discharges on the coastal marine environment. It is within the context of that background and experience that I would like to address the following remarks relative to the proposed modification of the secondary treatment requirement for discharge into marine waters.

When untreated domestic waste water is discharged into the sea, it is quickly attacked by bacteria and decomposed or oxidized to its inorganic constituents—carbon dioxide, phosphate, nitrate, and so forth—dissolved oxygen from the water being utilized in the process. Organic solids in the waste water sink to the bottom and are similarly decomposed, drawing upon oxygen dissolved in the surrounding in-

terstitial water of the sediments. Sufficient organic loading of either the water or the bottom sediments may completely exhaust the oxygen from the surrounding waters, rendering them anoxic and incapable of supporting higher forms of life. Mass mortality of marine life and ecological disaster ensues.

To prevent this chain of events, domestic waste water may be oxidized and decomposed by bacteria in a conventional activated sludge secondary sewage treatment process. Following vigorous aeration in the decomposition phase, the solids, now largely consisting of bacterial cells, are allowed to settle, leaving a clear well oxygenated and largely inorganic effluent which has no further biological oxygen demand or b.o.d. However the clean effluent does contain all of the oxidized, inorganic constituents of organic matter such as the nitrogen and phosphorus and these now serve as nutrients or fertilizers stimulating the growth of marine plants, largely the unicellular algae or so-called phytoplankton.

At low concentrations, the phytoplankton are invisible and are actually beneficial, since they constitute, directly or indirectly, the food of virtually all higher forms of life in the sea. At high concentrations, however, these micro-organisms produce what are known as algal blooms, discoloring and imparting a noxious odor to the water and generally degrading its esthetic properties, a condition often referred to as eutrophication. Furthermore, as these organisms slowly sink into deeper water and to the bottom, they too die and decompose removing dissolved oxygen from the water and, in extreme cases, again creating anoxia and mass mortality of marine life. The secondary crop of organic matter and its associated b.o.d. may be as large as or even larger than the organic loading of the original, untreated waste water.

Discharge of untreated wastes into marine areas where there are sufficient tidal exchanges and/or advective currents to rapidly dilute and disperse the organic matter does not result in any significant reduction of the dissolved oxygen in the water and causes no environmental problems. Similarly, the discharge of secondary effluent into such areas does not result in noxious or ecologically harmful algal blooms. It is in the restricted coastal estuaries, embayments, and harbors that have relatively poor tidal exchange, circulation, and flushing characteristics that discharged waste waters accumulate and environmental damage ensues. And it is in these latter situations, where it is clearly unacceptable to discharge untreated sewage, that the excessive fertilization of the water with the nutrients in secondary effluent and the creation of algal blooms is equally damaging to the environment. Where it is most needed, secondary sewage treatment accomplishes precisely nothing.

It is unfortunate that EPA originally jumped to the ill-advised conclusion that secondary treatment is a universal panacea for waste water disposal problems. Clearly, other alternatives would often be preferable, if only the Agency could learn to cope with decisions on an individual basis. Often, the money spent on secondary treatment plants designed to discharge within a constricted harbor or estuary would be better invested in a deep-ocean outfall extended out to the open sea.

The proposed modification is a slight indication that the original opt for secondary treatment may now be in some doubt, but, if so, it is a most modest admission. It is again unfortunate and most un-

reasonable that those seeking the exemption must demonstrate that their existing waste disposal systems are environmentally innocuous and incapable of improvement. Few would argue that current practices in most places along our coastline are blameless and without unfavorable environmental impact. Many if not most municipalities already have planned improvements ready for implementation. Why should not the effects of secondary treatment be compared with those of the best possible alternative. The one is no more or less difficult to predict than the other.

In apparent recognition of the limited benefits of secondary treatment in other respects, as discussed previously, EPA has leaned heavily on the assumed "incidental" removal of toxic pollutants—heavy metals and organic compounds—from waste water by secondary treatment, stipulating repeatedly in the proposed modification that dischargers must demonstrate that their existing effluents contain no more of these substances than would have been attained by secondary treatment. This is a rather curious argument that is somewhat difficult to defend, because secondary treatment processes have been neither designed nor constructed to remove toxic pollutants from waste water and any performance in that respect is truly incidental. It is quite true that many heavy metals are associated with particulate matter and that the removal of solids in secondary treatment will simultaneously remove those toxics. But other metals and certainly many organic compounds are in true solution in waste water and will remain in the secondary effluent. To my knowledge, the removal of toxic trace contaminants by secondary sewage treatment has not been well studied or documented. Indeed, EPA has not yet identified the substances of concern, nor does the Agency require that they be monitored in secondary treatment effluent discharges. Only those seeking the exemption must see that their effluent meets the hypothetical standard of secondary treatment.

It is perhaps worth pointing out here that a secondary sewage treatment plant is essentially an ecosystem in itself—a colony of bacteria—that is every bit as sensitive to toxic substances as is the marine ecosystem. Any toxic material that, after dilution with seawater following its discharge, is toxic to marine life would be very likely in its undiluted state to poison a secondary treatment plant and result in the discharge of untreated waste water together with the toxic components. Any one who has spent any length of time around a secondary treatment plant is very familiar with that experience, which happens much more often than many operators are willing to admit and that most of the public are aware of.

Clearly, the only dependable procedure for and the ultimate answer to removal of toxic pollutants from waste water is source control. Progress has been and is being made now in that important area. One wonders what priority future efforts to improve the quality of waste water at its source will receive if the premise is widely accepted that secondary treatment is an adequate solution to that problem.

Most of the arguments presented in this testimony have been developed and presented in more detail in an article by Dr. Charles B. Officer and myself entitled "Secondary Sewage Treatment Versus Ocean Outfalls: An Assessment," which was published in *Science* (vol. 197, pp. 1056-1060), on September 9, 1977. I would like to submit a copy of that article as a part of my testimony.

[The following was received for the record:]

[From Science, Sept. 9, 1977]

SECONDARY SEWAGE TREATMENT VERSUS OCEAN OUTFALLS: AN ASSESSMENT

(By Charles B. Officer and John H. Ryther)

About one-third of the population of the United States lives or works close to estuarine and coastal waters [1]. Understandably, there is concern about disposal of municipal and industrial wastes in the waterways adjacent to the larger metropolitan coastal communities—concern about how much and what types of waste can be assimilated by these waters and about what corrective actions should be taken to improve their quality.

These are not easy problems to solve. They require appropriate contributions from the marine sciences of physical oceanography, biology, chemistry, and geology as well as the related branches of civil engineering. The Environmental Protection Agency, under the terms of its enabling legislation, has taken the position that the solution shall be in the construction of secondary sewage treatment facilities [2]. However, environmental scientists and engineers alike have argued that secondary treatment of wastewater is unneeded and ineffective if discharges are made into open coastal waters, where there is adequate mixing, dilution, and advection to prevent oxygen depletion, eutrophication, and other adverse effects resulting from high concentrations of organic wastes [3-6].

Generally, there is agreement among environmentalists and the practitioners of waste disposal that untreated sewage should not be discharged into harbors, estuaries, or other confined coastal marine waters with restricted circulation and water exchange. A basic question is whether secondary treatment is the appropriate solution in such situations, or whether the high capital and operating costs of advanced treatment would be better spent on a comparable investment in ocean outfalls.

The construction costs related to the solution of these pollution problems are immense. For the coastal metropolitan areas of the United States they are measured in billions of dollars. For example, for one metropolitan area, Boston, the costs for secondary sewage treatment plants are estimated to be several hundred million dollars, and those for ocean outfalls are comparable [7].

In brief, secondary sewage treatment biologically, through the action of microorganisms, decomposes and oxidizes the dissolved and particulate organic matter in wastewater. This action, carried out under vigorous aeration followed by sedimentation of inorganic solids and the microorganisms themselves, results in the removal of 80 to 90 percent of the biochemical oxygen demand (BOD) and suspended solids, leaving a relatively clear, well-oxygenated effluent containing the inorganic compounds of nitrogen, phosphorus, and other constituents. Before discharge, the effluent is normally disinfected by chlorination.

Secondary treatment has no direct effect on eutrophication of the receiving waters, which may result from uptake of the mineralized nitrogen and phosphorus compounds by phytoplankton and the subsequent oxygen demand associated with respiration or decomposition of that secondary crop of organic matter. Further, it is applicable only to point sources of wastewater and has no potential impact on distributed sources. The questions are, then, how much effect does BOD removal by secondary treatment have on the possible pollution, measured in terms of dissolved oxygen deficits, of a particular area, and relatively how important is the eutrophication potential of the secondary effluent?

In this article we make a scientific assessment of this problem, using order of magnitude estimates. Although we appreciate that numerical modeling is often a necessity for final engineering planning, we feel that such approximate considerations are appropriate for the general problem addressed here and that they facilitate the separation and examination of the important variables.

MARINE BIOLOGICAL AND CHEMICAL OXYGEN DEMANDS

In most of the discussion that follows we will be concerned with the direct oxygen demand of the waste materials and the indirect oxygen demand associated with any eutrophication effects. The life history and ultimate fate of possible trace contaminants such as hydrocarbons, chlorinated hydrocarbons, and heavy metals or of pathogens such as viruses and bacteria will be considered only briefly. We do appreciate that these are also important problems for waste treatment and disposal.

The potential oxygen demands for the two processes—waste oxidation and eutrophication—are comparable. From Thoman [8], the total oxygen required for the ultimate biochemical oxidation of the organic wastes in an untreated municipal effluent—the waste biochemical oxygen demand (W OD)—is about 400 milligrams per liter. Ryther and Dunstan [9] argue that inorganic nitrogen, rather than inorganic phosphorus, is the limiting nutrient in marine phytoplankton growth. From Redfield *et al.* [10] we have that the combining atomic ratio of oxygen to nitrogen in the reversible equation for marine phytoplankton photosynthesis, or respiration, is 276:15.5, or 20:1 by weight. Again from Thomann [8], the inorganic nitrogen ($\text{NH}_4^+ + \text{NO}_2^- + \text{NO}_3^-$) in a municipal effluent is characteristically in excess of 20 mg/liter. Thus, the ultimate phytoplankton photosynthetic oxygen production or eutrophication oxygen demand [phytoplankton biochemical oxygen demand (PBOD)] of untreated wastewater will be in excess of 400 mg/liter.

In addition to the inorganic nitrogen referred to above, untreated effluents have an organic nitrogen content of 20 mg/liter [8]. In the secondary treatment process some nitrogen is usually lost, presumably to the atmosphere as NH_3 , and a typical secondary effluent has an inorganic nitrogen content of about 20 mg/liter [1]. The PBOD of a secondary effluent is thus at least as high as the WBOD of raw sewage and may, if nitrogen is not lost in the treatment, be double that amount.

ASSIMILATION CHARACTERISTICS OF RIVERS, ESTUARIES, AND COASTAL WATERS

We are interested in the average conditions within a definable volume of water, V , of a river, estuary, or coastal region. The dilution and reaction rate phenomena are treated in terms of a steady state box model. The important physical oceanographic variable is the flushing or retention time, τ , defined as the time necessary to replace any particular conservative quantity in the volume at the rate at which that quantity is being injected into the volume [12]. For rivers and lakes τ expresses the effect of the advective river flow, R , through the volume and is given simply by V/R . For estuaries it also includes the important effects of tidal mixing and density gradient—and wind-induced circulation flows. For coastal waters it includes all three of these effects plus that due to the coastal current structure.

The flushing time enters the calculation in two ways—in terms of the effective dilution and in connection with the reaction rates for oxidation, reaeration, or respiration. The volume-averaged concentration of a conservative quantity, c , is given in terms of τ as $C/(V/\tau)$, where C is the rate at which the quantity is being added. The flushing time here enters in terms of the quantity V/τ , which we refer to as the assimilation, and it is a direct measure of the dilution characteristics of the volume. The flushing time also enters in the first-order exponential reaction terms in the form $k\tau$, where k is the reaction constant. For small $k\tau$ values little reaction takes place within the defined volume: for large $k\tau$ the reaction is essentially complete.

TABLE 1.—FLUSHING TIME (T), VOLUME (V), AND DILUTION POTENTIAL ($1/f$) FOR VARIOUS RIVERS, ESTUARIES AND COASTAL REGIONS

Region	t , (days)	V , (10^6m^3)	$1/f$	Reference
Raritan River.....	8	36	2	(13)
Houston Ship Channel.....	56	67	1	(15)
Delaware River.....	28	1,330	2	(24)
Boston Harbor.....	2	67	24	(25)
Mersey Estuary.....	4	147	7	(26)
Raritan Bay.....	14	860	12	(13)
Passamaquoddy Bay.....	16	4,700	41	(27)
New York Bight.....	8	23,000	63	(22)
Bay of Fundy.....	76	880,000	52	(27)

Ketchum [13] showed that the freshwater flow or river discharge, R , into a tidal river, estuary, or coastal region can be used as a natural tracer to determine the flushing time. The flushing time is given by fV/R , where f is the volume-averaged freshwater fraction, and the assimilation is given by R/f . The quantity $1/f$ is then a measure of the dilution potential over that due to river advection only.

Values that have been determined for τ , V , and $1/f$ for various selected rivers, estuaries, and coastal regions are given in Table 1. The substantial increase in the dilution potential from rivers to estuaries and from estuaries to coastal regions should be noted.

WASTE OXIDATION MODEL

The waste biochemical oxidation can be considered, in a first-order approximation, to decrease in proportion to the amount of pollutant present, so that the WBOD will be proportioned to $\exp(-k_1 t)$, where k_1 is the WBOD decay coefficient and t is the time from discharge. We take as an estimate of the total demand within the volume the average value of the exponential over the flushing time τ , or $[1 - \exp(-k_1 \tau)]/k_1$, multiplied by the initial demand averaged over the volume, or $W/(V/\tau)$, where W is the combined waste discharge oxygen demand. This method of estimation is subject to question but is in keeping with the flow-through box model and order of magnitude considerations that are of interest here. The dissolved oxygen utilization within V , or the waste dissolved oxygen deficit (WDOD) with respect to a saturated condition, will then be

$$\text{WDOD} = \frac{W}{V} \left(1 - \frac{1 - e^{-k_1 \tau}}{k_1 \tau} \right) \quad (1)$$

where W is in units of grams per day, V in cubic meters, τ in days, k_1 in 1/days, and WDOD in milligrams of oxygen per liter. The oxygen will be replenished within V through reaeration; the rate of oxygen replenishment will, again in a first-order approximation, be proportional to the dissolved oxygen deficit. Then following the same procedures as before, we have for WDOD including reaeration,

$$\text{WDOD} = \frac{W}{V} \left(\frac{1 - e^{-k_2 \tau}}{k_2 \tau} - \frac{1 - e^{-k_1 \tau}}{k_1 \tau} \right) \frac{k_1}{k_1 - k_2} \quad (2)$$

where k_2 is the reaeration coefficient in 1/days. For large $k_1 \tau$ and $k_2 \tau$, Eq. 2 approaches $(W/V)(1/k_2)$, independent of τ .

To apply this simplified model, we take as our reference condition a saturated dissolved oxygen content, at a temperature latitude in summer, of 9 to 11 mg/liter. Thus, for values of WDOD > 10 mg/liter calculated from Eq. 2, we would anticipate that all or a substantial portion of V was anoxic. For values < 1 mg/liter, we would anticipate that there was no appreciable oxygen demand related to waste oxidation. And for values between 1 and 10 mg/liter, we would anticipate that there was a measurable oxygen demand, which for engineering planning should be further examined through numerical modeling techniques. Figure 1 is a graph of Eq. 2 with W/V plotted against τ for WDOD=1 and 10 mg/liter. In this graph we used the characteristic values $k_1=0.4 \text{ day}^{-1}$ and $k_2=0.2 \text{ day}^{-1}$ obtained by numerical model simulation of field data [14].

It is of interest to compare these simplified results with observations. O'Connor *et al.* [15] give waste-loading values of 207×10^6 grams of oxygen per day for the Houston Ship Channel and 624×10^6 g/day for the Delaware River. As shown in Fig. 1, the Houston Ship Channel plots above the 10-mg/liter curve and the Delaware River between the 1- and 10-mg/liter curves. The Houston Ship Channel is anoxic and the Delaware River has dissolved oxygen deficit values ranging from 2 to 8 mg/liter along its length from Trenton to Delaware Bay [15]. For Boston inner harbor the waste loading is only from storm-sewer overflows along the Charles River [15]. We have taken an excess loading of 100×10^6 g/day for this source. The determined value, as shown in Fig. 1, plots below the 1-mg/liter oxygen curve. The observed dissolved oxygen in Boston Harbor approaches saturation.

Figure 1 provides us with a convenient index for estimating the effects of alterations in the waste loading, outfall location, or other environmental factors within the system. We see that, in general, small changes will have little effect. If conditions are becoming anoxic, major changes will be necessary to attempt to return the receiving waters to a measurably uncontaminated condition.

One such major change would be secondary sewage treatment. For example, suppose we initially have an anoxic condition in an urban estuary with a substan-

tial waste loading of $W=400 \times 10^6$ g/day, a volume $V=40 \times 10^9$ m³, and a flushing time $\tau=10$ days. This original condition would then be as shown in Fig. 1. If secondary sewage treatment facilities were installed at all point sources, it might optimistically be hoped to reduce the loading by 90 percent [4, p. 9; 16]. In the resulting condition, as shown in Fig. 1, there would still be appreciable waste biochemical oxygen utilization.

Another major change would be the use of ocean outfalls. Here we take a coastal volume $V=4000 \times 10^6$ m³ and a flushing time $\tau=5$ days. In the resulting condition, as shown in Fig. 1, the wastes now have a negligible effect on the natural dissolved oxygen content of the receiving environment. In essence, the ocean outfall, in this example, permits an improvement of two orders of magnitude whereas the secondary treatment, at best, permits an improvement of only one order of magnitude.

EUTROPHICATION OXIDATION POTENTIAL

We are interested here in developing a nutrient-limited model for the eutrophication potential. As discussed above, we can consider this limitation in terms of the inorganic nitrogen waste loading (N , in grams of nitrogen per day) or, more conveniently for our purposes, in terms of the potential utilization of the oxygen in these waste nutrients by phytoplankton in their respiration or decay (P , in grams of oxygen per day). For this condition P is approximately $20N$. This approach to eutrophication is similar to that used by Garside *et al.* [17] others.

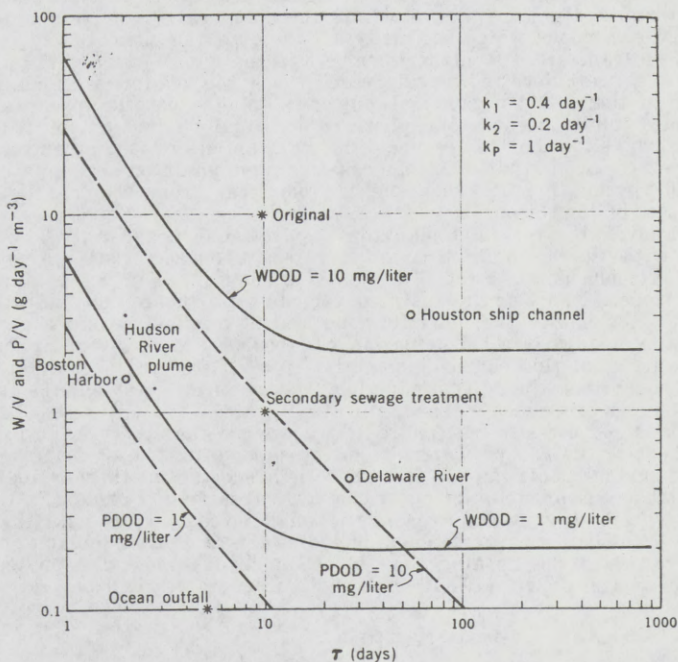


FIGURE 1.—Waste oxidation potential (WDOD) and eutrophication oxidation potential (PDOD) plotted in terms of waste loading (W/V and P/V) against flushing time (τ). The results for waste oxidation are compared with observations (°) for the Houston Ship Channel, the Delaware River, and Boston Harbor. Eutrophication oxidation results are compared with observation (°) for the Hudson River plume off New Jersey. (*) Possible effect of secondary sewage treatment (WDOD only) and ocean outfall (WDOD and PDOD) on an original pollution condition (see text).

The eutrophication phenomenon is not one of a miscible material, involving simple flow-through considerations and decay, as is the case for waste oxidation

of a clear effluent. Here we have biological retention effects as the phytoplankton material sinks to deep water and to the bottom and, subsequently, decays. The addition of a sink to the problem greatly increases the potential pollution hazard.

Considering the time constants of the system and system components, we treat the problem as one of a quasi steady state. We do appreciate that for longer time periods, measured in terms of a seasons of the year, phytoplankton blooms are not steady state phenomena.

For nutrients, particularly in our case inorganic nitrogen, to be the limiting constituents in phytoplankton blooms, a number of other conditions have to be met. For marine photosynthesis to occur at an optimum rate, it is necessary to have sufficient daytime solar insolation and sufficiently warm receiving waters; both of these conditions are generally met in temperate latitudes in the summer [18]. In addition, the natural turbidity of the water must be low [18]. This is a more serious limitation for urban estuaries, where the suspended sediment and detrital loads are often high, and precludes nutrients being the limiting factor in photosynthesis in these situations [17]. When light, temperature, and turbidity conditions are favorable, phytoplankton growth rates can be rapid; optimum values are characteristically around a doubling per day, or a corresponding value for the phytoplankton production coefficient of $k_p=1 \text{ day}^{-1}$ [18].

For eutrophication, or excess of oxygen utilization in the phytoplankton respiration or decay, to then occur, it is necessary that the phytoplankton be physically separated from the waters in which they are produced. For example, if the phytoplankton characteristic of a particular bloom are small and essentially miscible with the water, they will utilize for respiration the photosynthetically produced oxygen and that re-aerated in the surface waters as conditions become undersaturated. On the other hand, if there is nearly complete zooplankton grazing of the bloom, which is usually not the case, the ultimate oxygen utilization will be transferred to higher members in the aquatic food chain and their wastes. We are interested in the case where the plants or animals of the plankton or their solid wastes sink out of the photosynthetic upper waters and accumulate in the deeper subeuphotic waters and on the bottom. This corresponds to the situation that occurred in two examples of marine eutrophication that have been well studied. In one case the phytoplankton accumulated on the bottom [19], and in the other the phytodetritus from zooplankton grazing accumulated on the bottom [20].

The decay rates for phytoplankton respiration are generally low in comparison with the optimum production rates. A characteristic value for the respiration coefficient is $k_d=0.05 \text{ day}^{-1}$ [21]. Thus, if all of the available inorganic nitrogen, N , is continuously converted to phytoplankton and all of this material sinks out of the euphotic zone and is retained within the reference volume, the steady state accumulation will be N/k_d in terms of nitrogen content. The accumulation can be substantial; for $k_d=0.05$ the accumulated material will be 20 times the daily production. This material decays at the rate k_d so that the oxygen utilization will be at the rate P .

To take the most adverse condition, we assume that there is no oxygen replenishment to the bottom waters from the supersaturated, or re-aerated, water near the surface. This implies that there is a substantial thermocline or halocline with a consequent lowering of the vertical mixing coefficient in this zone, such that the hydrodynamic exchange is small in comparison with the normal flushing of the bottom waters. Then, including the rate of phytoplankton production in terms of the flushing time of the defined volume, the phytoplankton dissolved oxygen deficit (PDOD) for the bottom waters will be

$$\text{PROD} = \frac{P}{\tau} \left(1 - \frac{1 - e^{-k_p \tau}}{k_p \tau} \right) \frac{\beta}{\alpha} \quad (3)$$

where β is the fraction of the phytoplankton bloom that is retained and decays within the system out of the euphotic zone and α is the ratio of the volume of the bottom waters to the total volume, V . For large values of $k_p \tau$, Eq. 3 approaches $(P/V)\tau(\beta/\alpha)$ and is proportional to τ .

Equation 3 is graphed in Fig. 1 for PDOD=1 and 10 mg/liter. Values of $\alpha=\beta=1/2$ have been assumed for these calculations. The choice of the value of β is certainly subject to question. Not all of the plankton or plankton wastes will sink out of the euphotic zone and be retained within the reference

system for decay. Considering that for a characteristic sewage effluent W and P have approximately the same numerical value, we see that the BOD potential from eutrophication is greater than that from direct waste oxidation, particularly at large values of τ . This conclusion, however, should be tempered: eutrophication is only a potential, and for many marine areas the determining criteria of solar insolation, water temperature, turbidity, and reduced vertical mixing will not be met.

As with the waste oxidation model, it is of interest to compare these simplified calculations with observations. There is one example of cultural eutrophication in the marine environment for which there are sufficient data to make such a comparison. This is the anoxic condition that occurred off the coast of New Jersey during the summer of 1976 [19]. The mixed Hudson River water exits from the lower bay into the apex of the New York Bight and moves as a definable plume southward along the shore of New Jersey for some considerable distance. Ketchum *et al.* [22] define a volume $V = 750 \times 10^6 \text{ m}^3$ with a flushing time $\tau = 2.0$ days, or alternatively a volume $V = 1760 \times 10^6 \text{ m}^3$ with a flushing time $\tau = 2.8$ days, for the mixed Hudson River plume along the New Jersey shore. From Garside *et al.* [17], we have that $160 \times 10^6 \text{ g}$ of inorganic nitrogen is released each day into the New York waterways from the sewage effluents, and during the summer $117 \times 10^6 \text{ g/day}$ exits through lower bay.

The points for these two defined volumes are shown in Fig. 1. We see that the mixed Hudson River water falls in the critical region between the 1- and 10-mg/liter eutrophication curves. For this case the flushing time for the bottom waters beneath the Hudson River plume will not, in general, be the same as that for the plume itself but will depend more on the prevailing coastal current conditions. In the summer of 1976 the wind and current conditions were abnormal and may well have led to an extended residence time over the 2 to 3 days assumed in these calculations, as has been speculated [19]. It is pertinent to note that the anoxic conditions which occurred in 1976 were anticipated by Segar and Berberian [23] from measurements taken in 1974.

Let us now consider the possible effects of secondary sewage treatment or ocean outfalls on the eutrophication potential. Secondary sewage treatment will have no direct beneficial effect on the eutrophication potential; if anything, the eutrophication potential may be enhanced and accelerated because inorganic nutrients will be more rapidly and more completely available to the phytoplankton than they are when provided by the natural decomposition of wastewater in the sea. As shown in Fig. 1, the original condition will be unchanged by secondary sewage treatment. The installation of ocean outfalls, however, can virtually eliminate the eutrophication potential; in addition, the sewage nutrients can have the beneficial effect of serving as fertilizers for the aquatic food chain.

TRACE CONTAMINANTS AND PATHOGENS

The life history and ultimate fate of trace contaminants and pathogens introduced into the marine environment from municipal wastewaters comprise an important, albeit complex, subject. Initial source control, particularly for contaminants of industrial origin, may well be the most effective corrective action when it is possible [35]. In this section we consider the effects of secondary sewage treatment and ocean outfalls when such control is not possible.

Part of the concern about such trace toxic materials is due to their stability and their biological, chemical, or geological transformations which lead to longer retention times within the marine environment. If a toxic material is miscible with the receiving waters but has a decay time long compared with the time constants of the marine system, it may be considered to be conservative and its average concentration will be given by the simple relation $c = C/(V/\tau)$. According to Bascom [4, p. 9], secondary treatment may reduce C by 45 percent. Taking the example we considered in the section on waste oxidation for comparison, the quantity V/τ will be increased by a factor of 200 for an ocean outfall. The reduction in c for an ocean outfall is clearly superior to that for secondary treatment. If the toxic material is not miscible but has a longer retention time, T , in the system, T will replace τ in the defining equation. Although the values of T for an urban estuary and an ocean outfall may be considerably different, the advantage in the reduction of c would still appear to lie with the ocean outfall, considering the hundredfold increase in the dilution volume.

SUMMARY

Simplified models have been developed to obtain order of magnitude estimates of the oxygen demand of municipal and industrial wastes and of their potential eutrophication effects in the marine environment. The models have been applied to assess two major corrective actions that might be considered for such pollution problems—secondary sewage treatment and ocean outfalls. It is concluded that the arguments for secondary sewage treatment as the proper corrective action are not compelling and that the problem should be reexamined with appropriate scientific and engineering evaluations. One goal of such scientific evaluations should be a more thorough understanding of the life histories of possible trace contaminants and pathogens which may have long biological, chemical, or geological retention times in the marine environment.

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Mr. ROBERTS. Thank you, sir, and thank you for an excellent statement. I will say, that of all the hearings I have had, and of all the statements I have heard, this is the first time that I have realized that what we were requiring in secondary treatment was entirely inadequate for the job.

Mr. Clausen?

Mr. CLAUSEN. I do not have any questions, Mr. Chairman. It is excellent testimony.

Mr. ROBERTS. Ms. Kovalic?

Ms. KOVALIC. Dr. Ryther, could you address for us some of the characteristics of the east and west coast issues, such as sensitivity of the marine life, depth, and amount of dilution?

Dr. RYTHER. I would not know of any difference in the sensitivity to marine life between organisms on the two coasts. The major difference has already been stated by Dr. Brooks, that on the east coast there is a very broad continental shelf, which means that you have to go out a lot further to get into deep water than you do on the west coast.

The other physical characteristic is the east coast has a lot more of these shallow estuaries and embayments, often protected from the open ocean by a barrier beach. This is much more characteristic of the east coast, I think, than the west coast.

Ms. KOVALIC. Can you describe for us your sense of the relationship between suspended solids and toxins?

Dr. RYTHER. Well, as I said in my testimony, certainly there are some toxics that are associated with particulate matter, and these will then end up in the sediments, in the sludge, so-called, and these will settle out to the bottom.

This is particularly true with some of the heavy metals. I think, as I said, that this has not been very well-studied or documented in the case of many of the toxic materials.

Ms. KOVALIC. What do you know of the propensity of the heavy metals once they have accumulated, to actually be ingested by the marine life and subsequently by humans?

Dr. RYTHER. One of the curious things—and again, I think some more research needs to be done in this area—but one of the curious things that we have found in two or three different places is that animals living right in the sediments, heavily contaminated sediments, in some cases, do not seem to accumulate the metals or the organic compounds that we have found in the sediments themselves.

We found this to be true of clams and mussels, in heavily contaminated part of Boston harbor, and a little fly-ash pit up in Casco Bay, in Maine. This was actually shown experimentally, I think, by some scientists at Johns Hopkins University, that although the sediments themselves may contain large quantities of heavy metals, the animals do not seem to pick them up from them.

Ms. KOVALIC. Would you comment on Professor Bascom's statements concerning the toxicity of metals at the point of discharge?

Dr. RYTHER. Well, this is again something that is not very well known or understood. There are examples of this, and the best examples I know are those that have been produced by his group. But it is true that metals are altered in seawater, and they are altered presumably in secondary treatment. And nobody knows what the relative toxicity is of most of these things before and after these alterations.

Mercury can, through the action of bacteria, become toxic. Other things like chromium, obviously, become less toxic, in the process.

Ms. KOVALIC. Thank you.

Mr. ROBERTS. Dr. Ryther, I think you are going to make that airplane.

Dr. RYTHER. Thank you very much, indeed. It was a pleasure to be able to testify.

Mr. ROBERTS. Thank you very much for a very fine statement. We are overwhelmed by the group we have here today, and we do appreciate it.

We will try to go right on through. Our final witness today is Dr. Alyn Duxbury. Dr. Duxbury is research associate professor of oceanography at the University of Washington in Seattle.

He has his doctorate in physical oceanography from Texas A. & M. University. I am glad we also have another man here from Texas A. & M.

Dr. Duxbury is a member of the American Academy for the Advancement of Science, as well as the American Society of Limnology and Oceanography, and a member of the division of marine resources at the Washington University. He is a scientific advisory to the State of Washington Environmental Agencies.

Among various articles published by Dr. Duxbury are "Orthophosphate and Dissolved Oxygen in Puget Sound."

Doctor, we are pleased to have you. Would you proceed, sir?

TESTIMONY OF DR. ALYN DUXBURY, ASSISTANT DIRECTOR FOR NEW PROGRAMS, DIVISION OF MARINE RESOURCES, UNIVERSITY OF WASHINGTON, SEATTLE, WASH.

Dr. DUXBURY. Thank you very much, Mr. Chairman.

I would like to add one little caveat about my background with regard to oceanography. I grew up as an oceanographer. I had the very unique opportunity to undertake an undergraduate curriculum in oceanography back in 1951 and became an apprentice, studying Puget Sound, and have retained an interest in this area ever since.

I appear to be the only one here in the defense of estuaries, thus I would like to present a little bit of background so that we can distinguish between estuaries as compared to the oceanic environment.

By definition, an estuary is any arm of the sea which is semienclosed with no definition as to how much enclosure is required, and suffers net dilution. It has to have land runoff, and have a lower salt content than the immediate oceanic environment.

There are all kinds of estuaries. Where I come from, we talk about Puget Sound as an estuary—yet it should not be considered a single estuary. It has many component parts, each one functioning differently.

Mr. Chairman, I would like to refer to the METRO study "A Study of the Nutrients in the Main Basin of Puget Sound" by Eugene E. Collias and John H. Lincoln, 1977 and "A Water Budget Study of Puget Sound and its Subregions" by Mark A. Friebertshauser and Alyn C. Duxbury, *Limnology and Oceanography*, Vol. 17, No. 2, pp. (See page 246.)

Mr. ROBERTS. The study referred to will be received for the record.

Dr. DUXBURY. What can be done in one particular arm, or at one particular location in an estuary, cannot be done at others. With regard to discharge practices, we have to really get down to studying the microstructure of the system.

In Puget Sound, we have a complex system. The major arms of Puget Sound enter into a central basin, which then discharges through the Admiralty Inlet, and into the Strait of Juan de Fuca, and thence into the Pacific Ocean.

In this process there are two kinds of flows that occur. We heard several times today and yesterday the statement that tidal exchange helps in dispersion of an effluent discharged into an estuary. However, we must remember that tidal flow is oscillatory flow. It goes back and forth and usually has no preferred direction.

Superimposed on this is the estuary, you have a net circulation. This is because you have a river input always tending to dilute and add water to the system and you have a deep flow coming in at depth, adding salt to maintain the salt balance. The resulting seaward flow that goes out the entrance of the estuary is the combined river flow plus what enters at depth. This is the net circulation.

Some time ago, I undertook a fresh and saltwater budget study in Puget Sound published in 1972, to determine the net circulation flux in the Puget Sound region. This study has been verified by a more recent calculation.

It turns out that the circulation that we have in the central basin of Puget Sound is estimated to be about 59,000 cubic meters per second, the influx rate. What goes out is almost 60,000 cubic meters per second. Dr. Gross, who is here today, helped me recall, because I could not remember, the average discharge of the Columbia River, 7,000 cubic meters per second. Thus, we have a net exchange in Puget Sound that is roughly 8 to 9 times the discharge of the Columbia River. This turns out to be about 60 times the discharge of the Susquehanna that you have here.

Our sewage is discharged into a system that has a net circulation that carries materials seaward at or near the surface. As this flow goes out of Puget Sound, it enters the Strait of Juan de Fuca, where the southern end of the Strait of Georgia adds a contribution to it, and the seaward flux rate increases to almost 20 times the average flow of the Columbia River.

This is the type of dynamic situation that we are discharging into. The net flow and tidal activity we have in Puget Sound, coupled with a shallow entrance at Admiralty Inlet, produces good turbulent mixing over this entrance sill.

This turbulent mixing tends to combine bottom water with surface water, and we find that within the basin of Puget Sound, at typical depths of 600 to 900 feet in the central basin, we have oxygen contents in percent saturation that are 2 to 3 times the oxygen saturation content you would find out in the open sea at the same depth. So our central basin water is oxygen-enhanced.

We can take these fluxes and multiply them times their phosphate concentrations and determine the magnitude of phosphate input and output.

There has been recent research that shows that in the main basin the net circulation, brings in somewhere in the neighborhood of 1,200

metric tons of phosphate per day at depth. Almost the same amount goes out at the surface, slightly less. This means, to the accuracy at which we can determine it, that phosphate is removed within Puget Sound, and goes into plant production.

The natural flux of phosphate can be compared to the total input of phosphate from all sewage disposal systems entering into the central basin. We have 1,200 metric tons per day, the natural flux, compared to around 12 metric tons per day from sewage courses.

So what is man's impact compared to Nature's? You were asking earlier for some perspective on magnitudes. This comparison helps us understand how small man's impact is in our area.

We have a rather unique estuary system, and we in the Puget Sound area are very proud of it. We are also very conscious of our aquatic environment.

You might recall that the State of Washington was the first State to have had an acceptable coastal zone management plan acceptable under Federal law.

On top of that, we recognized our environmental problems with regard to sewage disposal quite early in the game, certainly before the environmental legislation came along, with and certainly before EPA. Locally, we formed something called METRO, which is the Municipality of Metropolitan Seattle. This organization undertook to solve the problem of the eutrophication of our freshwater systems by diverting our discharges of treated effluent from the freshwater system to saltwater.

As a result, the lake systems have rehabilitated themselves, and we feel that we are in very good shape at the present time.

The Municipality of Metropolitan Seattle also volunteered to finance a study program over the last couple of years. A program designed to look at Puget Sound and to determine scientifically if sewage discharge had a significant impact on the central basin and whether the taxpayers should indeed pay the money to go to secondary treatment.

METRO-hired people from academia and some private consultants, to design studies in their particular area of expertise that would yield the best possible analysis of the situation and to come up with some significant answers as to the state of Puget Sound.

These researchers looked at heavy metals, dispersion of effluent, phosphate balances, you name it. There is a series of 12 reports available. I brought some of them with me, and I would be glad to have a set forwarded to the committee.

Mr. ROBERTS. Please, sir.

Dr. DUXBURY. After these reports were circulated to State and Federal agencies, the bottom line of all the information collected was presented at a meeting of representatives from State and Federal agencies. I sat in on that meeting and after hearing the presentations and then the questions that were asked afterward, I could only come to the conclusion that the material that was presented had not been digested, or else, if it had been read, it had not gotten in the people's hands that made the decisions.

We feel we have made a case to be granted a waiver, if the problem created by marine discharges is b.o.d., turbidity, and pH. We find now in the EPA regulations that there is a whole new ball game being

generated, and that the concern has shifted primarily to heavy metals and organic toxicants.

What we find is that the restrictive nature of the regulations, specifically with regard to estuaries, precludes anyone from ever being granted a waiver. I would like to address a few of these points, if I may.

What I see is kind of a catch-22 situation. It is almost as if you are damned if you do and damned if you don't. For instance, in the regulations, you have requirements of alternate treatment and are directed to use the one which is more restrictive.

We can show, for instance, in the heavy metals, that if we are allowed our initial dilution zone—which is indeed about 100 to 1 within 100 meters of pipe—that we do meet the requirements. But the regulations seem to say, if you meet that requirement, then you have to go to the more restrictive treatment. It means that you have to go to secondary or some auxiliary treatment anyway, because it is known in secondary treatment that some additional amount of heavy metals would be stripped out by their adherence to the particulate matter which would be removed.

By the way, I should say that the Puget Sound area is really unique, regarding heavy metals and toxicants. We do not have the type of industrial base that most of you are familiar with. We have looked at where our heavy metals come from, and if you worry about zinc and copper, we find a goodly portion of it comes out of our freshwater supply system. This is because we use zinc and copper pipes and we have very soft freshwater, which is slightly acidic.

Most of the heavy metals that we do find in the environment come from rivers, from atmospheric fallout or from land runoff. Specifically, there are several papers that cite the sources of these materials. You will find in these that the municipal sewage sources contribute only about 8 percent of the total input of heavy metals in the region. I would like to refer to "Heavy Metals From Waste Disposal in Central Puget Sound," by William R. Schell and Ahmad Nevissi, *Environmental Science and Technology* (vol. 11, No. 9, pp. 887-893, September 1977), and METRO study "Base Line Study of the Trace Heavy Metals in Biota of Puget Sound," by Scharleen J. Olsen and William R. Schell, 1977.

Mr. ROBERTS. The items referred to will be received for the record. (See page 257.)

Dr. DUXBURY. River runoff, land runoff, atmospheric fallout, contribute the remainder.

We have what we consider to be fishable, swimmable waters. We have had them all along, and have had no problem in the marine system. But we are told now by EPA if we do not install secondary treatment and seek a waiver that we have to place a greater burden on our industries for an even greater pretreatment practices than required elsewhere. Even then I wonder if we could still meet the standards because of the land runoff which is a portion of our sewage,

The toxic organics are presented as a nonending list that is to be kept open. We are asked to meet standards which I think are somewhat arbitrary.

I was looking in the water quality criteria book at heptachlor, and it is said that you have to take it down to .001 micrograms per liter, which is one part per trillion.

Well, we have hard testimony about one part per billion. One part per trillion is one-one thousandth of that. I did a calculation last night, and I think I am correct. To give you an idea of what we are looking for, that is one drop of vermouth in about 27 million gallons of gin, a very dry cocktail.

Dr. Bascom stated this morning, that you could measure routinely down to parts per billion. But it turns out there are only a few laboratories, probably, that are equipped to measure to the levels which the regulations are stating that we should meet. To boot, the regulations do not allow even the initial dilution at the discharge pipe to help reach the required concentrations on these organics. This is very restrictive.

The view I have with regard to the regulations that are presently recorded is that they tend to be almost conflicting and capricious, and that within the time frame that is set in these regulations for requesting a waiver, it would be impossible for an applicant to actually fulfill the requirements.

Within these regulations, it says that EPA wants waiver applicants to submit data that meets the satisfaction of the Administrator. I am curious what kind of a yardstick would be used to arrive at that point. There are certainly no standards for it. It almost appears that the regulations are written so that you could not get a waiver, no one could qualify, but then, at the discretion of the administration, a waiver might be granted based on a political basis and not really the scientific merit of the case.

The time frame which is set in order to fill the obligations to qualify for a waiver does not take into consideration that you have seasonal changes in estuaries. The organic toxicants which we have in our area are primarily those which are used as pesticides on people's lawns and farms. These come off in different amounts during the summer than during the winter. There is no way to document the seasonal type of variation within the allowable time frame.

There also seems to be a certain lack of understanding about estuaries. Within the regulations, it states that the estuaries are to be classified according to Hansen and Rattray, a paper which appears in "Limnology and Oceanography." This particular classification is one which tells you how much of the estuary salt is transported either by diffusion or by advection, or if the estuary is well-mixed or partially mixed, or is a salt-wedge type.

However, the real knowledge needed is the flux rate that carries the introduced materials seaward. There is no way this rate can be obtained from that particular type of analysis.

EPA also seems to be concerned, about the freshwater input and the freshwater storage. This is done historically, for if you take the freshwater stored in an estuary, divide it by the freshwater input, it will give you a residence time for the freshwater; how long is a parcel of freshwater apt to stay in the estuary.

However, if you look at the water budget of Puget Sound, you find out that the river through-put is only about one-sixtieth of the total flow. The other 59 parts of the total flow is composed of the saltwater in circulation within the system, and that is the flow that really does the job in flushing an estuary.

EPA further wants the wind and tide effects documented in conjunction with the influences of different tidal and wind conditions, different stratification conditions, and their modification by geographical and geomorphological conditions in time for the application deadline.

They do not seem to realize that this requires estimates over extended time periods to catch the vagueries of nature. In fact, not even physical tidal models, such as those built at great expense by the U.S. Corps of Engineers can do this, for they cannot model the winds.

The mathematical predictive models can give you some gross numbers, but in terms of the finesse with which you need to understand the fluid flow, it cannot be obtained except by physical modeling or measurements in nature.

Unfortunately, Puget Sound being unique in the United States, is the only major estuary that does not have a model under the Corps of Engineers, so we cannot test circulation and flow that way. We have a small research model of the Sound at the University of Washington that has been used to great advantage to look at problems associated with the location of diffuser pipes; to look at how well the effluent is dispersed, and to compare one location against another or the effect of placing a pipe at different depths. You can gain a great understanding of how an effluent will disperse in nature using this type of a model. This is something you cannot do in actual practice. You cannot afford to go out and put in a pipe and see what is going to happen. You have to do it by some other means.

Even the large amount of information that is available from the National Ocean Survey of NOAA, on tidal currents, is not collected in a manner that would give you any indication of net flow or indeed, the type of turbulent flow. It also does not indicate what kind of eddy structure you have and where materials would be going.

I think that the regulations are put together with good intentions, but they seem to indicate to me that possibly, people have been reading the literature and saying, "Oh, this is good, let's incorporate it." It is almost as if they were put together by those people who have been confined to a desk too long, and are not really cognizant of what happens in nature or the difficulty that you face in analyzing nature.

Mr. ROBERTS. Excuse me, Dr. Duxbury. We have a recorded vote on the floor, and we have to be there in 15 minutes. I am just trying to determine whether we should go over and come back.

Dr. DUXBURY. I will just make one very brief statement, and then I will stop.

We would like to hold our options open in the Puget Sound area with regard to sewage treatment. We realize that we would like to treat stormwater runoff. This means we have to collect it and hold it so that we can then schedule the rate at which it comes down through the pipe to the treatment plant.

It also means that as our population grows to the east, we have to incorporate more service areas into our system, so that we do not recreate the problems caused by the addition of nutrients to our freshwater systems using decentralized treatment facilities. This is not allowed in the waiver process.

We feel that if we have to change the location of an outfall to get better dispersion, it should be done, or if we have to reschedule flow

from one outfall to another to benefit the environment, it should be done.

The regulations leave no alternatives open and do not leave room for the creation of effective management plans for sewage disposal.

Thank you.

Mr. ROBERTS. Thank you, sir.

We tried, in all honesty, to give the administration the flexibility, but the way the regs are written, there is no flexibility at all, and he has no choice, I think.

Mr. McCormack had to leave. He has a bill up on the floor, I believe. But he asked me to ask you one question.

Is the flow and the size of Puget Sound such that it can handle the discharge of both domestic waste and waste from pulp and paper mills without damaging the marine environment?

Dr. DUXBURY. At the present time, we have several pulpmills on Puget Sound—Port Angeles, Port Townsend, and the Everett area. In the immediate area of the pulpmills, you will find an oxygen draw-down caused by sulfite waste, liquor if they are a sulfite mill. They have been operating for sometime but yet, in the same area where they discharge, there is commercial fishing and shellfish harvesting. Their impact depends on how large an area you allow as your initial dilution zone, and what you allow to be sacrificed.

Mr. ROBERTS. Thank you.

Mr. Clausen?

Mr. CLAUSEN. Just one question. As you know, EPA has very substantial resources, they have got highly dedicated people, and very knowledgeable, competent people. But yet, their views seem to be very much in contrast with what we have heard from expert witnesses here this morning.

What do you perceive to be the reason for this kind of difference?

Dr. DUXBURY. I think I would react the same way that EPA did if I were in their shoes. They are given the charge of protecting the environment, when we do not really know how to do it. We don't really know what does protect the environment, or what you can allow and what you cannot allow. So if you are in doubt, and you have the responsibility of protecting the environment, then the thing to do is close all doors.

I believe this is the reason for EPA's position and the type of regulations that now exist. Especially since these regulations have to cover all instances and environments.

The other viewpoint expressed by those testifying comes from the scientific knowledge gained from research in specific instances and from specific locations. It also stems from a thorough appreciation of the magnitude of the forces, motions, and assimilation capability of the marine environment. Research has shown that trends are not yet evident that indicate a degrading of the marine environment in specific areas. Thus since we are not dealing with irreversible processes there is time to continue present use practices and make only those corrections indicated by a monitoring program.

Somehow these two approaches must come together and be resolved on the merits of individual cases.

Mr. CLAUSEN. Thank you.

Ms. KOVALIC. In yesterday's testimony, Dr. Craven indicated that adding nutrients to an estuary can cause eutrophication. Could you comment on this?

Dr. DUXBURY. Yes. Dr. Craven is quite right. He comes from an area with lots of sunshine and very little seasonal variation in its intensity. In this kind of an area you have year-round radiation to promote plant growth, and you do tend to strip out the nutrients. The amount of plant production then is governed by nutrient supply. Thus, the addition of nutrients can cause increased plant growth.

In our area, the nutrient levels remain high all the time and our plant growth is keyed almost specifically to the seasonal cycle of the solar radiation.

Ms. KOVALIC. Can you tell us to what degree toxics are associated with suspended solids and hence would be removed by secondary treatment?

Dr. DUXBURY. As I mentioned, our industrial base is such that we have very little input of toxic materials. But it is known that if you have secondary treatment, you do remove some of the heavy metals since they adhere to suspended solids that are removed.

Mr. ROBERTS. Dr. Duxbury, this is a vote on the North Atlantic Alliance, so I will have to go. Would it be agreeable—counsel on both sides have a couple of questions they would like to submit in writing; would that be agreeable to you?

Dr. DUXBURY. Certainly.

Mr. ROBERTS. And let me thank all of you for your indulgence this morning, and above all, for your presence and your testimony. It has been the best I have ever heard, and we appreciate it very much.

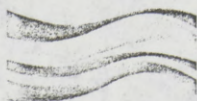
Mr. WOOD. Mr. Chairman, considering the depth and the competence of the witnesses and the testimony, it might be appropriate, when we put our committee report together—Mr. Clausen was going to suggest this—to have the staff and the Library of Congress work together to put a report out on these hearings.

Mr. ROBERTS. I think certainly, the type of witnesses we have had this morning deserve that kind of recognition, and again, we do appreciate it, and we hope we do not have to bother you with too many questions, but I am sure there will be some.

The subcommittee will stand in recess.

[Whereupon, at 12:49 p.m., the subcommittee was adjourned.]

[Dr. Duxbury's submissions for the record follow:]



DIVISION OF MARINE RESOURCES

UNIVERSITY OF WASHINGTON • A SEA GRANT COLLEGE

May 31, 1978

The Honorable Mike McCormack
1202 Longworth House Office Building
Washington, D.C. 20515

Dear Representative McCormack:

I was sorry that we did not have time to talk at the recent hearings regarding estuaries and their use as a receiving environment for sewage discharge. However, I felt that I should pass on some information to you that might clarify some points raised in the hearings.

Several times those testifying regarding ocean discharge mentioned that one should not discharge into estuaries. John Craven mentioned that the addition of nutrients to estuaries caused eutrophication. Dr. Ryther also made a similar statement. These people were quick to recognize the difference between the oceanic environments of the East and West Coasts of the United States and that the West Coast was a better receiving environment. They could also have made similar distinctions between individual estuaries--but did not.

Puget Sound is the only deepwater fjordlike estuary in the continental United States. Its waters are cold, rich in nutrients and high in oxygen. The large intertidal volume and narrow channels aid in producing turbulence and mixing. This tidal-generated turbulence, however, is not the process that assures the flushing of the Sound and the seaward transport of effluent discharged into the Sound. The net circulation, the inflow of sea water at depth and the seaward flow of surface water equivalent to the river inflow plus the incoming sea water, is the important transport mechanism. In the central basin of Puget Sound this transport has been calculated at approximately $59,000 \text{ m}^3/\text{sec}$ or 8-9 times the average flow of the Columbia River.

This transport of water also carries dissolved chemicals in and out of the Sound. The natural transports of phosphate are estimated to be about 1,200 metric tons per day, whereas the phosphate added to the central basin from all sewage sources is approximately 12.6 metric tons per day. The large exchange between the Sound and the ocean and the large natural flux of nutrients creates an environment that is nutrient rich. Plant production in the central basin is not limited by nutrient supply. Instead the available solar radiation acts to control plant growth. In Hawaii available solar radiation does not have a large annual variation and indeed nutrients may well be limiting as suggested by Dr. Craven.

The problem in Puget Sound is that as a particular marine environment it is capable only of receiving a fixed rate of input of toxicants. This rate is determined by the allowable concentration of these toxicants in the environment and the rate at which the natural circulation can transport these toxicants seaward.

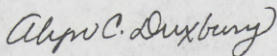
There are many sources of these toxicants--sewage effluent, land runoff, rivers and the atmosphere. The real task is to reduce the total toxicant inputs from all sources to stay below the assimilation and dissipation capability of the Sound. In Seattle, the sewage system handles both municipal wastes and land runoff. Other areas do not have combined sewage flows. I believe the challenge is to reduce total mass emissions of toxicants to the Sound and connecting freshwater bodies. To do so requires management planning, redesigning discharge and treatment facilities, construction of heavy runoff storage facilities, and changes in sewage service areas. All of these efforts may require actions that would not be allowed under the proposed EPA regulations. Yet these actions would be directed toward reduction of total mass emissions, the real key to protecting the environment.

The EPA requirements speak primarily to concentration levels of toxicants in the effluent pipe of municipal discharges. Therefore, a sewage system that does not handle land runoff could meet the regulations but the area served by such a system could have a higher total input of toxicants. Whereas a combined sewage system (which treats both sewage and land runoff as in the Seattle area) could, through rational treatment, result in a lower total discharge of toxicants to the environment and still not satisfy the EPA regulations.

The proposed EPA regulations leave little room for management practices that tackle the total problem of toxicant discharge to the marine environment. Any encouragement you might give EPA to consider the total problem and to evaluate municipal discharges in this light would be greatly appreciated.

If I can offer any assistance or information that has bearing on this problem, I would be happy to do so.

Sincerely,



Alyn C. Duxbury
Assistant Director for New Programs
Division of Marine Resources

ACD:nw

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A WATER BUDGET STUDY OF PUGET SOUND AND ITS SUBREGIONS¹

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ABSTRACT

A water budget study for Puget Sound and its principal subregions, based on the freshwater, seawater, and total water budgets, determines the mean fluxes of water into and out of these regions, the freshwater content, and the change in freshwater content by month and by year. Data used to calculate the budgets include monthly mean values of precipitation, evaporation, runoff, changes in sea level, mean salt content, and the salinities of inflowing and outflowing waters for each subregion. The fluxes of water calculated in the budget analysis yield an approximation of flushing efficiency and replacement time for Puget Sound and its subregions. The monthly freshwater content, along with the fluxes of water and their salt load, indicates that river runoff does not by itself control the freshwater content of a particular subregion; considerable freshwater is added by the inflow of water from an adjacent embayment.

INTRODUCTION

Estuaries, the partially isolated arms of the sea along the coast where freshwater dilutes seawater, have a net circulation that is driven by the addition of freshwater and modified by tidal and wind mixing. This net circulation controls the flushing of estuaries and determines many of the properties of the water within them.

The net circulation, or inflow and outflow of water, at the mouth of an estuary can be determined by direct measurements of flow with depth across the mouth. Direct measurements must be made over a considerable period to permit determination of both a temporally and a spatially integrated net flow. The expense and effort required to obtain a measured net flow distribution with depth on a seasonal basis lead most investigators to arrive at estimates of the net circulation in an estuary by an indirect approach using a budget analysis.

The budget approach in its simplest form

assumes that the volume of water and total salt content in an estuary, as averaged over a given period, are constant. Therefore water from all sources flowing into an estuary must be compensated for by an outflow of equal magnitude, and the salt carried in by one flow must equal the salt carried out by another. These assumptions are crude and tend not to hold in real estuaries, especially if periods over which budgets are calculated are less than a year.

Rivers adding freshwater to estuaries suffer periodic changes in their discharge rates, and thus the amount of freshwater contained in an estuary must vary and the total salt content as well. Changes of density within an estuary, and seasonal fluctuations in atmospheric pressure, cause a variation that is measurable as a sea level change. The change in freshwater content and in the volume of the estuary affects the exchange of water with the sea at the estuary mouth to complicate further the assessment of the actual budget. Processes external to the estuary also play a role in the budgets; coastal upwelling or downwelling alters the density of the water delivered to the estuary and may significantly change the inflow rate if this water can bodily displace the deeper water lying behind the entrance sill of the estuary.

Puget Sound has many more factors controlling the influx and efflux of water than

¹ Contribution No. 618 from the Department of Oceanography. This research was supported by National Science Foundation Grant GH-66 under the Washington Sea Grant Program and done under the auspices of the Department of Oceanography, University of Washington. The Washington Sea Grant Program is part of the National Sea Grant Program, which is now maintained by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce.

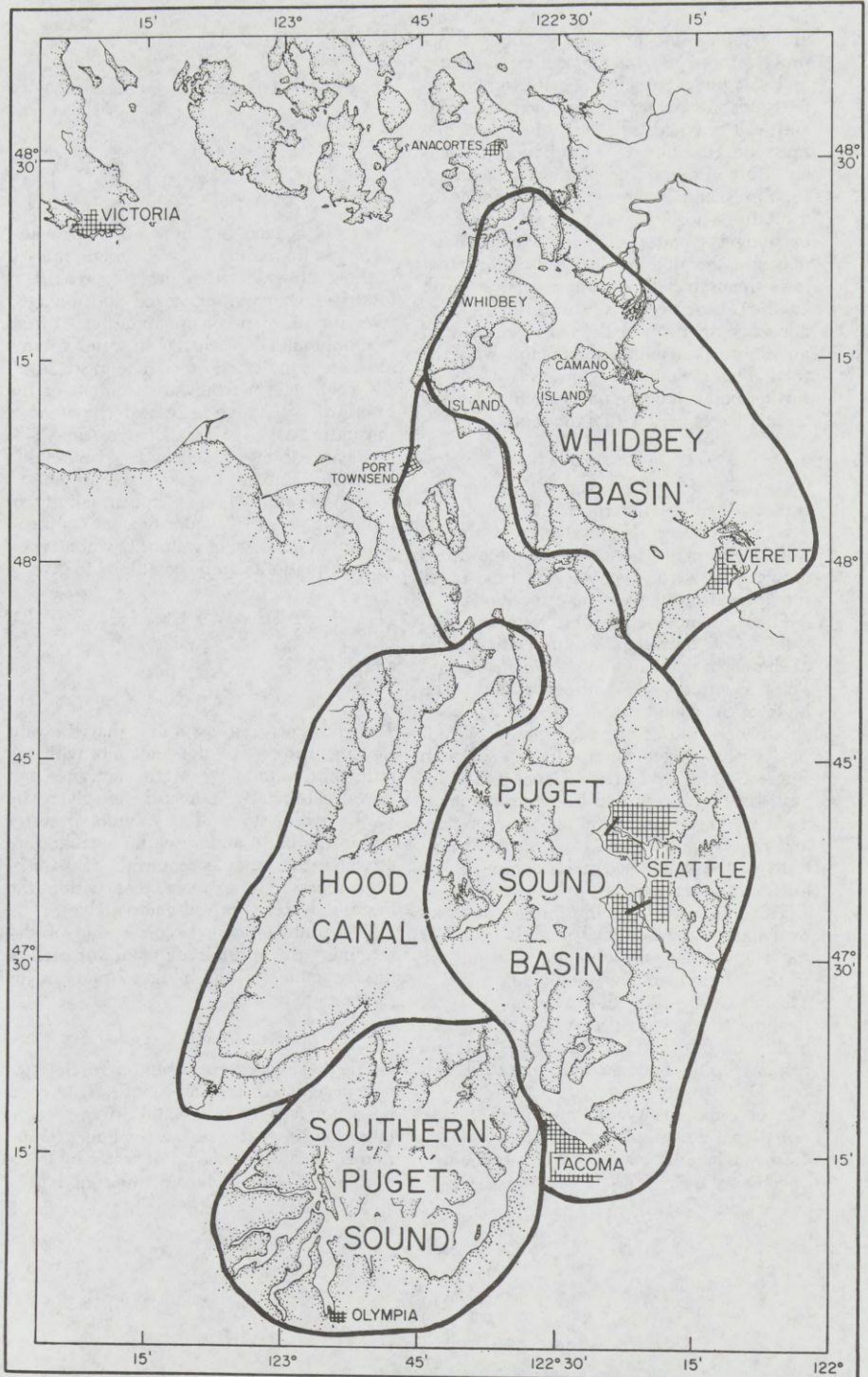


FIG. 1. Subregions of the Puget Sound system.

are assumed in the simplest budget approach; the equations that define the water and salt budgets cannot be the simple expressions of "water in equals water out" and "salt in equals salt out." More variables must be considered. This paper presents an effort to determine physically meaningful fluxes and budgets of Puget Sound as a total system, using a more applicable set of budget equations. Since Puget Sound may also be divided into subregions that lend themselves to the same analyses, calculations have been made accordingly. This allows comparison of the net circulation of one subsection with another and with the total Puget Sound region and leads to further understanding of the factors causing circulation to vary within the sound.

WATER BUDGET EQUATIONS

Analysis of a time variable and complex estuary involves determining three budgets: total water; freshwater; seawater or salt. These may be used to calculate fluxes of water and salt over varying time bases for the entire estuary or its subregions.

Puget Sound includes all waterways inside a line between Middle Point at the north end of Quimper Peninsula and Point Partridge on Whidbey Island. The body of the sound in this analysis has been subdivided into four subregions: Whidbey basin, Puget Sound basin, southern Puget Sound, and Hood Canal (Fig. 1). Statistical data required to determine areas and volumes, precipitation, evaporation, and runoff contribution from ungaged portions of the watershed were compiled but are not reported here.

This study presents the budget analyses over monthly and annual periods for all of the sound and its subregions, using the method described by Waldichuk (1957). The analysis also allows calculation of flushing times, which give insight into the ability of the sound to exchange water in response to the factors controlling the water budgets.

According to Waldichuk (1957), the equations governing total water budget, freshwater budget, and seawater budget respectively are:

$$T_i + R - T_o - \Delta W = 0;$$

$$\Delta F = R + \left(\frac{S_b - S_i}{S_b} \right) T_i - \left(\frac{S_b - S_o}{S_b} \right) T_o;$$

$$\Delta P = \Delta W - \Delta F$$

$$= \left(1 - \frac{S_b - S_i}{S_b} \right) T_i - \left(1 - \frac{S_b - S_o}{S_b} \right) T_o,$$

where T_i = average rate of inflow of water from sea to basin, T_o = average rate of outflow of water from basin to sea, R = total freshwater input, gaged and ungaged river runoff + direct precipitation - direct evaporation, ΔW = change in water volume of basin as indicated by change in sea level, ΔF = change in freshwater content of the basin, ΔP = change in seawater content of the basin, $\Delta W - \Delta F$ (all in vol/time); S_b = mean salinity of seawater available to fill basin if no freshwater were present (a reference salinity); S_i = mean salinity of inflowing water (T_i water type); S_o = mean salinity of outflowing water (T_o water type). These equations can be combined to give

$$T_i = \frac{S_o}{S_i - S_o} (R - \Delta W) + \frac{S_b}{S_i - S_o} (\Delta W - \Delta F),$$

and

$$T_o = T_i + R - \Delta W.$$

The flushing time, assuming that the outflowing water (T_o) does not mix with the inflowing water (T_i) at the entrance but flows continually seaward, is given by V_o/T_o , where V_o is the volume of water within the basin and T_o is the average rate at which the water is removed. This flushing process also assumes that within the basin T_i water is mixed completely.

The problem now becomes one of determining the appropriate values of each of the parameters in the budget equations for each month or year.

RUNOFF CALCULATIONS

The freshwater contribution to the system designated here as runoff, R , is composed of river discharge and direct precipitation on the water surface of Puget Sound minus the direct removal of water by evaporation from the surface of the sound.

TABLE 1. *Gaged river contribution* by month, $\times 10^6$ m³, in Puget Sound†*

	WB	SPS	HC	EPS
Jan	2,891.5	274.1	345.2	4,203.0
Feb	2,549.9	219.2	284.0	3,677.1
Mar	1,921.2	186.6	254.0	2,760.4
Apr	1,958.9	143.6	159.2	2,661.7
May	2,569.2	93.2	133.7	3,223.1
Jun	3,278.6	87.8	158.0	3,970.5
Jul	2,144.4	60.3	91.2	2,576.8
Aug	1,132.8	63.2	49.6	1,458.2
Sep	988.9	64.9	68.3	1,321.4
Oct	1,775.1	109.0	194.6	2,325.6
Nov	2,093.1	139.3	255.7	2,790.1
Dec	3,017.5	213.0	374.4	4,164.2
Total	26,321.1	1,654.2	2,367.8	35,132.1

* Determined from data in Water Resour. Data for Wash. (1965, 1966, 1967, 1968).

† WB = Whidbey basin; SPS = southern Puget Sound; HC = Hood Canal; EPS = entire Puget Sound area.

The monthly mean values of gaged river discharge are given in Table 1. However, freshwater can also enter the rivers below the lowest gaging station as ungaged river flow, and the sum of the gaged and ungaged portions is the total river discharge required here. Gaged river flow was evaluated for years of low stream flow (Water Resour. Data for Wash. 1952, 1958, 1966) and for years of high stream flow (Water Resour. Data for Wash. 1954, 1956, 1959) to determine if there was any significant variability; the annual mean gaged discharge into the sound could vary from 0.8–1.2 times the annual mean discharge for the period 1965–1968 used here.

The ungaged portion of the river contribution was estimated as equal to precipitation minus evaporation times the ungaged land area. We assumed that all of the excess precipitation over evaporation falling on the portions of the drainage basins below the gaging station returns to the sound as surface runoff and determined the monthly mean precipitation and evaporation values over the ungaged land area for each subregion (values were obtained from Climatol. Data for Wash. 1965, 1966, 1967, 1968). Data from three weather stations in the ungaged drainage basin area of each subregion were used to estimate the monthly mean precipitation by subregion.

Evaporation values were not available for Puget Sound on a monthly basis, but on an annual basis the evaporation rate for the entire region is about 64 cm yr⁻¹ (P. E. Church, personal communication; Puget Sound and Adjacent Waters Study 1970). Monthly values were estimated by taking those of Waldichuk (1957) for the Strait of Georgia area and increasing them all by a factor of 1.05 to make their annual value equivalent to 64 cm. We assumed that the evaporation pattern in Puget Sound is similar to that of the Strait of Georgia so that the adjusted values would reasonably estimate the evaporation pattern.

The land area comprising the ungaged portion for each subregion (Puget Sound Lit. Surv. 1954, v. 1, Sec. 3) was used to determine the ungaged river contributions. During summer months when evaporation exceeded precipitation, this flow is assumed to be zero. The annual average of the ungaged river contribution was 9.3% of the gaged flow and thus is a minor component of the freshwater added to Puget Sound. A second small source of freshwater is that supplied by direct precipitation on the surface of the estuary. This contribution was determined from direct precipitation times subregion water surface area. The monthly mean precipitation rate is assumed to be the same as that used in the previous calculation of ungaged river flow. The weather stations used to determine the monthly mean precipitation over the ungaged land areas were located in the Puget Sound lowlands, and it was assumed that the precipitation over water was similar to that over these areas.

The monthly loss of freshwater from the water surface of each subregion was calculated from the evaporation rates used in the calculation of ungaged river flow. This again assumes that the monthly evaporation rates for the sound are similar to those for the Strait of Georgia and vary with time but not location. The monthly loss of water from each subregion due to evaporation is comparable in magnitude to direct precipitation. The gain of freshwater by precipitation exceeds its loss by evaporation

TABLE 2. Total freshwater input, R , by month, $\times 10^6 \text{ m}^3$

	WB	SPS	HC	EPS
Jan	2,934	648	549	5,010
Feb	2,605	436	394	4,169
Mar	1,940	357	425	3,299
Apr	1,960	193	187	2,767
May	2,560	85	127	3,169
Jun	3,271	88	150	3,956
Jul	2,135	51	82	2,523
Aug	1,127	62	45	1,436
Sep	977	59	62	1,269
Oct	1,849	357	323	2,897
Nov	2,195	453	433	3,597
Dec	3,220	640	725	5,593
Total	26,773	3,429	3,502	39,685
Mean	2,231	286	292	3,307

over the annual cycle, but evaporation exceeds precipitation during summer.

The total freshwater input (R) for each subregion as calculated from the components, river flow (gaged and ungaged), direct precipitation, and direct evaporation, is listed in Table 2. The total determined by this method closely approximates the freshwater influx of $41,780 \text{ m}^3 \times 10^6$ given in the Puget Sound and Adjacent Waters Study (1970).

Two distinct periods of high runoff are apparent in the annual cycle: December and June. The December peak coincides with the time of maximum precipitation. The second peak occurs in June and is caused by the spring melt of snow at higher elevations of the drainage basin. If the subregion's drainage basin has little area in the snow-covered elevations, as do southern Puget Sound and Hood Canal, then the June peak is almost insignificant. However, for Whidbey basin the June peak caused by snowmelt entering the Skagit River is nearly as great as the December peak (this is the largest river entering Puget Sound, contributing 40–50% of the total river input).

A calculation of potential water supply was made to check on the annual average runoff and to estimate if a large volume of water reaches the sound by way of subsurface or groundwater flow. This potential was evaluated by establishing a curve of

annual precipitation vs. elevation and using the amount of drainage basin land area by elevation from the Puget Sound Lit. Surv. (1954, v. 1, sec. 3). Assuming an evaporation rate of 64 cm yr^{-1} for the entire drainage basin area, the amount of freshwater available to the rivers flowing into Puget Sound equals the total rainfall for elevation interval times area of elevation interval minus evaporation times drainage basin area. A rough calculation, using the average precipitation between 0 and 305 m times the watershed area for this increment plus the average precipitation between 305 and 1,982 m times the area of this increment minus the assumed annual average evaporation rate of 64 cm yr^{-1} times the total area, gave a potential freshwater supply of $38,325 \times 10^6 \text{ m}^3 \text{ yr}^{-1}$, close to the value shown in Table 2. This suggests that the supply of freshwater to the sound by groundwater is minor compared to surface runoff. The annual volume of freshwater (R) contributed to all of the sound would have a height of 15.9 m and an area equal to Puget Sound.

CALCULATION OF THE CHANGES IN WATER VOLUME OF THE BASINS, ΔW

The monthly change in basin water volume (ΔW) due to change in sea level height (Δh) has been calculated using the monthly mean change for the 1933–1963 period for Seattle. These unpublished data, obtained from the National Oceanographic Survey Environmental Data Service, are a record of the vertical displacement between a benchmark and the mean level of the water surface in Puget Sound by month in Seattle. The volume change is assumed to be Δh times the surface area of Puget Sound. It is assumed that the change in sea level at Seattle is representative for all of the sound and that the surface area does not change with Δh . Values of Δh and ΔW are shown in Table 3.

CALCULATION OF THE FRESHWATER CONTENT AND ITS CHANGE, ΔF

The monthly freshwater storage of the sound and its subregions can be evaluated

TABLE 3. Change in water volume (ΔW) due to change in sea level height, by month, $\times 10^6 \text{ m}^3$

	WB	SPS	HC	EPS	Δh (cm)
Jan	+0.58	+0.42	+0.37	+2.52	+0.1
Feb	-37.50	-27.46	-24.22	-163.57	-6.6
Mar	-30.38	-22.25	-19.63	-132.52	-5.3
Apr	-7.22	-5.29	-4.66	-31.50	-1.3
May	-2.88	-2.11	-1.86	-12.57	-0.5
Jun	-1.45	-1.06	-0.93	-6.31	-0.3
Jul	-2.88	-2.11	-1.86	-12.57	-0.5
Aug	+5.78	+4.23	+3.74	+25.22	+1.0
Sep	+14.46	+10.59	+9.34	+63.08	+2.5
Oct	+27.43	+20.09	+17.72	+119.65	+4.8
Nov	+39.06	+28.61	+25.23	+170.39	+6.9
Dec	-5.78	-4.23	-3.74	-25.22	-1.0

from the expression $(S_b - S_p) S_b^{-1} \times \text{vol of water in a basin} = \text{vol of freshwater present}$, where S_b is the salinity of the source seawater undiluted by freshwater, and S_p is the average salinity of the water volume in question. If there were no freshwater present to dilute the estuary, it would have the salinity of the source water; if freshwater is present, the estuary will have a salinity lower than S_b . The average salinity can be determined for the diluted estuary and one can calculate from the above equation the volume of freshwater required to reduce the salinity from S_b to S_p .

The value of S_b is assumed to be 33.8‰, the value used by Waldichuk (1957) in his study of the Strait of Georgia, which also has as its source water the Strait of Juan de Fuca. The value of 33.8‰ approximates the salinity found at midchannel near the bottom of Juan de Fuca Strait; it may approach 34.0‰ in late summer or drop to 33.5‰ in winter (Puget Sound Lit. Surv. 1954, v. 3, Sec. 12). The freshwater content calculated in this manner is not rigorously quantitative since the value of 33.8‰ assigned to S_b is somewhat arbitrary, but the volume evaluated on this basis can be regarded as relative (Waldichuk 1957).

It was necessary to examine the monthly salinity distribution for each subregion to determine a reasonable value for S_p . The volume of water in 10-fathom (18.3 m) depth increments was available from McLellan (1954) and was used to obtain the

volumes for the depth increments 0–10 m, 10–50 m, 50–100 m, and 100 m–bottom for each subregion.

An S_p value for each subregion was obtained by determining the total salt content by month for each depth interval of each subregion. Salinity data required for this process were chosen from Collias (1970). Four stations were selected for each subregion. Two salinity profiles with depth from a common month were drawn for each station, and from these profiles the average monthly salinities and total salt content determined for each depth interval. The sum of the salt content by depth layer was then determined for a subregion. This total monthly salt content divided by the total volume of the subregion, assuming that the density of seawater equals 1.00, yielded the average salinity of that subregion.

The monthly freshwater content obtained by using the S_b and S_p values derived in this manner was then used to determine the monthly change in freshwater content (ΔF). Although the arbitrary assignment of a value to S_b makes the evaluation of ΔF arbitrary, the values found for ΔF in the subregions have significance in that the amounts of freshwater possessed by each subregion and their change in time are relative to each other. More serious is the problem of evaluating S_p for each basin. Salinity data, taken over a great many tidal cycles each month and uniformly distributed over each basin, are needed to assure an accurately integrated value of total salt content, but these are not available. We hope that the values of S_p used here are reasonable approximations of those that would be found if more data were available. The total salt content of each depth increment is expected to have a greater error than the total salt content of the entire volume formed from their sum.

The relationship between the monthly variation of runoff and total freshwater content of the basins for each subregion is depicted in Figs. 2–6. In Whidbey basin the large amount of freshwater that enters from the Skagit River results in a delay of less than a month between the runoff peak and the peak of the freshwater content curve. In

TABLE 4. Average salinities (‰) of outflowing (S_o —left) and inflowing (S_i —right) water, by month

WB	SPS	HC	EPS		WB	SPS	HC	EPS
26.5	28.5	27.8	28.8	Jan	30.0	29.5	29.9	30.8
25.5	27.8	27.8	28.9	Feb	29.2	29.1	30.0	31.3
26.9	29.2	28.5	28.9	Mar	29.8	29.7	29.9	32.4
26.6	27.9	28.9	28.4	Apr	28.8	28.5	30.2	33.0
26.4	28.0	28.4	28.4	May	29.8	29.1	30.3	32.5
26.4	28.3	27.9	30.1	Jun	29.2	29.1	30.8	33.0
26.8	28.4	28.5	29.0	Jul	29.8	29.3	30.8	33.0
26.7	28.7	28.9	30.9	Aug	29.6	29.5	30.8	33.1
29.1	29.8	29.4	29.8	Sep	30.5	30.4	31.1	33.2
26.0	28.6	28.9	30.2	Oct	30.3	30.1	31.1	32.7
26.0	29.8	29.5	29.6	Nov	30.5	30.4	30.9	32.5
28.0	28.7	26.8	27.8	Dec	30.1	29.9	29.8	31.8
26.7	28.6	28.4	29.2	Mean	29.8	29.6	30.5	32.4

Puget Sound basin, southern Puget Sound, and Hood Canal, the delay is from 2–3 months, probably because of the lower input by local rivers and the greater contribution of freshwater from adjacent basins by the entering T_i -type water. In all of the graphs, there is a noticeable decrease in the freshwater content for March and a recovery in April, caused by high S_p values determined from survey data for March and low ones in April (which cause oscillations in the calculated freshwater content). These S_p values and their effect may not be typical.

DETERMINATION OF THE AVERAGE SALINITY OF THE OUTFLOWING AND INFLOWING SEAWATER, S_o AND S_i

We determined the average monthly salinity of the outflowing water (S_o) by drawing distributions of salinity with depth for stations on the inside of the sill for each subregion. The halocline almost always occurred at 10 m. It was assumed that outflowing water, T_o , was primarily of the type found at depths above that, and the average salinity of the top 10 m was used as the monthly value of S_o for each subregion.

The average monthly salinity of the inflowing water (S_i) was determined from station data at the entrance side of each subregion slightly seaward of the sill. Again monthly salinity profiles with depth were drawn, and the average salinity below sill depth (below 50 m for Whidbey basin)

was used as the value for S_i . Values for S_o and S_i are shown in Table 4.

The accuracy of S_o and S_i values, like that of S_p values, is in doubt. Again samples taken over many tidal cycles would be needed to obtain representative values of the salinity at the mouths of the subregions. It would also be desirable to have vertical current profiles integrated with time over each month to determine the depth distribution of T_i and T_o flows, which could then be used to establish the depths over which S_i and S_o should be determined and to serve as a check on the values of T_i and T_o calculated from the water budget analysis.

Despite the errors in T_i and T_o that may be generated by S_i , S_o , and S_p values, a budget analysis of this type giving values of exchange rates to even a $\pm 30\%$ accuracy is better than none at all. The overall accuracy of the estimates of T_o and T_i in this analysis cannot be assessed, and the $\pm 30\%$ is stated only for the sake of perspective.

The values of the component parts of the equation used in calculating T_i are in Tables 2, 3, and 4; tabulations of T_i and T_o are in Table 5. The monthly replacement or flushing time as calculated from the basin volume and T_o is given in Table 6.

DISCUSSION

The budget calculations, despite their shortcomings, yield some insight into the behavior of Puget Sound and its subregions.

TABLE 5. Average flux of inflowing (T_i —left) and outflowing (T_o —right) water, by month ($\times 10^6 \text{ m}^3$)

WB	SPS	HC	EPS		WB	SPS	HC	EPS
15,403	13,602	2,209	39,889	Jan	18,337	14,251	2,753	44,896
23,851	10,014	8,422	76,560	Feb	26,493	10,478	8,842	80,890
13,826	11,059	3,271	5,251	Mar	15,797	11,438	3,716	8,683
26,519	16,712	7,516	27,728	Apr	28,487	16,910	7,709	30,526
16,570	4,067	983	24,338	May	19,133	4,155	1,113	27,518
30,954	8,757	2,121	47,068	Jun	34,225	8,842	2,280	51,030
26,389	5,871	4,843	38,221	Jul	28,527	5,922	4,928	40,755
16,879	6,686	3,871	37,014	Aug	18,000	6,746	3,914	38,425
8,221	5,902	4,990	11,235	Sep	9,184	5,950	5,044	12,441
13,140	8,986	3,177	39,351	Oct	14,961	9,323	3,483	42,129
9,079	2,300	-816	7,088	Nov	11,235	2,724	-408	10,515
44,267	12,888	6,700	29,056	Dec	47,495	13,531	7,428	34,672

The monthly mean addition of freshwater by surface runoff and the freshwater content of the sound (Fig. 2) show that the latter always exceeds the former. Further, it appears that the maximum or minimum freshwater content occurs 1.5–2 months after the maximum or minimum influx of freshwater. Several factors create this time lag.

Within a basin, mixing of the freshwater with seawater by tidal turbulence causes a change in the efficiency of the seaward transport of surface water, T_o , in removing freshwater from the basin. If equal parts of freshwater and basin water form the surface water flowing seaward, then the seaward flow rate must be about twice the river contribution and contain about half inflowing-type water. However, tidal mixing outside the basin between T_o and T_i waters tends to add freshwater to the T_i -type water. Thus, the T_i flow must increase to

bring in salt to suppress the local freshening of the basin water and T_o flow must increase to maintain continuity. Hence, changes in the supply of freshwater trigger a change in the T_o and T_i flows. Since response of these flows is not immediate, some time lag is created.

Other factors affecting the ability of the freshwater content to keep pace with the local contribution by rivers are outside influences that produce changes in the freshwater content of T_i water in addition to mixing between inflowing and outflowing water at the basin entrance. In spring, considerable freshwater is added to the Strait of Juan de Fuca system from Canadian sources, where tidal mixing tends to add freshwater to the water forming the T_i flow. In late summer, coastal upwelling tends to increase the salinity of the water forming the T_i -type available to the sound. The net

TABLE 6. Replacement time* (in days)

	WB	SPS	HC	EPS
Jan	46	33	272	113
Feb	32	45	85	62
Mar	54	41	202	582
Apr	30	28	97	166
May	44	114	672	184
Jun	25	54	328	99
Jul	30	80	152	124
Aug	47	70	191	132
Sep	93	80	149	407
Oct	57	51	215	120
Nov	76	174	-183	480
Dec	18	35	101	146
Mean	40	56	177	152

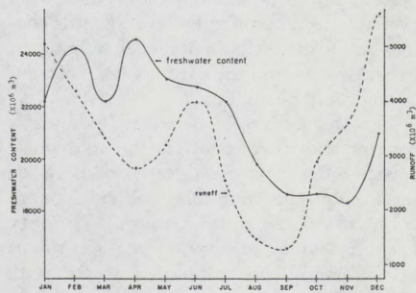
* Replacement time = basin volume/ T_o .

FIG. 2. Total freshwater contribution and freshwater content to Puget Sound, monthly mean values 1965–1968.

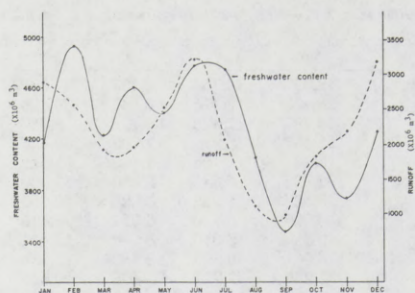


FIG. 3. Total freshwater contribution and freshwater content to Whidbey basin, monthly mean values 1965-1968.

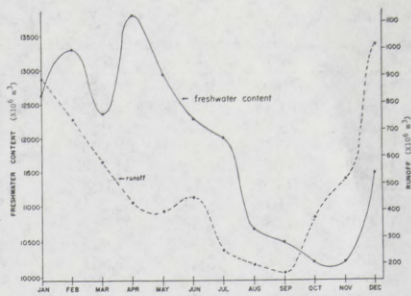


FIG. 4. Total freshwater contribution and freshwater content to Puget Sound basin, monthly mean values 1965-1968.

result of these factors is the relationship between freshwater content and river runoff depicted in Fig. 2.

Although the two peaks of river runoff, in winter from heavy precipitation and in spring from snowmelt, are of obvious origin, the maxima and minima in the freshwater content in February, March, and April have no clear explanation. It appears that the average salt content determined during March might have been too high (or for April too low). However, a check of the calibration data and duplicate sample analysis performed at the time the samples were run indicates that the salinities were correct and acceptable. Since no fault could be found in the salinity values and the data were treated the same for all months, the irregularity in the freshwater content curve must stand. Presumably if more data were available to determine the average salt content for a given basin for each month, S_p irregularities in the freshwater content curve would be minimal.

The relationships between freshwater content and river runoff in the subregions (Figs. 3-6) show the differences between these subbasins and their individual contribution to the total pattern. Whidbey basin has winter and spring peaks in runoff of comparable magnitude (Fig. 3), with the freshwater content closely coupled to river discharge. This indicates that the primary sources of freshwater in Whidbey

basin are local rivers, with the importance of freshwater added by T_i -type flow accordingly reduced. Whidbey basin has one feature not common to the others: It has no sill to restrict inflow and outflow of water at its entrance, and has less tidal vertical mixing at its mouth for this reason. Lessened vertical mixing allows the T_0 and T_i flows to occur readily and not affect each other appreciably at the basin mouth. Freshwater content lags behind freshwater input less for Whidbey basin than for any of the others. The runoff in Whidbey basin is by far the largest source of freshwater to Puget Sound (Table 2) and can thus enter into the other subbasins as a freshwater component in the T_i -type flow.

The central basin is the common region into which the subbasins cast their T_0 flow and from which they receive their T_i -type water. A meaningful T_i , T_0 transport cannot be calculated for this central basin by the methods applied to the entire sound or its major appendages. However, its freshwater runoff and freshwater content can be calculated and are shown in Fig. 4. These two curves show that the peak freshwater content lags behind the peak wintertime input of freshwater in a manner similar to that for the total system. As freshwater input decreases, the time lag between the minimum freshwater content and freshwater supply decreases because the summer influx of high salinity water produced by coastal upwelling and large values of T_i (Table 5)

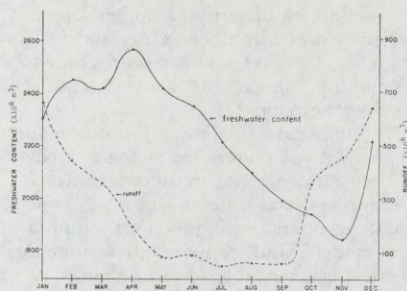


FIG. 5. Total freshwater contribution and freshwater content to southern Puget Sound, monthly mean values 1965-1968.

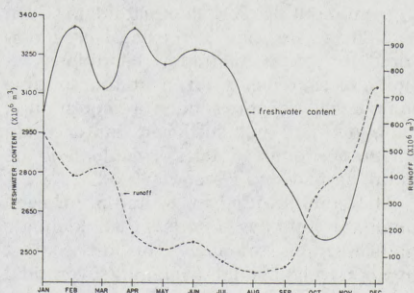


FIG. 6. Total freshwater contribution and freshwater content to Hood Canal, monthly mean values 1965-1968.

rapidly lower the apparent freshwater content of the central basin.

Southern Puget Sound and Hood Canal behave similarly in their freshwater cycles (Figs. 5 and 6), although the time lag between the peak of the local freshwater runoff and the peak of the freshwater content is greater for the latter than for the former. The delay during late winter-early spring is because the freshwater in the inflows of these basins has its primary source in Whidbey basin and has worked its way through the central basin to the entrances of Hood Canal and southern Puget Sound. This indicates that Hood Canal has, in general, a poorer circulation than southern Puget Sound. The recovery of freshwater content for Hood Canal in fall, however, appears to be more rapid than in southern Puget Sound, due probably to the closer proximity of the entrance of Hood Canal to the source of freshwater from Whidbey basin, which increases at the same time as local river runoff to Hood Canal.

The replacement time (in days) gives an indication of the ability of a basin to flush itself (Table 6) and may be looked upon also as a flushing efficiency. If a month is 30 days, then 30 days divided by the tabulated monthly flushing times and multiplied by 100 gives a percent efficiency of flushing for each basin and each month. A month showing a flushing time of 60 days for a given basin indicates that half

the water in the basin can be exchanged that month, a 50% efficiency.

The flushing times or efficiencies so determined do not necessarily indicate what actually happens in nature, because the inflowing water does not completely mix with the water in a basin. During late summer, the T_i water entering the central basin from the Strait of Juan de Fuca is at its densest and may spill over the sills to displace the less dense, deeper water of the various basins. Thus a 100% displacement of deeper water in a basin may occur over a relatively short period, with a less efficient exchange occurring above. Once this deep water replacement has occurred, then the further introduction of water of lesser density may increase the exchange with the shallower water, but have little effect on the deeper water.

The irregularities in the freshwater content already mentioned produce changes in the sign and magnitude of the freshwater content that may not be real but that produce irregularities in T_i and T_0 affecting the calculation of replacement times. Negative values of replacement times have no significance. The -183 days replacement time calculated for the period between November and December in Hood Canal presumably represents a period when flushing was active and replacement time was short.

The irregularities in calculated freshwater content arise primarily from the determination of the mean salt content of a basin for

a given month from inadequate data. Even though the area has been extensively monitored for its oceanographic conditions, salinity measurements taken at four or five midchannel locations once a month in a subregion are not sufficient for accurate integration of the total salt content of the entire basin over a 1-month period.

The salinities used for S_0 and S_i for each month also are based on less than adequate data since measurements of salt content are not available for averaging over tidal cycles. Salinities measured near the entrance to the major subbasins yield a different pattern on the rising than on the falling tide. This variation must be averaged out several times during the month to obtain values representative for the whole month.

However, despite the overall problem in evaluation of the budgets owing to the lack of available basic data, the results are reasonable and consistent with what we know about Puget Sound from a descriptive viewpoint. Thus it seems reasonable to accept the results of this analysis as a first approximation of the month-by-month water budgets of the sound and its subregions.

The water fluxes found here represent the base data necessary to carry on many studies in Puget Sound. The R , T_0 , and T_i transports can be used along with additional chemical data to determine the efflux and influx of nutrients. This coupled with observed changes of nutrients within the sound and its subregions can be used to obtain a first order approximation of organic production. The data presented here also can

be used to aid in verifying numerical model schemes presently under study and furnish a guide for developing smooth functions describing annual changes by month of freshwater input.

A numerical model using this information to make predictions of the changes of chemical constituents and transports can in fact produce refined estimates of S_0 , S_i , and S_p that can upgrade the functions required in the model. Until representative numerical models are available to tell us more about the mass budgets of Puget Sound, and until we have more measurements in both time and space, refinement of the water budget will be difficult.

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Heavy Metals from Waste Disposal in Central Puget Sound

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One of the sources of the Puget Sound metals which are measured in this study—Pb, Cd, Zn, Hg, Cu, and Ni—is the liquid effluent from the Municipality of Metropolitan Seattle (METRO) sewage treatment facility which is discharged through diffusers at West Point, Seattle, Wash. The focus of this study (a part of the Puget Sound Interim Studies) is on the measurement of heavy metals in water, biota, and sediments collected near and far from the sewage treatment plant at West Point. Seasonal collections of water and biota samples show that there are few significant differences between the amounts and kinds of metals measured in samples collected near the outfall and at control stations. The concentrations of metals in Puget Sound water, except for Pb and Cd, are similar to the reported values for open ocean water. The intertidal and benthic biota show only small increases in concentrations at control stations. The sediment cores dated by ^{210}Pb techniques have given information on the history of metal accumulation in Puget Sound over the past 100 years. The concentrations of several metals in the surface sediments are 1–3.6 times greater than the concentrations in sediments deposited 50 years ago.

The key problems in the control of aquatic pollution are how to dispose of liquid wastes caused by man's activities and how to determine the amount of liquid waste that can be carried by the receiving waters without damage to the ecosystem. Information on the disposal of heavy metals into salt water from large municipal sewage disposal plants, such as the one at West Point in Seattle, is limited. An assessment of these disposal problems must include quantitative measurements of the levels of heavy metals in the ecosystem and the comparison between the natural levels and pollution levels in samples. This report presents data on concentrations of the heavy metals Cu, Cd, Pb, Hg, Ni, and Zn which have been measured in water, biota, and sediment samples collected near a domestic sewage outfall in Central Puget Sound and from control areas.

Puget Sound is a fjord-like estuary in Northwestern Washington State (USA), located some 200 km from the ocean and to the east of a coastal range of mountains. Marine water from the Eastern Pacific enters the Sound at depth through the Strait of Juan de Fuca; freshwater enters the estuary from several rivers, from local runoff, and from precipitation. Overall, the waters inside the Sound are a continuously changing mixture averaging about 10 parts ocean water and 1 part river water (1). Superimposed on the net surface outflow and deep inflow are large oscillating tidal currents. These

tidal currents are the primary source of energy for vertical and horizontal mixing through the Sound. The volume of the basin is about 169 km^3 and encompasses an area of 2600 km^2 ; the mean volume of water in the tidal exchange is 8 km^3 . With such a large volume of water constantly in motion, the mean residence time for much of the water is only 120–140 days. However, water in isolated inlets and in deep basins has a much longer mean residence time.

The sources of heavy metals entering Central Puget Sound, in addition to the natural input by rivers, are the liquid effluent from sewage, industrial waste, shipping, runoff water which carries eroded materials from land development areas, and atmospheric fallout. The largest sewage treatment plant located on the Sound is operated by the Municipality of Metropolitan Seattle (METRO) at West Point in Northwest Seattle. This single plant now processes most of the domestic and industrial sewage of Seattle and the surrounding region. The raw sewage receives primary treatment and sludge removal. The effluent is chlorinated prior to discharge through a 2.44-m diameter pipe extending 1113 m from shore. The diffuser section of the pipe has 203 ports of 11.4–14.6 cm diameter and is located at an average depth of 70 m (2). At the location of the discharge there are strong tidal currents which contribute to the mixing and dispersion of the effluent. The plant has an average dry-weather flow capacity of 470 million L a day and a peak hydraulic capacity of 1240 million L a day.

Experimental Methods

The locations of the West Point and three smaller outfalls (identified as water treatment plants, WTP) in Central Puget Sound are shown on the map in Figure 1. Water, sediment, and biological samples have been collected at stations located in the immediate vicinity of the West Point outfall and from several remote areas.

Two methods have been used in sampling the water column for heavy metals. The first is by closely spaced profile sampling through the pycnocline to the bottom, both within and away from the expected effluent plume, utilizing 30-L Niskin water bottles for the instantaneous collections (3). The second method is by continuously sampling over 1–2 h at two or three discrete depths with a polyethylene hose, a plastic pump, and Battelle large-volume water samples (BLAWS) made from polyethylene to minimize metal contamination (1). This sampling method concentrates certain heavy metals on filter/sorption beds in the field from large volumes of water. It also partitions the metals into the particulate fraction, $>0.3 \mu\text{m}$, using Millipore filters, and into the soluble fraction, using Chelex-100 resins. While the separation of the fraction of the total concentrations entering the marine waters into the

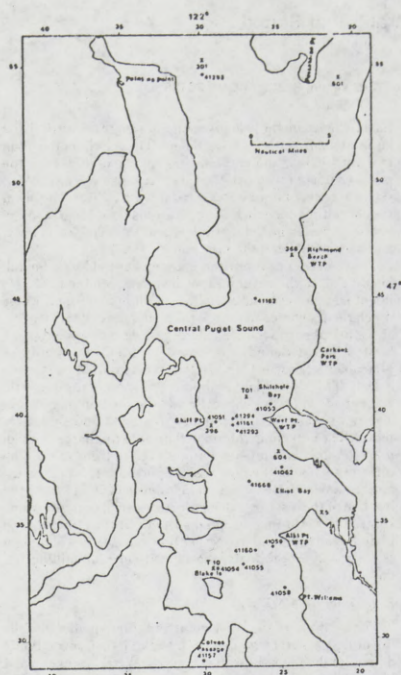


Figure 1. Location of water treatment plants (WTP) and sampling locations for cores, $\bullet$, and for water, $\circ$, in central Puget Sound.

particulate, colloidal, soluble inorganic, soluble organic species would be desirable, no satisfactory method to accomplish this speciation has yet been devised. The BLVWS with sorption beds, however, do permit some field speciation to be made in addition to measuring the total concentrations. Detailed evaluation of the technique has been made recently by Hunter (5).

The chemical and physicochemical speciation of heavy metals may be important to the mechanisms of uptake by biota. For example, the form of mercury in edible fish muscle is almost completely methylmercury (6) which is more toxic chronically than other forms of mercury. Other heavy metals have not been evaluated sufficiently to give toxicity guidelines for specific chemical states of metals in the marine environment.

The apparatus and the techniques for the integrated and discrete sampling methods have been calibrated internally against each other and externally with other institutions in a joint sampling cruise (5). The results showed that the total concentrations of heavy metals measured by the two methods were similar and that agreement was found for several heavy metal concentrations measured by the BLVWS technique compared to other techniques in the external intercalibrations as shown in Table I.

Sediment cores were taken with a 5 cm diameter gravity corer and a 3.5-cm damped piston corer, using plastic core

liners. Benthic and pelagic samples of biota were collected with nets, using the College of Fisheries vessels, *R. V. Com-mando* and *Alaska*; intertidal samples were collected by hand. All samples were placed in polyethylene bags and frozen immediately after collection.

Samples were processed under conditions which minimized possible contamination by heavy metals. The Millipore filters from the BLVWS were dissolved in distilled reagent grade HNO_3 and wet-ashed with HClO_4 (7). The resin beds from the BLVWS were placed in specially cleansed polyethylene columns and eluted with distilled reagent grade 2 M HNO_3 (8). The biological samples were dissected by using Teflon-coated tools and stainless steel knives, and then were dried and homogenized. The sediment core samples were sectioned into 1-cm slices and the outer 3-mm portions were removed; the sections were then dried, homogenized, weighed, and a portion was wet-ashed with distilled HNO_3 and HClO_4 . Note: caution should be practiced when using HClO_4 . After wet-ashing, the samples were diluted to volume with distilled 0.3 M HCl for atomic absorption spectrometry analysis (AAS) or for ^{210}Pb analysis (9). Small aliquots (0.5–1.0 g) of the dried biological and sediment samples were weighed accurately and placed in 2/5-dram polyethylene vials for neutron activation analysis (NAA). The Triga reactor at Washington State University, Pullman, Wash. (neutron flux of $10^{13} \text{ n cm}^{-2} \text{ s}^{-1}$), or the teaching reactor at the University of Washington (neutron flux of $10^{12} \text{ n cm}^{-2} \text{ s}^{-1}$) was used for the irradiations. After irradiation and a 1–2-week "cooling" period, the resulting radionuclides were measured by calibrated Ge(Li) detectors at the Laboratory of Radiation Ecology (LRE), and the

Table I. Inter- and Intra-Laboratory Comparisons of Batch and BLVWS Samples for Zn, Cu, Ni, Cd, Co, and Mn in Fresh (Lake Washington) and Salt (Juan de Fuca Strait) Water. Concentrations in $\mu\text{g/kg}$

	Zn	Cu	Ni	Cd	Co	Mn
Juan de Fuca Strait						
Filtered						
OSU ^{a,c}	0.5	0.4	0.4	0.1	0.14	0.9
	0.6	0.8	1.3	0.1	0.15	1.1
LRE ^{b,d}	0.42	0.02	0.37	0.09	0.81	0.47
	0.47	0.02	0.50	0.20	1.02	1.27
Unfiltered						
OSU ^c	0.4	0.4	0.35	0.5	0.11	1.4
	0.5	0.4	0.36	0.6	0.15	1.2
LRE ^c	<0.02	0.87	...	0.03	0.18	...
	0.39	...	...	0.03	0.29	...
LRE ^d	0.50	0.05	0.43	0.10	0.91	1.67
	0.51	0.05	0.58	0.24	1.20	2.96
Lake Washington						
Filtered						
OSU ^c	1.6	0.2	0.5	0.02	0.03	0.5
	1.3	1.3	0.7	0.02	0.06	0.7
LRE ^d	0.28	...	0.10	0.08	0.22	0.60
	0.17	...	0.42	0.16	0.40	1.28
Unfiltered						
OSU ^c	0.3	1.0	0.4	0.02	0.03	4.1
	0.3	1.0	0.7	0.01	0.3	4.1
LRE ^c	0.55	0.63	...	0.03	<0.02	...
	5.17	1.06	...	0.09	0.05	0.02
LRE ^d	0.72	...	0.10	0.33	0.18	4.53
	0.79	...	0.42	0.16	0.40	4.04

^a OSU, Oregon State University, N. Corvallis. ^b LRE, Laboratory of Radiation Ecology. ^c Discrete water samples—solvent extraction. ^d Sequential BLVWS samples.

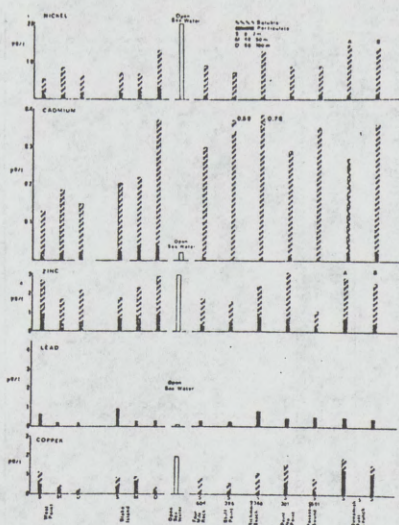


Figure 2. Concentrations of heavy metals in particulate and soluble fractions

Total concentrations of metals in water collected with BLVWS at eight locations in central Puget Sound are compared with open ocean water. Collections made at three depths: surface/S, 0.5-2 m; mid-depth/M, 40-50 m; and deep/D, 90-100 m. (Concentrations in $\mu\text{g/L} \pm 15\%$ propagated analytical error)

spectral data were analyzed by computers. Blank, control, and standard (interlaboratory comparison) samples were measured together with each group of samples. The quality control of the measurements was monitored by an outside group who prepared "unknown" standard solutions of heavy metals for measurement with each group of samples.

Results and Discussion

The concentrations of the heavy metals Ni, Cd, Zn, Pb, and Cu in the water collected by using the BLVWS at the eight stations are shown in Figure 2. The histograms show the concentrations of heavy metals in the particulate ($>0.3 \mu\text{m}$) and soluble fractions of seawater from Central Puget Sound and the open ocean (10). The concentrations of Cd and particulate Pb in Central Puget Sound waters appear to be higher than those found in open seawaters. The concentrations of soluble Pb also were measured in samples (range, 2-7 $\mu\text{g/L}$), but were not included in Figure 2 because of the uncertainty of the measurements. This uncertainty resulted from the low collection efficiencies for soluble Pb (10-15%) found by using the BLVWS technique with sorption beds of Chelex-100. [See Nevissi and Schell (11) for the calculation method.] However, the particulate concentrations measured for all samples and the soluble concentrations measured for the metals, except for Pb, should be valid. Patterson and Settle (12) have illustrated the many contamination problems in measuring Pb from natural waters; the contamination problem cannot be completely ruled out in the measuring of our samples either. On the other hand, Riley and Taylor (8) found that Pb was retained on Chelex-100 with high efficiency from seawater samples; thus, the Pb would be expected to be collected as well

as the other metals by the Chelex-100 used here. If the soluble Pb in Puget Sound is in a different chemical state than that measured by Riley and Taylor, then the low collection efficiencies found for the soluble Pb by the BLVWS technique could be understood. Additional effort needs to be made to resolve these discrepancies.

The results of the measurements can be illustrated best by comparing the concentrations of heavy metals in the water at two stations; for example, at West Point and Blake Island. The concentrations of metals found near Blake Island, which is far from any sewage treatment plant, are not markedly different from those found at the West Point Station which is downstream. The general circulation of surface water is from the south to the north, and the concentrations of most elements measured do not seem to be elevated nor much different at the two stations. The increase in metal concentrations which would be expected from the METRO outfall effluent has not been observed by measurements of samples collected in the water column. Zirino and Lieberman (13) report measurements of Pb and Cd in Puget Sound waters using an automated anodic stripping voltammetric instrument. They reported Cd values of 0.1 $\mu\text{g/L}$ and Pb values ranging from 0.10 to 0.21 $\mu\text{g/L}$ in the first leg of their cruise. However, during the second leg of their cruise, which followed four days later over essentially the same route, the values measured for Pb and Cd were a factor of three lower than those made on the first leg. These discrepancies were attributed to the rapid changes in water and/or instrument performances. No additional measurements were given to estimate their instrumental reliability at these low levels.

Certain biological samples may be indicators of metal buildup. Organisms show different uptake of metals, due to variations in feeding patterns and mechanisms, morphology, and environment. Within each organism the organs have varied capacities and storage times for trace metals which are related to their biological functions (14). The Bay mussel, *Mytilus edulis*, is prevalent in the intertidal zone and has been found to be an indicator organism for several metals (15, 16). The concentrations of Pb and Hg found in mussels are shown in Figure 3. Also shown in the figure are the metal concentrations measured in brown algae, *Fucus* sp., green algae, *Ulva* sp., and clams collected at the same times and locations as the mussels. The results of the analysis at each station are presented in the histogram from south to north, with the West Point outfall at the center. The concentrations of Pb appear to be slightly elevated at the West Point stations, with a range of values between 0.5 and 2 $\mu\text{g/g}$, wet weight. The Hg concentrations do not show a clear pattern for the different types of organisms at the sampling locations. The range of Hg values is 2-15 ng/g wet weight for all the biota measured; the guideline recommended by the Food and Drug Administration (FDA) for human consumption of shellfish is 500 ng/g wet weight (17).

Sediments are the sinks for the trace metals in the water column; thus, changes in the water concentration with time should be indicated in sediment core profiles. Dating sediment layers by the ^{210}Pb technique (18), together with the analysis of trace metals in the same core profile, has contributed to the understanding of local deposition of the metals in Central Puget Sound. The ^{210}Pb method measures the sedimentation rate, which can be used as a geochronological tool in evaluating the trace metal input over the past 10-100 years. We have dated 14 cores from different areas of Central Puget Sound by the ^{210}Pb radiometric technique (to be published elsewhere). The results show that there are wide variations in the sedimentation rates at different regions within Puget Sound (0.1-2 cm yr^{-1}).

The basic assumptions for the ^{210}Pb dating technique are: constant influx of ^{210}Pb from water column to the sediment,

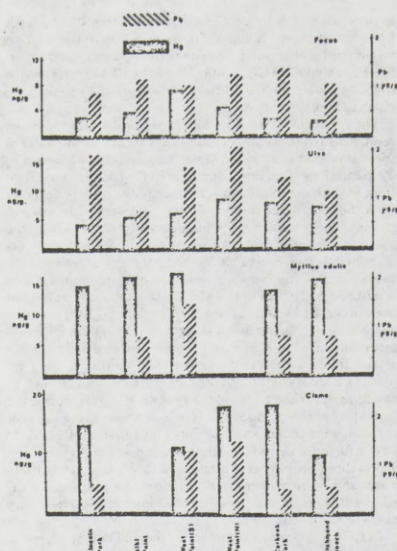


Figure 3. Concentrations of Pb and Hg in intertidal organisms (*Fucus*, *Ulva*, *Mytilus edulis*, and clams) collected in central Puget Sound. Each value represents 5–30 individual organisms. (Pb concentrations in µg/g dry, $\pm 15\%$ analytical error; Hg concentrations in ng/g dry $\pm 15\%$ analytical error)

constant sedimentation rate, and immobilization of ^{210}Pb within the sediment (18). These conditions may not be the same for all coring stations. The input of ^{210}Pb and trace metals to sediment at each location in Puget Sound depends on the currents, sediment morphology, biological activity in the sediment, and the proximity of stream and river input of sand and silt from the land. The organic carbon content of the sediments and the sedimentological parameters (percentage of gravel, sand, silt, and clay) have not been measured in the cores used for this study. However, a granulometric survey of the marine surface sediments from the Strait of Juan de Fuca and Puget Sound was reported by Roberts (19). By matching the core sampling stations from this study with the stations in the Roberts report, these sedimentological parameters as shown in Table II were estimated. Considering the above factors, an attempt was made to compare the past history of trace metals deposition at each core location with the present concentrations using the ^{210}Pb dating technique to establish the time history.

Examples of the typical core profiles for ^{210}Pb dating are shown in Figure 4. In core 41054, collected north of Blake Island, a gradual decrease in the ^{210}Pb concentration occurs with depth, and a sedimentation rate of 0.9 ± 0.1 cm/year was calculated. In core 41160 collected near Alki Point, an apparent constant ^{210}Pb concentration occurred to a depth of greater than 12 cm. At lower depths, the ^{210}Pb concentration decreased at a gradual rate, and a sedimentation rate of 0.37 ± 0.01 cm/yr was calculated. In core 41161, collected in a deep area near the West Point outfall, no change in the ^{210}Pb concentration was found from the surface to a depth of 46 cm. Because of this anomaly, an additional core from this area was collected at a different time, and similar results of the ^{210}Pb

Table II. Surface Sediment Enrichment of Trace Metals in Central Puget Sound, 1955–1975 Time Periods Are Divided by Those of 1500–1520 Period

Area		West Point			Elliott Bay			Alki Point			Central Stations		
Core #		41293	41294	41053	41051	41062	41059	41058	41055	41054	41162	41157	41292
Lat. N		47°39'43"	47°39'54"	47°40'30"	47°38'49"	47°37'40"	47°36'50"	47°33'46"	47°33'35"	47°33'35"	47°32'31"	47°29'5"	47°50'48"
Long. W		122°28'13"	122°27'49"	122°25'44"	122°29'14"	122°24'56"	122°26'52"	122°25'23"	122°24'53"	122°28'5"	122°25'42"	122°30'5"	122°30'44"
Water depth, m		246	240	100	190	175	196	250	157	187	196	283	102
Particle size, %													
Sand		9.4	85.6	8.6	85.6	4.7	4.2	30.9	39.1	72.8	85.9	65.9	87.9
Silt		51.6	6.5	50.7	6.5	49.4	49.2	34.6	34.5	13.4	6.8	17.5	2.7
Clay		39.0	7.8	40.7	7.8	45.9	46.7	34.6	26.4	13.7	7.3	12.3	2.8
Zn		1.1	b	1.8	1.4	1.0	1.4	1.1	1.4	1.1	1.3	1.2	b
Cu		b	1.0	1.2	b	b	1.1	b	b	1.0	1.4	1.0	b
Ni		1.0	1.1	2.8	1.3	b	1.5	1.0	1.7	1.0	1.3	1.1	b
Pb		1.8	11.1	3.6	1.6	1.1	1.7	b	2.2	1.2	1.9	1.5	1.8
Co		1.0	1.0	1.2	1.2	b	1.1	1.1	b	b	1.3	1.2	1.0
Mn		1.1	1.0	1.3	1.2	b	1.3	c	1.0	b	1.7	1.0	c
Cr		1.0	1.0	1.2	1.2	1	1.1	1.0	1.0	1.0	1.2	1.3	1.0
Co		1.0	1.0	1.2	1.2	1	1.1	1.0	1.0	1.0	1.2	1.3	1.0
Hg		2.4	1.3	1.8	1.3	c	c	1.4	1.7	1.3	1.6	1.6	c

* Reported by Roberts (19). * Meaths deposited in top layers. * Not measured.

* Reported by Roberts (19). ^b Metals depleted in top layers. ^c Not measured.

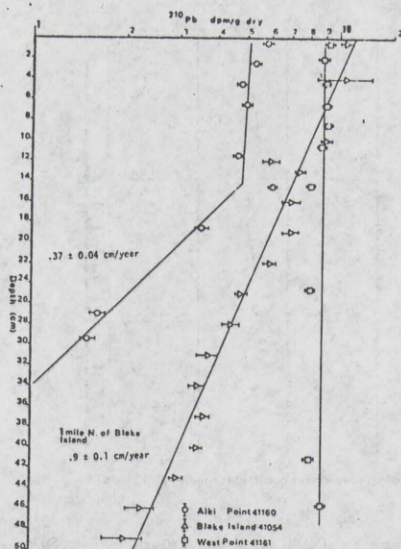


Figure 4. Examples of ^{210}Pb concentrations measured in three cores collected in central Puget Sound. Sedimentation rates determined by least-squares fit of data. (Concentrations in dpm/g, dry, $\pm$ SD single sample counting error)

concentrations were found. The ^{210}Pb concentrations did not follow the normal sedimentation profile at this location; at least 46 cm of sediment material with concentrations which were near the present atmospheric levels must have been deposited during a short time interval.

The observed deficiency of ^{210}Pb in the top section of core 41160 and the constant activity of ^{210}Pb in core 41161 could be attributed to: a higher sedimentation rate in recent years, mobilization of ^{210}Pb within the sediment column, bioturbation and mixing of ^{210}Pb to lower depths of sediment due to biological and bacterial activities, or a combination of the above factors. Since prior to January 1973 sludge was routinely discharged from the present outfalls into the Puget Sound, and since dredge spoil has also been dumped in this area periodically, the formation of man-produced sediment (20) near the outfalls appears to be the reason for these patterns in the sediment profiles. The discharge of dredge spoil into the Sound and the loss of metals from spoil deposition are discussed elsewhere (21).

Calculation of the approximate time of the deposition of the spoils has been attempted, but must be used with caution until further evaluations of the methods used are completed. These estimates of the time of deposition have been made by assuming that the sediment input of ^{210}Pb from the water column is the same for core 41054 as for the other two cores; this value is about 12 dpm/g. The upper 12 cm of core 41160 has a value of ca. 6 dpm/g. Thus, the time of the deposition of this material as sediment is calculated to be 24 years ago or 1952. The upper 4 cm of sediment appear to have returned to the pre-1952 rate (0.37 ± 0.04 cm/yr), although the data are limited to measurements of two sections of the core. The West Point core has a ^{210}Pb concentration of 9 dpm/g, dry weight.

Thus, the time that this material was deposited is calculated to be about 10 years ago or 1966.

The heavy metals measured in these same core profiles are shown in Figure 5. Core 41054 has high concentrations of heavy metals in sediments even though it was taken at a region far from the outfall plume. The metal concentrations do not appear to have changed greatly at this station over the past 50 years (49 cm). The metal values measured in the surface section (Pb, 54 ppm; Cu, 52 ppm; Zn, 122 ppm; Cr, 47 ppm) are comparable to concentrations measured in sediment cores collected near the industrial areas and population centers of Puget Sound. The area where the core was taken must be a natural sink for sediment, which may be due partly to the eddies which are formed at the north end of Blake Island (21).

Core 41160 shows high and almost constant concentration of ^{210}Pb and heavy metals such as Hg in the upper 12 cm of sediment. Below 12 cm there is a gradual decrease of Hg concentration with depth to the level of 30 cm. This sediment layer (30 cm) is estimated by the ^{210}Pb measurements to have been deposited about the year 1900. The West Point core shows high and essentially constant heavy metal concentrations from the surface to 28 cm. These data, together with the ^{210}Pb values, which are essentially constant to a depth of 46 cm, point toward a single or short-time deposition of material at this location.

In an area which may be contaminated by man's waste material, the natural background of heavy metals cannot be obtained from any measurement of contemporary samples of the water, sediment, or biota. It must be determined from samples collected at a previous date, before man's impact. However, if measurements of samples are not available, an indication of the amount of heavy metals which were present at the previous date, at least in the sediments, may be obtained from the measurement of the heavy metal concentrations in accurately dated core profiles. It has been assumed that the migration of elements in the sediment profile is negligible, although this assumption may not be valid for certain elements, sediment types, and water conditions.

The use of the ^{210}Pb dating technique for 14 cores collected in central Puget Sound (to be published elsewhere) and the enrichment of the heavy metal concentrations in sediment layers between the time period of 1900-1920 and 1955-1973 are shown in Table II. Since the sedimentation rates differ at various core sampling locations, the ^{210}Pb dating technique has been used to reconstruct (normalize) the average concentrations of trace metals which were deposited as sediment during the above-mentioned time periods at each station. The most significant enrichment of several heavy metals is found at station 41053, which is located two miles north of the West Point outfall, and at station 41051 which is located two miles west of the West Point outfall. At these two stations the particle size measurements show that the silt and clay fractions are greater than at other nearby stations; this indicates that the pollutant heavy metals are associated with fine sediment particles. The maximum enrichment (station 41053) is for Cu (2.8) and Pb (3.6); all other metals measured have an enrichment of less than a factor of 2. The enrichment appears to be localized in the immediate vicinity of the outfall, although the data are too limited to give better regional distributions. Duplicate core samples gave results which were significantly higher (15-25%) than the analytical errors (3-5%). Part of the larger errors was attributed to the use of a single corer for sampling and identical locations could not be sampled easily due to drifting of the ship by the strong tides and winds.

Examples of the total input of the three metals Cu, Pb, and Zn in the Puget Sound are shown in Table III. Sources other than effluent from the METRO sewage treatment plant are shown to account for most of the metal concentrations mea-

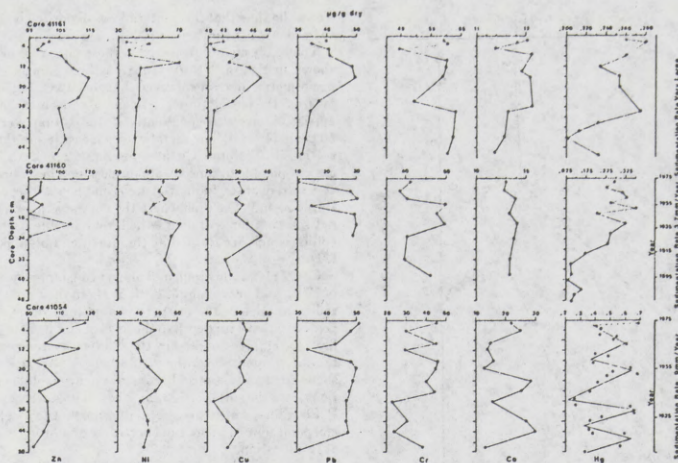


Figure 5. Concentration profiles of Zn, Ni, Cu, Pb, Cr, Co, and Hg in three cores collected in central Puget Sound (Concentrations in $\mu\text{g/g dry}$, $\pm 15\%$ single sample analytical error)

sured in water, biota, and sediments (22). The input of Cu, Pb, and Zn from the West Point outfall is less than 1.5% of the total input from other sources (rivers, atmospheric input, vessels, advective input, urban runoff, and other municipal discharges). The effluent from West Point is diluted initially by a factor of ca. 100 at the diffusers (23) and then by a factor of ca. 5 during a single tidal cycle (24). Thus, the resulting net increase in water concentrations of trace metals near the outfall is not significantly greater than the concentrations measured at control stations.

Conclusions

The results of the measurement of heavy metals in Central Puget Sound waters show that effluent from the West Point sewage outfall does not greatly increase the existing concentrations of the heavy metals measured in the water column and in the biota. The concentrations of Pb and Cd in Central Puget Sound are higher than the average open seawater values; the concentrations of Cu, Zn, and Ni are at or below the open seawater values. The Pb and Hg concentrations measured in the intertidal organisms, *Ulva* sp. (green alga), *Fucus* sp. (brown alga), mussels, and clams show a trend toward higher values near West Point, but the concentrations are within a factor of two at all stations and are probably similar to the within-sample variability. The amount of Hg found in the shellfish is lower by a factor of 10 than the FDA guideline on human consumption of shellfish.

The sediment measurements show that at certain locations rapid deposition of material with heavy metal concentrations has occurred. This probably has resulted from dumping dredge spoils or sludge from sewage treatment plants. The time of this dumping has been estimated by the ^{210}Pb dating technique of cores. The enrichment of heavy metals in sediment layers has been determined from the values obtained at the surface when compared with those values obtained from layers which were over 50 years old. The background heavy metal concentrations have been estimated from the deeper (older) layers of the cores, deposited prior to 1900. The total

input of the Cu, Pb, and Zn from all sources into Puget Sound is much greater than the input from the West Point sewage treatment plant; less than 1.5% of the total concentration of each element is estimated to be coming from the plant. These data are similar to those of Crecelius et al. (25) for the As and Sb budget of Puget Sound, in that natural rather than man-made sources contribute most of the trace elements to Puget Sound. The study is continuing, and more measurements of heavy metals in samples are being made and tabulated for computer modeling studies. The results of the study should give a better evaluation of the existing concentrations, carrying capacity of the water, and sources and sinks of the heavy metals in Central Puget Sound.

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We acknowledge the assistance given by D. Huntamer, S. Olsen, and R. Meixner for the chemical analyses; by C. Vick and R. King for the counting of samples and data processing; by G. Christian and E. Knudsen of the University of Wash-

Table III. Sources and Inputs of Copper, Lead, and Zinc in Puget Sound (Metric tons/yr)^a

Source	Copper	Lead	Zinc	Estid SD, %
Rivers (Lake Washington Ship Canal included)	787	2032	1624	50
Metro's West Point Plant	29	9	56	10
Other municipalities in Puget Sound area	22	16	26	50
Atmospheric input	450	2730	820	50
Vessels' protective measures and fuel consumption	360	9-12	140	...
Urban runoff (Seattle)	15	350	50	...
Advective transport	306	1640	874	50

^a From Zafiroopoulos (22).

ington, Department of Chemistry, for the interlaboratory standard analyses and quality control; and to D. Zafiroopoulos for collecting the budget information. The assistance of personnel at the Washington State University, Nuclear Radiation Center, Pullman, for neutron activation under the WSU-ERDA Reactor Sharing Program is appreciated.

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ADDITIONAL ITEMS RECEIVED FOR THE RECORD

PACIFIC LEGAL FOUNDATION,
Sacramento, Calif., May 23, 1978.

HON. HAROLD T. JOHNSON,
Chairman, Committee on Public Works and Transportation,
U.S. House of Representatives,
Room 2165, Rayburn House Office Building,
Washington, D.C.

DEAR CONGRESSMAN JOHNSON: This letter is in response to your recent communication concerning subcommittee hearings on the scientific and technological considerations concerning a modification of the secondary treatment requirement for municipalities which discharge into marine waters. We will not be present at the hearings; however, we did wish to provide to the subcommittee some brief comments on the subject.

We have been working for over a year to attempt to obtain reasonable discharge requirements for the City of Los Angeles Hyperion Wastewater Treatment Plant. Our attention was initially attracted to significant adverse consequences to air, land, energy consumption, and a number of other factors which affect the people of the region and which would result from Environmental Protection Agency (EPA) orders to modify the Hyperion discharges. Since becoming involved, however, we have conducted an extensive literature search and talked with experts in the field on the subject of the protection of the marine environment. We believe we can offer the subcommittee some helpful observations, based on this background.

Our most important comment is that it is both wasteful of resources and ineffective to approach the subject of protection of the marine environment using the secondary treatment requirements as a baseline. The three criteria for secondary treatment are: 1. BOD (Biological Oxygen Demand), 2. pH (acidity/alkalinity), and 3. Suspended solids.

Neither BOD nor pH is a pollutant of any significance in marine waters of adequate depth and circulation, if the discharge is reasonably diffused. Solids are a problem to the extent that they tend to settle in a limited area and may create anoxic conditions. However, it is *settleable* solids which may create this problem. The suspended solids measured for secondary treatment typically will drift away before combining sufficiently to settle in the immediate area of the discharge.

Rather than approaching the subject as a question of how to modify secondary treatment requirements, regulation of discharges to marine waters of adequate depth and circulation should concentrate on toxic substances and settleable and floatable materials. However, we offer two caveats on these areas:

1. The subject of toxicity in marine waters is greatly different from toxicity in other environments. In particular, the "heavy metals" which have received so much attention and are the subject of EPA ocean dumping regulations appear to have no adverse impact in marine waters in a typical or expected situation. The need for the greatest concerns appears to be the chlorinated hydrocarbons, which compounds are *not* effectively removed by secondary treatment.

2. The problem with disposition of solids must be approached in a balanced fashion. Although severe concentrations of settleable solids are known to create adverse conditions in the marine environment, the overall adverse impacts of alternative methods of disposing of solids—especially when the high energy demands of alternatives are factored in—may well make ocean disposal the least undesirable alternative.

We have attached for the information of the subcommittee a copy of one of the more readable and understandable summary statements of the scientific and technical considerations by Mr. Willard Bascom, Director, Southern California Coastal Water Research Project. The careful conclusion in this brief statement is supported by years of research and extensive scientific and technical studies.

Very truly yours,

RONALD A. ZUMBRUN,
President and Legal Director.

To: Water Pollution Control Federation
Ocean Outfalls Seminar
April 18, 1978
Washington, D.C.

THE EFFECTS OF OCEAN OUTFALLS,
U.S. WEST COAST

Willard Bascom

This paper consists of answers to a series of questions that a person not familiar with ocean outfall matters might logically ask. It gives essential information about several ocean outfalls and describes how their effects can be quantified. Those measurements available to the author are presented.

WILLARD BASCOM
Director

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(313) 322-3080

WHAT ARE THE ESSENTIAL DIFFERENCES BETWEEN THE VARIOUS U.S. COASTS?

From the point of view of waste disposal the most important considerations are the extent to which the waters of the disposal area are exchanged with those of the open sea. This exchange permits tiny suspended particles to move seaward where they eventually deposit in the ocean basins. Major factors in this exchange are the depth of the water at the discharge site, the steepness of the slope into deep water, the amount of wave or tidal energy at the disposal site, and the velocity of the currents that will carry the waste away. The deep release of effluent, steep slopes, a high energy regime, and constant currents are most favorable for ocean disposal. These characterize most of the west coast outfall areas.

Figure 1 shows the relative steepness of coastal waters in various parts of the U.S. Generally speaking, steeper coasts are more likely to be exposed to strong currents because there is less bottom resistance to the flow of water.

WHAT ARE THE SPECIAL CHARACTERISTICS OF OCEAN OUTFALLS?

This discussion is limited to properly designed modern outfalls with a discharge of more than 10 million gallons a day that release effluent through a diffuser into waters that are exposed to ocean winds, waves, and currents. The release is continuous and the wastewater discharged is immediately diluted

by at least 100 times as much ocean water. This kind of discharge, in which the effluent is mixed with cool bottom waters, is quite unlike "dumping" in which batches of concentrated material are periodically mixed with ~~relatively warm and light surface waters~~. Whereas the surface waters may be moved shoreward by winds, the subsurface currents generally move alongshore and offshore.

It is certainly not appropriate to compare the effects of municipal waste on deep, freely-moving, well-oxygenated open ocean water with discharge into confined fresh waters with limited oxygen.

WHERE ARE THE EXISTING OUTFALLS AND WHAT DO THEY DISCHARGE?

The locations of some of the larger existing outfalls of the Pacific coast are shown on Figure 2; Table 1 gives their characteristics. A number of large new ocean outfalls are planned and numerous other small ones are now in operation.

HOW MUCH DILUTION IS ACHIEVED AT THE TIME OF DISCHARGE?

Most ocean outfall pipes do not discharge out the end, which is closed, but through many small portholes in the sides of a diffuser section which is several thousand feet long. Usually there are hundreds of ports 4 to 10 inches in diameter and a hundred feet apart on both sides of the diffuser. The effluent

squirts out of these openings, entraining seawater and creating a new mixture that is a little warmer and less saline than the surrounding water. This mixture is lighter and it continues to rise until ~~equilibrium is reached~~ and a layer of new density is formed. The diluted waste, now called the "plume", moves away with the current.

When the effluent mixture loses its original momentum the initial dilution process is complete. The dilutions thus achieved have been measured by several independent methods around four large outfalls in California and been found to be equal to or better than that claimed by the designer. These minimum initial dilutions in the axis of the wastefield range from 100 to 300.

WHAT EFFECTS DO OUTFALLS HAVE ON THE SEA?

Any discharge into the sea, even if it be a clear stream of fresh water, will cause some marine animals to adjust. Some species will prefer the new conditions and changed food supply; others will die out in the affected area because they cannot successfully compete or because their predators have grown stronger. Change is certain and no man can say which animals are the "right" ones for any area.

One of the materials discharged from outfalls is the organic solids from human wastes. These solids are acceptable food for many marine animals; they are not toxic. However, if there is an appreciable buildup of these solids on the sea bottom an anoxic environment can be created.

Often there are contaminants attached to the particulates and these have caused a large part of the ecological damage that has been observed. By far the most serious problems have been caused by the toxic chlorinated hydrocarbon compounds, mainly PCB and DDT.

Other contaminants, such as metals and oils that are often associated with municipal wastes, have been found to have very low toxicity in the sea. Metals in ionic form (which is the only way that toxicity tests are made) remain below the lowest levels of chronic (long-term) toxicity. Most of the metals in the bottom are kelated or complexed or in non-toxic forms which have not been shown to damage sea animals. Chromium and mercury, for example, as they exist in the sea, are virtually non toxic.

WHAT ARE THE NATURAL OR BACKGROUND CONDITIONS WITH WHICH THE EFFECTS OF OUTFALLS CAN BE COMPARED?

Any statement about the condition of the sea and its life may elicit the logical question, "Relative to what?" Everyone wants to know what the coastal waters were like before man interfered. Hopefully this answer is provided by "control" or "reference" stations.

The selection of suitable location for comparative measurements is more difficult than one might suppose and, since the meaning of all other measurements depends on the reference stations used, the matter is worth some careful thought. Probably no one location is suitable for the reason that there is considerable

natural variation and a range of values is more useful than any specific number. A survey of locations that are supposedly unaffected by man is required to determine if indeed those locations are natural. Along some of our shores where man has long influenced the coastal waters there may be no natural areas; instead the control survey produces a range of "background" conditions that can be used for reference. These are not quite pristine because of a great many non-specific effects such as fishing, ship traffic, runoff from land, and aerial fallout of pollutants.

The search for data on what constitutes natural conditions in southern California extended along about 450 km of coast. At a depth of 60 meters (the average of our outfalls) trawls and bottom samples were taken every 10 km. See Figure 2. We removed from consideration as controls all those samples taken near urban areas where contamination seemed likely and used the remainder to establish the range of control values shown in Table 1. Using those criteria we then reassessed all the samples. A number of these showed that control conditions existed off suburban areas; others immediately off urban areas were not quite such high quality. These are deemed to be the urban background.

UNDER WHAT CIRCUMSTANCES DO PARTICULATES BUILD UP ON THE SEA FLOOR?

Most possible pollutants are attached to waste particles; these, like the material in solution, are immediately diluted by the large factors previously mentioned. However,

particulates discharged into seawater may break up into smaller particles or agglomerate into larger ones. The larger particles may settle to the bottom in the vicinity of the discharge point, thus reconcentrating the pollutants there. The location and distribution on the sea bottom of organic materials with pollutants attached is an integrated record of the combination of settling velocity and water motion.

If all the particles discharged remain too small to settle to the bottom within a day or two they will drift away, continuing to disperse, and there will be no measurable buildup of organic materials on the sea floor, regardless of the amount discharged.

Measurements of actual outfall deposition can be made by analyzing samples of the bottom surface to see if there is an increase in volatile solids or organic carbon above the natural range for the area.

Estimates of deposition rates at any location are difficult but they can be estimated by combining laboratory measurements of settling rates of effluent (appropriately diluted with seawater) with measurements of currents.

WHAT IS THE EFFECT OF WASTE PARTICULATES ON THE BOTTOM?

Most of the particulates discharged are organic materials, these are acceptable foods for many animals and in small amounts they appear to cause an enhancement of sea life (more and larger animals) without changing the species composition. Somewhat

larger amounts of organic materials on the bottom give deposit-feeding animals (mainly molluscs) an advantage with the result that animals which feed in the water column are correspondingly reduced. Very large deposits of organic materials causes an increase in the number of worms present and can lead to anoxic conditions with a buildup of sulfides in the sea bottom. Thus, although a little organic material may be a useful food supplement a super abundance of such material does not seem to be beneficial.

Widely dispersed organic particles will not alter the environment if they have no substantial amounts (more than 1 part per billion) of synthetic organic chemicals such as PCB or chlorinated compounds attached. Clearly those are the most damaging chemicals and a continuing effort must be made to prevent them from reaching the sea.

✓ || As for other contaminants, including metals, that are likely ||
	to be attached to waste particulates, after years of intensive	
	looking we find no evidence that (at the levels and conditions	
	encountered) these cause any harm to marine life.	

HOW CAN THE AREAL EXTENT OF THE BIOLOGICAL EFFECTS OF AN OUTFALL BE DETERMINED?

The presence or absence of certain animals that live in and on the bottom is one of the best indications of the extent of an outfall's influence. One of the best ways is to make a grab-sample bottom survey of an area larger than is believed to be affected and to work out the Faunal Index numbers for each sample.

Then these numbers can be compared with the numbers at control and background sites.

The Faunal Index, devised by Jack Word of SCCWRP, is a number from 0 to 100 that indicates the response of the benthic infauna to the amount of available organic material on the bottom. It is obtained by counting 25 taxa (species) of animals caught by a 1 mm screen and using them in a simple equation. These taxa are distributed among 4 groups which range from water-column feeders that live only in pristine areas to deposit feeders that live mainly in bottoms high in organic matter such as those which may exist near outfalls. (The specific groups and taxa are given in Appendix A, as is the Faunal Index formula).

In southern California we find that Faunal Index numbers above 80 show the area is at or near natural conditions. Off our urban shores a Faunal Index number of 70 represents the present background level. We believe, but we are not yet certain, that with minor adjustments these same taxa can be used nearly anywhere in the open coastal waters of the world with similar results.

There are other ways of using grab sample data to assess bottom conditions. For example, volatile solids, total organic carbon, or biological oxygen demand of the sediments give a similar picture.

HOW CAN THE LOCAL EFFECT OF AN OUTFALL BE DETERMINED?

The change of species from water column feeders to deposit feeders as evaluated by the Faunal Index is only one way of expressing the effects of an outfall. Two other ways are to use the number of individual animals present or to use the total weight of animals (biomass of living tissue) relative to the numbers in control samples. In either case one would count or weight only those from a known area of bottom. (Our standard sampler retrieves exactly one tenth of a square meter).

In an outfall area it is not unusual to have several times as many animals per square meter as in control areas. The biomass may be similarly increased.

✓ As far as I know all of the small animals in the bottom (clams, worms, amphipods, etc.) are of equal value. Therefore, an increase in the number or weight of the animals in an outfall area would seem to be an advantage. These animals feed partly on the organic materials discharged, then they, in turn, serve as food for the fish and larger animals in the area. The result is likely to be an increase in fish and other seafoods.

ARE FISH DISEASES CAUSED BY EFFLUENTS?

Fish, like humans, have various diseases that do not seem to be related to environmental factors. Tumors, for example, are found mainly in young fish of several species; they seem to

✓ occur with about the same incidence around the north Pacific rim. Tumors are not caused by municipal waste waters.

Fin erosion syndrome is caused by man's chemicals (probably by PCB and possibly by DDT) and so is related to material that has been discharged. It occurs occasionally in about 30 species of fish but it is mainly seen in three species of sole and the greenstriped rockfish. Fin erosion is probably the visible evidence of a late stage in the effect of some chemical that probably causes liver damage and possibly nervous system damage.

✓ Evidence indicates that these fish obtain the pollutant from the sediments--most of which resulted from past discharges--rather than from the materials now discharged.

WHAT IS THE PRESENT STATUS OF THE AREAS AFFECTED BY DISCHARGE?

✓ About 6 square miles of bottom of the 200 square mile area of Santa Monica Bay has an excess of volatile solids over the level at control stations, which probably came from the outfalls. Off the Palos Verdes Peninsula the area of excess could be as much as 40 square miles. This increase in organic materials is accompanied by a substantial rise in the levels of metals, DDT and PCB. In about 10% of this area the surface sediment smells of H_2S .

✓ A large part of these contaminants are the result of discharges more than 7 years ago; the present discharges are only partly responsible. Thus, even if the discharges went to zero

✓ today it would be 5 to 20 years before the old waste material on the bottom decayed, was eroded, or covered over by new sediments.

The present condition of the bottom in the areas just referred to is certainly not desirable. It is decidedly changed and degraded but it is not an "ecological disaster area" or a
 ✓ "sea of death". Actually there are more small animals and probably more edible fish in these areas than before.

The areas affected are not enlarging and the conditions are improving somewhat as shown by a rise in the Faunal Index and the reduction of available DDT. When two short outfalls were
 ✓ abandoned (by L.A. City and Orange County) the bottom returned to its original condition in about a year, showing that the effects are reversible.

WHAT SHOULD BE DONE?

It is evident that improvements in the quality of material discharged would be helpful in some areas. The two items that are important are (1) the maximum reduction of PCB and other chlorinated hydrocarbons (the discharges are already very low, rarely exceeding 2.5 ppb) and (2) the reduction of organic materials that, after mixing with seawater, will settle to the bottom within 2 days.

✓/ Other items such as BOD, pH, metals and ammonia simply do not make any difference in the ocean and no special effort should be made on these non-problems. There is an unlimited supply of oxygen, pH after dilution of over 100 cannot be significant, and
 || metals do not reach the ocean in a form and at a level that will ||

✓ cause problems. Ammonia is, if anything, a beneficial plant nutrient.

As for the level of treatment (here I am speaking only as an oceanographer) it seems reasonable to me that, if the chlorinated hydrocarbons and larger organic particles are removed, the least treatment is the most desirable. There is every reason to believe that human wastes are as valuable to the sea as they are to the land.

HOW DOES OUR COUNTRY BEST PROTECT THE ENVIRONMENT?

Persons truly concerned with ecology understand that it concerns relationships between all animals and all environments. They recognize that energy usage is an environmental cost as is the waste of land and labor and raw materials.

Every proposed change requires bulky Environmental Impact Reports but these do not tell the reader the one thing that would be most useful. They do not honestly compare the various options with respect to all forms of environmental damage, energy use, and cost, so one can consider all the possibilities and decide if the proposal is sensible. Ideas that sound great at one level of expenditure may be terrible ideas at 5 or 10 times that level.

✓ In California we have seen some nonsensical construction and some foolish proposals put forward in the name of protecting the environment. For example, a new \$600,000 secondary sewage plant has been built at San Clemente Island for less than 100 residents. A scientific survey showed that the effects of the previous outfall (a low-flow 3-inch pipe) extended a maximum of

about 30 feet.

✓ Another example: The City of Los Angeles may be required to truck its sludge (40 trucks running constantly on a 72 mile round trip) to an inland canyon (where no estimate of environmental effects has ever been made) instead of continuing to discharge it into a submarine canyon 7 miles offshore where one of the effects is enhanced fishing. The estimated capital costs of the new plants is \$250 million plus about \$50 million a year in operations and maintenance.

The public should have a chance to decide whether it is worth such sums to trade sea disposal for land disposal.

A national agency is needed that will protect the environment by simultaneously considering land, sea, air, and energy. An agency that understands that deserts, mountains, forests, lakes, and oceans are different environments and that these have sub-environments--each of which should be specifically considered instead of subjected to blanket regulations that cannot make sense in all situations. This agency should work closely with state and local groups to make plans that will optimize results rather than directing them from afar; it should do research before making regulations; it should be concerned with making overall improvements in the environment at the least overall cost. I suggest we call it the Environmental Protection Agency.

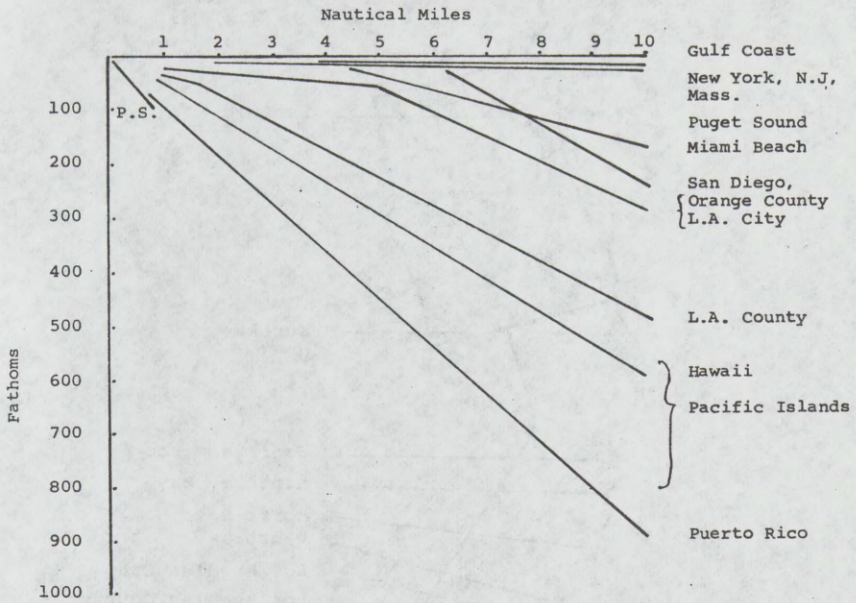


Figure 1. Approximate offshore slopes in areas used or considered for ocean disposal

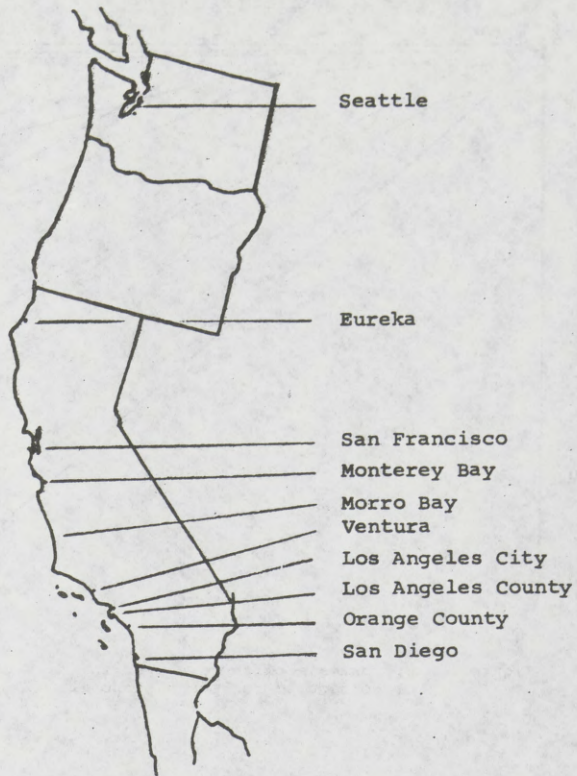


Figure 2. Locations of major existing and proposed ocean outfalls on the West Coast.

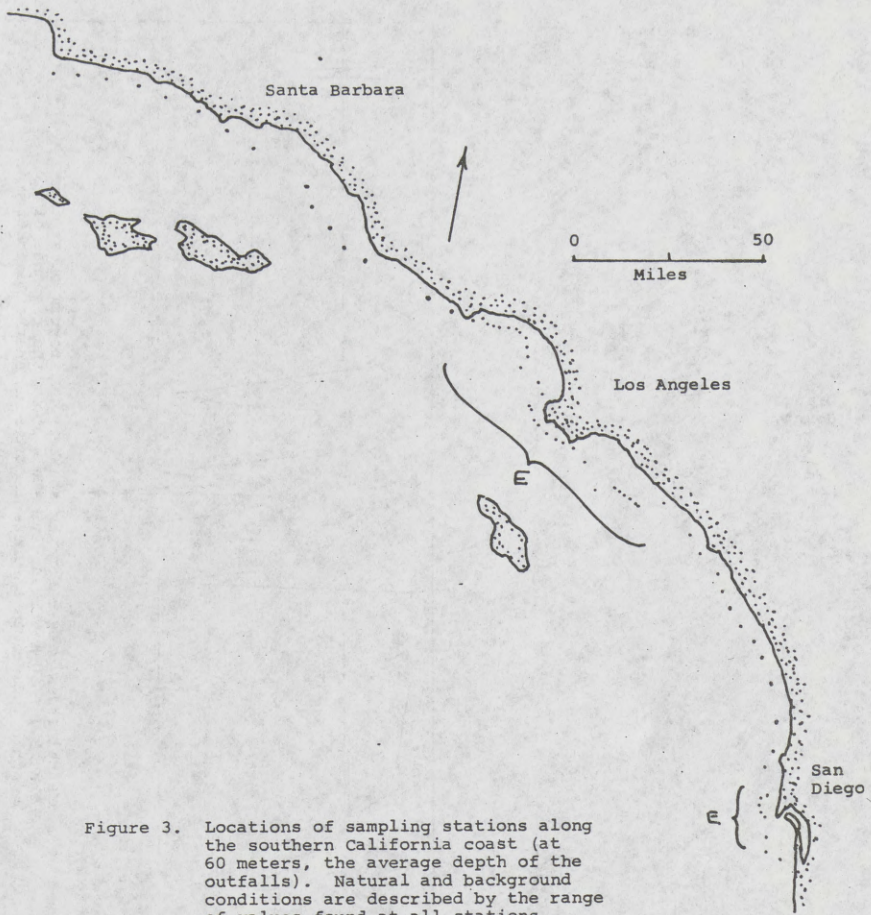


Figure 3. Locations of sampling stations along the southern California coast (at 60 meters, the average depth of the outfalls). Natural and background conditions are described by the range of values found at all stations except those in the E brackets.

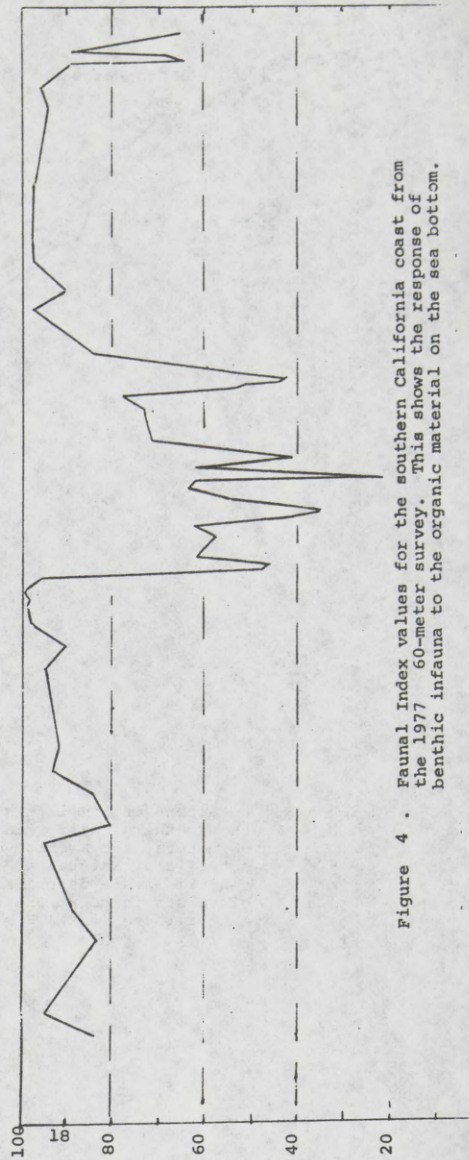
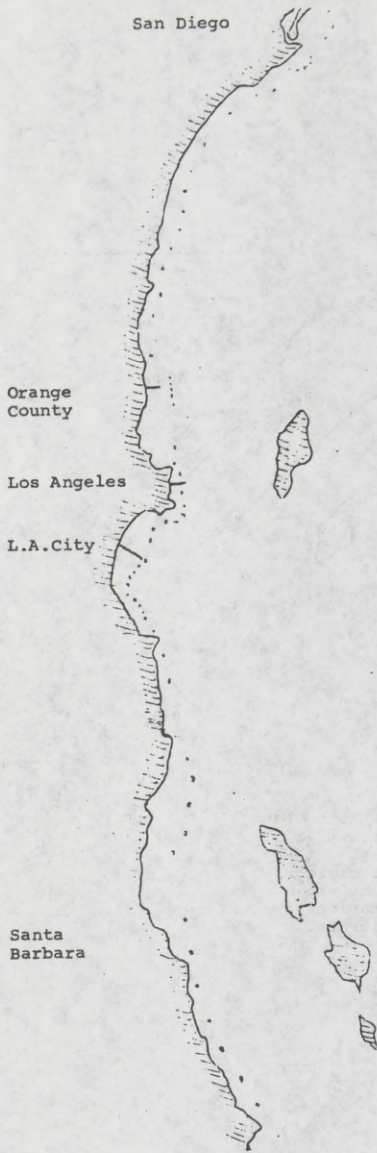


Figure 4 . Faunal Index values for the southern California coast from the 1977 60-meter survey. This shows the response of benthic infauna to the organic material on the sea bottom.

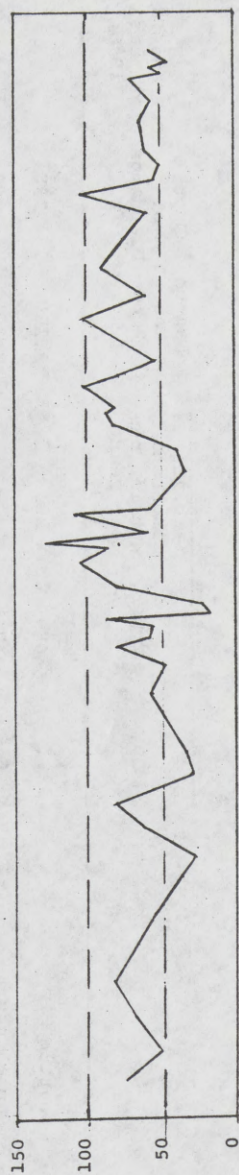
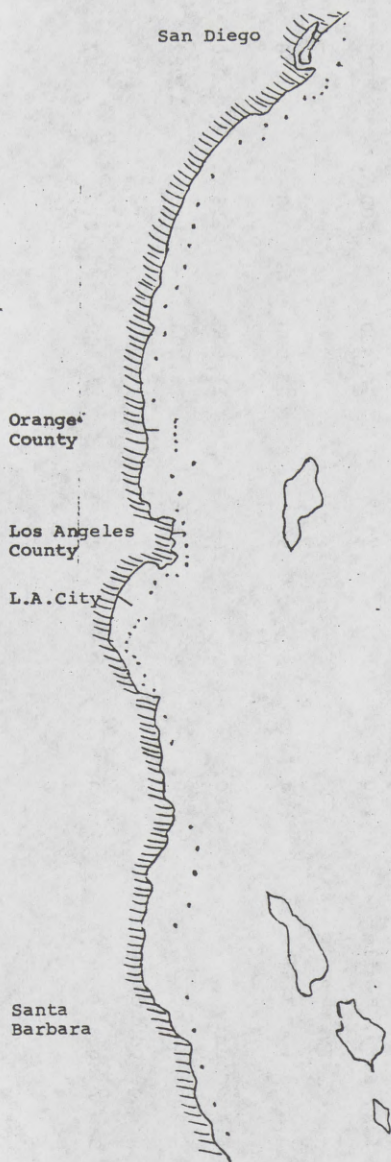


Figure 5. Living organic material in sediments at 60-meter survey stations. Units are grams per square meter.

Table 1. Characteristics of Ocean Outfalls

	Discharge		Type	Solids Thousand Metric Tons per Year (1977)	Length of Pipe ft.	Depth of Discharge ft.	Kg DDT and PCB per year (1976)
	MGD						
Seattle	118.		P	13.	3,160	230	15
Santa Cruz	6.6		P	-	3,000	40	-
Morro Bay	7.8		P	-	800	30	-
Santa Barbara	7.5		P	-	6,000	90	-
Ventura	18.0		P	1.5	6,000	52	7
L.A. City, 5-mile	240		P	27.3	26,400	200	135
L.A. City, 5-mile	100		S	-	"	"	-
L.A. City, 7-mile	4.5		S + sludge	51.5	35,000	300	136
L.A. County	380.		P	102.	11,900	215	2,080
Orange County	130.		P	33.6	23,000	180	1,022
Orange County	10.		S	-	"	"	-
San Diego	90.		P	20.7	11,400	210	277

Table 2. Range of Natural Conditions.

Analysis of soft bottom samples taken at 29 control stations between May and August 1977 at 60 meter depth along the southern California coast in areas virtually unaffected by man.

	Average	Lowest	Highest
Faunal Index	92	80	99.6
% sand	43.5	5.2	86.8
% volatile solids	3.5	1.4	10.0
C.O.D. (mg O ₂ per kg sediment)	24,250	9,200	69,400
Nitrogen (milligrams per liter)	756	295	1,360
Acid volatile sulfides (mg/kg of sediment)	0.013	<0.003	0.06
Silver (milligrams per kilogram)	ND	<0.1	<1.5
Cadmium "	ND	<0.1	2.4
Chromium "	25.0	7.8	43.0
Copper "	8.4	2.8	40.0
Nickel "	19.2	4.9	51.0
Lead "	6.0	1.4	12.0
Zinc "	42.9	10.0	110.0

ND - Not determinable

Note the wide range of values within samples, all of which seem to represent natural conditions on the California coast.

APPENDIX

TAXA FOR CALCULATION OF FAUNAL INDEX NUMBERS

Group 1 - Suspension Feeders
(pristine area)

<u>Phoronis</u> spp.	Phoronid
<u>Amphiobia</u> spp.	Brittle star
<u>Sthenelasma</u> <u>uniformis</u>	Worm
<u>Ampelisca</u> spp.	Amphipod
<u>Paraphoxus</u> spp.	"
<u>Heterophoxus</u> <u>oculatus</u>	"
<u>Metaphoxus</u> <u>frequens</u>	"

Group 2 - Mixture of Feeding Strategies

<u>Mediomastus</u> spp.	Worm
<u>Myriochele</u> spp.	"
<u>Tharyx</u> spp.	"
<u>Axinopsida</u> <u>serricata</u>	Clam
<u>Mysella</u> spp.	"
<u>Photis</u> spp.	Amphipod
<u>Euphilomedes</u>	Ostracod

Group 3 - Deposit Feeders, mainly molluscs

<u>Parvilucina</u> <u>tenuisculpta</u>	Clam
<u>Macoma</u> <u>carlottensis</u>	"
<u>Bittium</u> spp.	Gastropod
<u>Spiochaetopterus</u> <u>costarum</u>	Worm

Group 4 - Deposit Feeders, mainly worms
(outfall area)

<u>Armandia</u> <u>bioculata</u>	Worm
<u>Shistomeringos</u> <u>longicornis</u>	"
(= <u>Stauronereis</u> <u>rudolphi</u>)	"
<u>Ophryotrocha</u> sp.	"
<u>Oligochaeta</u> , UI	"
<u>Capitella</u> <u>capitata</u>	"
<u>Dorvilleidae</u> , UI	"
<u>Stenothoidae</u> , UI	Amphipod
<u>Solemya</u> <u>panamensis</u>	Clam

$$\text{Faunal Index} = 100 - 33.3 \left(\frac{EN_2 + 2EN_3 + 3EN_4}{EN_1 + EN_2 + EN_3 + EN_4} \right)$$

where N = the number of animals counted
in a sample from the appropriate group.

GOLETA SANITARY DISTRICT,
Goleta, Calif., May 31, 1978.

Re: Proposed regulations—Modification of secondary treatment requirements for discharges into marine waters.

Director, Municipal Construction Division (WH 547), Office of Water Program Operations, Environmental Protection Agency, Washington, D.C.

DEAR SIR: Enclosed with this letter are the comments of the Goleta Sanitary District on the proposed Environmental Protection Agency Regulations regarding modification of secondary treatment requirements for discharges into Marine waters. These comments have been developed by the Governing Board of the Goleta Sanitary District, its attorneys and engineers in consultation with a number of other affected agencies. As you may be aware, the Goleta Sanitary District is a relatively small public agency serving approximately 60,000 people near Santa Barbara, California. Thus, the District is particularly concerned that the final EPA Regulations are written in a manner that will allow granting of modifications from the secondary treatment requirement without an unreasonable burden being placed on the smaller agencies. To that end, District representatives have appeared at the EPA hearing held in San Francisco on February 22, 1978, at which time they submitted both oral and written comments. On April 12, 1978, the District submitted written comments on the Preliminary Concept Paper circulated by EPA. In addition to submitting the enclosed comments, the District also plans to have representatives at the EPA hearings on the proposed Regulations to be held in Washington, D.C., on June 2, 1978, and in Seattle, Washington, on June 8, 1978.

I have indicated above our participation in the formation of the proposed Regulations to emphasize our District's sincere concerns. I trust that our comments will be given your earnest consideration.

Sincerely yours,

ELBERT W. TRANTOW, *President.*

Enclosure.

MAY 31, 1978.

Re: Proposed regulations—Modification of secondary treatment requirements for discharges into marine waters.

Director, Municipal Construction Department (WH 547), Office of Water Program Operations, Environmental Protection Agency, Washington, D.C.

DEAR SIR: The purpose of this letter is to comment on the proposed Regulations under the Clean Water Act of 1977, Section 301(h), regarding modification of the secondary treatment requirement for discharges into marine waters, as published in the Federal Register, Vol. 43, No. 80, p. 17484 (April 25, 1978). (All page references are to the proposed Regulations as so published unless otherwise indicated.)

These comments are submitted on behalf of the Goleta Sanitary District, a relatively small public agency located near Santa Barbara, California, on the California Coast. The treatment plant and ocean outfall currently serve an area with a population of approximately 60,000 persons. The area served includes a portion of the City of Santa Barbara, the Isla Vista Sanitary District and facilities of the County of Santa Barbara and University of California, at Santa Barbara. The total discharge to the Pacific Ocean by means of an ocean outfall is between 5 and 6 million gallons per day. The ocean outfall extends into the Pacific Ocean approximately one mile to a depth of approximately 93 feet.

These comments have been discussed with many of the Pacific Ocean dischargers, both large and small. The more general comments, we believe, reflect the opinions of almost all dischargers. However, some of our comments are specifically directed to the problems of the smaller discharger.

A. EXISTING DISCHARGE

Probably the most troubling concept in the Regulations is EPA's interpretation of "existing discharge." Throughout the proposed Regulations, EPA has interpreted the term to mean actual in-place treatment levels and in-place outfalls and diffusers. If this interpretation prevails, we know of no major discharger on the Pacific Coast who could qualify for a waiver with one possible exception. Fortunately, EPA has asked for comment on this interpretation which we are happy to provide.

First of all, we do not agree with the implications of EPA's statement with regard to "... the plain language of the statute and its legislative history ..."

(See p. 17487 and Appendix A dated May 3, 1978) The language of the statute at most could be interpreted to require an applicant to be currently discharging into marine waters. To hold otherwise, would be directly contrary to the Legislative History which included a list of some 50 different California ocean outfall sites which are likely to meet the criteria of the law. This list (which included many smaller agencies including the Goleta Sanitary District) was introduced no less than four times. (See Remarks of Congressman Roberts, 123 Cong. Rec. H 12929, Congressman Anderson, 123 Cong. Rec. H 12956, Congressman Johnson, 123 Cong. Rec. H 12943, and Senator Muskie, by introducing a letter from Thomas C. Jorling, Assistant Administrator of the EPA, which letter included the list of California locations, 123 Cong. Rec. S 19646).

With regard to the specific questions asked by EPA in Appendix A of the proposed Regulations, we offer the following:

1. We believe that Congress intended to allow any modifications to the treatment plant or ocean outfall which will meet the objective of preventing pollution of the receiving waters. This would include upgrading treatment, relocation or extension of the outfall and modifications in the diffuser system.

2. EPA can make an accurate predictive judgment of the effect of proposed facilities in the same manner it now routinely makes such judgments in the existing permit and construction grant program. Such evaluation should be made on the basis of scientific and engineering evidence presented with the application. The burden of proof required should be no greater than is now required in the existing permit and construction grant programs.

3. It is essential that pretreatment and non-industrial source control programs be given consideration in determining if a discharge will comply with State water quality standards. Smaller agencies such as the Goleta Sanitary District with a limited number of industrial users will rely heavily on its pretreatment and industrial as well as non-industrial source control programs in controlling the discharge of toxic wastes. The Congress clearly anticipated the use of such programs when it provided for a test of their effectiveness by requiring a monitoring program and review of the waiver after five years.

4. Modifications to the applicant's discharge should be completed as to California dischargers when required by the California State Water Resources Control Board and not later than when the modification permit is renewed in five years.

5. In the event modifications are not completed on time and there is no good cause for the delay, the modification permit should be revoked. In the event good cause for the delay is shown, reasonable extensions should be granted.

A related problem to that of interpretation of the term "existing discharge" is the assumption in the Regulations that the technical information already exists on which applicants can base their application. The "Supplementary Information" portion of the proposed Regulations (page 19485) continues to refer to the testimony to Congress of certain municipalities that "... they had accumulated sufficient evidence to demonstrate the scientific merit of their claims for exemption." EPA then declares that although the Regulations require that information be submitted to the EPA no later than September 24, 1978, this should not be an onerous requirement because such evidence has been accumulated and applicants have known since Section 301(h) was enacted what requirements they would have to meet. We object to the assumption that such information was available to the smaller discharger or that we even now know what the final requirements will be. Although the Goleta Sanitary District has already retained engineers to acquire the necessary information for the application, the District cannot in good conscious authorize all the expensive tests suggested until it knows they are absolutely necessary under the final Regulations. Thus, the new provision in the proposed Regulations allowing submission of additional information after September 24, 1978, on a case-by-case basis is greatly appreciated. It is hoped that EPA will administer this provision in an understanding and reasonable manner particularly as to the relatively smaller agency which has not been able to acquire data prior to the passage of the new law.

B. SMALL DISCHARGER

EPA has asked for public comment with regard to whether the smaller dischargers should be treated differently than large dischargers with significant industrial and non-industrial sources of toxic substances. First of all, the definition of a large discharger should not be so restrictive as to preclude different

treatment of the relatively small discharger such as the Goleta Sanitary District. Particularly, for purposes of determining the degree of proof necessary and the testing required for the Application, the definition of a small discharger contained in Section 233.18 (under 20,000 population) should not be used. Rather, the degree of proof should be commensurate with the relative size of the discharger. Not only is the smaller discharger unable to afford the huge expenditures required but the risk of deleterious pollution is much less with the smaller volume of the discharge. For example, the testing required for toxic substances will cost the Goleta Sanitary District approximately \$2,500 per sample. To insist that all 65 substances be tested will result in a tremendous expense without commensurate benefit. Also, the reference to obtaining dilution at 200 or more feet must obviously be relaxed in the case of the smaller discharger. The ultimate test should be the effect on the receiving waters rather than an arbitrary test based on depth of the ocean outfall.

C. INCREASED DISCHARGES

EPA has also asked how increased volumes of wastewater and pollutant loadings should be dealt with under Section 301(h) (7) of the Act. As far as effluent volume is concerned, allowing the flow to increase up to the applicant's design flow capacity would be reasonable assuming such capacity provides for normal growth. However, to prevent any increase in any pollutants (mass emissions) seems far from reasonable. There will always be the normal increases in flow within the applicant's design flow capacity which will naturally mean an increase in mass emissions. Such an increase is bad only if it has a deleterious effect on the receiving waters. Monitoring will determine if there has been such an effect and, if so, EPA can force compliance with the receiving water standard.

The objective of achieving recycle/reuse of water can be achieved if the applicant is moving toward such recycling or reuse as is the case with many agencies, including the Goleta Sanitary District. However, to absolutely prohibit increases in flow or mass emissions during the period prior to beneficial uses being found for such recycled water is unreasonable.

D. COMPLIANCE WITH STATE WATER QUALITY STANDARDS

For the proposed Regulations to be meaningful for a California discharger, we must assume that EPA will approve the revised California State Ocean Plan prior to September 24, 1978. If so, then Section 233.12 of the proposed Regulations should be changed to reflect the discussion at page 17488, which provides: "If a state has no water quality standard for BOD, the applicant may satisfy the requirements of section 301(h) (1) by demonstrating compliance with an approved standard for dissolved oxygen." Section 233.12(a) (1) (i) (page 17, 494) requires a standard for both BOD and dissolved oxygen and Section 233.12(a) (2) requires that such standard be met. This problem can be solved by changing Section 233.12(a) (1) (i) to read as follows:

"(i) For biochemical oxygen demand, State water quality standards for biochemical oxygen demand or dissolved oxygen; and"

E. SECONDARY TREATMENT REMOVAL EQUIVALENCY

In several places in the proposed Regulations, EPA continues to refer to a requirement that removal of toxic pollutants be equivalent to that attained by secondary treatment. This requirement would seem to require that no matter how small the concentrations of these toxic pollutants, or how negligible the effects of these low concentrations on the environment, it must be demonstrated that the removal of these substances is equivalent to those achieved with the secondary treatment. The test should be the effect of such discharges on the receiving waters, not the artificial standard of secondary treatment. Also, the effect of pretreatment programs undertaken by applicants for both industrial and non-industrial sources must be included in any evaluation of toxic pollutant removal.

F. COMPLIANCE WITH EPA MARINE WATER QUALITY CRITERIA

The proposed Regulations state that each applicant must meet EPA Marine Water Quality Criteria or the limitations obtainable through secondary treatment, *whichever is more stringent.* (p. 17488 & 89). As EPA states, it expects to publish "within the next several months" new criteria for many substances and

revisions of some of the existing criteria for 19 of the toxic pollutants. How then can an applicant demonstrate compliance? It is obviously impossible without the criteria available. Again, it is clear that applicants cannot have all the information necessary for their application when they do not know what criteria they must meet. It is respectfully requested that EPA revised the proposed Regulations so that the above facts are taken into consideration.

G. BALANCED INDIGENOUS POPULATION DEFINITIONS

We suggest that the definition of "balanced indigenous population" as defined in Section 233.1 (h) be revised to read as follows:

"(h) The term "balanced indigenous population" means that ecological community of organisms which exhibits characteristics of natural ecological communities reasonably similar to those existing in comparable conditions of depth, substrata composition, temperature, salinity and hydrologic regimes assuming the presence of man. Among these characteristics are species distribution and abundance stratification, feeding relationships, seasonality, succession and direction of community development."

The definition in the proposed Regulations is far too restrictive in that the first portion of the definition seems to require a population which exist in the absence of any discharge. The above revised definition would provide a more reasonable test.

H. GENERAL

The Goleta Sanitary District appreciates EPA's responsiveness with regard to certain of its comments on the previously issued Preliminary Concept Paper. The District particularly appreciates the recognition that additional information may have to be provided after September 24, 1978. We also trust that EPA's reference to "terms and conditions" to be contained in the permits indicates a reasonable approach in issuing such permits. Such an approach will allow the flexibility needed to meet the intent of Congress in enacting the modification procedures.

Respectfully submitted,

ARTHUR A. HENZELL, *Attorney.*

HUMBOLDT BAY WASTEWATER AUTHORITY,
Eureka, Calif. May 26, 1978.

Hon. DON CLAUSEN,
U.S. House of Representatives, Washington, D.C.

DEAR MR. CLAUSEN: Please accept these comments for inclusion in the record of the current hearings of the House Public Works Committee concerning EPA regulations to govern applications for modifications of secondary treatment of marine dischargers.

In reviewing the proposed criteria and procedures as recently published by EPA (Federal Register April 25, 1978) it appears to me that it would be extremely difficult if not impossible for almost all marine dischargers to obtain an approval of modification of secondary treatment. I am particularly concerned in that I understood that the intent of Congress was to achieve reasonable reductions in secondary treatment of domestic wastes, while maintaining firm control of treatment and discharge of toxics. This would appear to make it possible for domestic waste dischargers who have little or no industrial connections, to achieve some reduction in secondary treatment for removal of BOD and suspended solids which would be cost effective and produce significant conservation.

In the specific case of the Humboldt Bay Wastewater Authority, our regional project has been designed and will be ready to go to construction as soon as current litigation is concluded. The project is intended to remove eight existing small domestic waste discharges from the sensitive environment of Humboldt Bay and to substitute a single secondary treatment plant discharging to the open waters of the Pacific Ocean by long ocean outfall. The treatment plant as currently designed is a complete-mix activated sludge plant meeting fully the criteria established under the 1972 Federal Water Pollution Control Act. Under the intent of the 1977 Amendment we desire to change the treatment method from activated sludge to trickling filter. This would result in very slight reduction in the degree of treatment provided, while being more cost effective and energy effective.

In addition, we are subject to extreme peak wet-weather flows, which are very dilute in nature. Again, in the interest of cost effectiveness and energy conservation we desire to provide primary treatment only of the extreme peak portions of these highly-diluted flows and blend them with the secondarily treated base flows.

I am including more complete comments in the form of a letter which was sent to the office of General Counsel of EPA on March 9, 1978, which is enclosed. Also enclosed is a copy of a letter of May 8, 1978 to Larry Walker, Executive Director, Water Quality, California State Water Resources Control Board. This letter was directed to EPA's Division of Municipal Construction concerning Section 301(h) Modifications. I believe it states cogently some of the problems with the proposed regulations which would make it extremely difficult if not impossible for us to make successful application under the proposed regulations.

We do believe that the regulations should be established in such a manner that small-to-moderate sized domestic-waste-only dischargers, such as our case, should be allowed to make relatively simplified application, providing necessary assurances of meeting all required control of toxics.

Sincerely,

JOHN R. STRATFORD, P. E.,
General Manager and Chief Engineer.

COMMENTS REGARDING PROPOSED REGULATIONS FOR THE MODIFICATION OF
SECONDARY TREATMENT FOR MARINE DISCHARGES

(California State Water Resources Control Board, P.O. Box 100, Sacramento, Calif. 95801)

1. The proposed regulations require that an applicant for modification demonstrate that he has reduced the concentrations of heavy metals and synthetic organic compounds to at least the level which would have been attained with secondary treatment. It is a fact that primary treatment or an intermediate degree of treatment consisting of primary treatment with chemical addition cannot achieve the degree of reduction of heavy metals and synthetic organics that can be achieved with biological treatment. This fact is true whether the effluent sewage is wholly domestic or a combination of domestic and industrial wastes. Because of this fact inclusion of this provision requiring the equivalency of removals of heavy metals and synthetic organics is equivalent to precluding any successful request for modification.

We do not believe that this was the intention of Congress in adding the modification procedure contained in Section 301(h). Furthermore, we see nothing in the legislation to require that such equivalency be a principle consideration in determining the merits of the request for modification.

Heavy metals and synthetic organics are found throughout the environment and are present in very small amounts even in uncontaminated mountain streams. What is important is that such substances are below levels which cause any adverse effect. It is difficult to understand why the condition of removal efficiency has been selected as a principle criterion when the agency is requiring great quantities of information on actual environmental effect. If the environmental effects from a discharge are proved to be negligible but the present removals are demonstrated to not be equivalent to secondary treatment, the logical conclusion is that such removals are unnecessary. This conclusion would be consistent with the purpose of Section 301(h). However, the proposed regulations would result in the denial of the request for modification even if environmental harm is detected.

Furthermore, the proportion of some toxicants coming from domestic sources is a significant fraction of the total load for some pollutants. Hence it can not be expected that effective pretreatment programs would serve to make up the difference in removal efficiencies between primary and secondary treatment, if such a credit is allowed.

Thus, we feel that this condition for the equivalency of removal with regard to heavy metals and synthetic organics should be deleted from the regulations and that EPA base its primary emphasis on the evaluation of actual environmental effect. If this condition remains it will constitute an arbitrary exclusion which will prevent successful demonstration by an applicant.

2. In response to the original mandate of Public Law 92-500, many coastal communities sought to improve their discharges in connection with the specific directives. These municipalities prepared the necessary studies and developed solutions including phased construction of secondary treatment facilities, outfall relocation, and even the transfer of discharges from sensitive, confined inland waters and bays to open coastal sites. Of course, such municipalities sought to obtain the assistance of federal construction grant funds to construct the necessary facilities. However, for a variety of reasons generally beyond the control of the municipality, it has not been possible to fully construct these facilities to date. We do not feel that it is equitable or desirable to completely ignore these plans for physical facilities in light of the fact that at least part of the reason such works are presently unavailable is the inherent delays associated with construction grants program. For these reasons, we feel the term "existing discharge" should include all those facilities which have been proposed and approved under Steps I, II, or III of the federal construction grants program.

We feel that this suggested approach is consistent with the overall purpose of Section 301(h) to prevent unnecessary expenditure of public funds. In the Senate History, the statement by Senator Gravel is especially enlightening in that he stresses the need to provide for reasonable regulation avoiding the expenditure of public funds for no real environmental purpose even if such reasonability results in heavier burdens upon the administrative agency. Furthermore, the statement by Congressman Roberts indicates that Title II funds shall be used to provide for proper location of outfall lines. This is a clear indication that the alterations to present facilities should be considered in the modification process. Thus, we hold that considering the alterations proposed under the Step I, II, or III of the construction grant program is logical, reasonable, and consistent with the legislation.

In treating this subject in the proposed regulation, EPA has asked:

1. How can EPA make predicative judgments regarding environmental effects?
2. In determining chemical composition, should the effects of pretreatment programs be considered?
3. When should EPA require the modification of treatment facilities be completed?
4. What action should EPA take if the modifications of treatment facilities are not completed at the prescribed time or if the actual impact is more severe than predicted?

The predicative judgments associated with the evaluation of proposed facilities are of no greater difficulty than the routine judgments that are required in administration of either the permit or construction grant programs. There does exist a defined body of engineering and biological knowledge to base meaningful projections. Secondly, there exists a large body of actual field data on outfalls of various capacities and geographic areas which permits reasonable projections of actual impacts. While predicative judgments are less certain than descriptive evaluations, the basic formulation of the modification procedure provides for additional and continuing assessment and correction.

We feel that projections of chemical composition should reflect the degree of pretreatment which will be in place. However, such projections cannot be accurately made at this time because of the absence of defined federal pretreatment standards.

There is no simple, uniform answer to the question of when should such modification facilities be in place. The time to complete the modification of the treatment facilities will vary depending principally upon the type and size of the proposed alterations. The modifications should be completed as soon as possible. However, we do recognize a need to establish an outside date and therefore, we suggest that this be the same date which other dischargers have been given to finally achieve the secondary treatment requirement (July 1, 1983).

The final question posed regards the question of enforcement. This question defines simple answers and the appropriate enforcement determination must be tailored to particular factual circumstances. If any discharger fails through his own fault to make the necessary modifications in a timely fashion or institute effective pretreatment, those conditions of his permit should be enforced to the maximum extent provided. If a discharge proves to have an adverse environmental effect, despite the best technical predications, no further alterations of facilities should be allowed and the modification should be revoked and the discharger required to install secondary treatment according to a specific time schedule.

3. EPA proposes to require as a condition of modification, compliance with EPA marine water quality criteria. In the case of metals, compliance will be determined after initial dilution. However, in the case of synthetic, man-made substances, compliance with the quality criteria will be determined in the effluent as discharged. Thus, the water quality criteria for these substances will serve as fixed effluent limitations.

EPA water quality criteria was not originally developed to reflect what would be necessary for the discharge of an undiluted effluent, but rather to reflect concentrations which would provide the necessary degree of protection after mixing with the receiving water. To apply these concentration limits directly to effluents is contrary to the purpose for which they were developed and would preclude the possibility of any successful modification to the secondary treatment requirement. For example, the EPA criterion for PCB is 0.001 mg/l. Despite the fact that the general use of PCB was prohibited in the early 1970's, almost all municipal wastewaters in California still have PCB levels at concentrations ranging from 0.3 to 4 mg/l, which are hundreds to thousands times greater than would be allowed under the proposed regulations. Even those facilities utilizing full secondary treatment cannot comply with such a stringent effluent requirement.

The levels of reported PCB's in municipal effluents are very consistent between municipalities and constant with time. It is expected that present levels are the result of residues remaining in sewer systems. In the absence of significant industrial sources, and we cannot find significant contribution sources, it is impossible to reduce the levels of PCB's to that contained in the criterion regardless of the treatment level employed.

We recommend that the regulations specify compliance with the criteria as they were designed to be applied as water quality standards applicable after initial mixing. EPA should concentrate its effort on man-made toxicants in its programs where regulations can be direct and successful. However, if EPA remains convinced that single, uniform effluent levels must be imposed for such substances, these effluent standards should be derived and reviewed by interested parties as part of the toxic standards. In addition, such limitations, if necessary, should be universally imposed regardless of water body or specific type of treatment.

4. The draft regulations also require compliance with State Water Quality Standards, EPA Water Quality Criteria, and Section 307, toxic materials limitations at the time of application for modifying secondary treatment requirements. This would amount to compliance with something near one hundred or more quantitative effluent and receiving water standards. It is quite possible that a discharge would have little impact on the marine environment yet still exceed one or more of the applicable standards. This could happen because almost all standards contain some margin of safety; hence, exceeding a standard need not always be an indication of adverse water quality impact.

To assure that meritorious applicants are not rejected on technical violations of requirements, rather than substantive water quality issues, we recommend that the regulations be written to place the primary emphasis on an evaluation of receiving water quality which must not be degraded at the time the application is filed. If there are technical violations of standards when the application is filed, the Administrator should condition the exception to the timely correction of the violations in accordance with a time schedule he has approved. Violation of the time schedule should then constitute sufficient grounds for revoking the exception.

5. EPA has chosen to limit the waiver to the design flow rate of the present facilities and the existing pollutant loading on the date of application. While the statutory language may not be completely clear, we believe the Senate and House reports do clarify the intent to limit the waiver to that flow which is expected over the five year duration of the modification. This opinion is based upon the statement of Senator Muskie and Congressman Anderson:

"... and if the volume of discharge of the pollutant will not increase beyond that specified in the modified permit *for the period during which the waiver is granted.*" (emphasis added)

"This provision does not mean that treatment works applying for a modification are to be restricted to the current volume or capacity of their plants. In the interest of continuing the policy of encouraging regionalization these treatment works may increase their discharges overtime as capacity permits as long as the controls are maintained. The volume of discharge may be revised just as any

other permit condition may be altered, as warranted by changes in circumstances."

Philosophically, we support EPA's approach in making a strict interpretation, in that reclamation of wastes otherwise discharged to the ocean would be encouraged to a much greater extent. However, from a practical standpoint, this approach presents problems, i.e., upon receipt of a permit, all growth would have to stop until reclamation projects are brought on line three to five years later.

To achieve this same end, we would suggest an alternative approach. Namely, inclusion of a permit condition which would:

- (a) required detailed Step I studies of potential reclamation projects.
 - (b) require implementation of reclamation projects where feasible and where grant funds are available of cost effective reclamation projects,
 - (c) and, further, state EPA's intent upon renewal of the permit to reduce anticipated allowable flows by the amount of flow which can be reclaimed.
6. In the Section dealing with information and data which must be submitted in support of an application, the requirements appear to be in some cases more specific than might actually be needed (e.g., Instruction and Definitions, Part 4, B. Ocean Discharge 4-11, and C. Estuarine Discharge, Page 21). In view of the short time for filing an application, it can be expected that most of the data submitted would be data which already exists. Overly specific and arbitrary prescriptions for data, especially in areas where these should be scientific, discretion should be avoided.

STATE OF CALIFORNIA—THE RESOURCES AGENCY,
STATE WATER RESOURCES CONTROL BOARD,
Sacramento, May 11, 1978.

DIRECTOR, MUNICIPAL CONSTRUCTION DIVISION (WH-547),
Office of Water Program Operations, Environmental Protection Agency, Washington, D.C.

PROPOSED REGULATIONS IMPLEMENTING SECTION 301(h), MODIFICATION OF SECONDARY TREATMENT FOR DISCHARGES TO MARINE WATERS

The proposed regulations preclude any successful application for the modification of secondary treatment for discharges to marine waters for the following reasons:

1. The requirement for no greater level of toxic constituents than would occur if complete secondary treatment were installed.
2. The requirement that EPA's water quality criteria for man-made toxic constituents be achieved in the effluent prior to discharge.
3. The requirement that the discharge be in compliance with *all* applicable water quality standards at the date of application.

The first two of the above requirements will successfully preclude issuance of any modification nationwide. The last requirement defeats efforts of states, like California, which have adopted stringent water quality standards for ocean waters. California has given the discharges a reasonable amount of time to comply with the standards. Consequently most coastal communities will not meet ocean water quality standards by the date of the application.

Each of the above points are not exact measures of the true environmental impact of coastal discharges. Instead they are useful as environmental indicators where actual environmental assessments are not available. However, the regulations require an applicant to make actual, detailed environmental measurements. Yet the proposed regulations would require rejection of applications based upon noncompliance with an indirect measure of environmental quality, even if the direct environmental assessment demonstrates no environmental problem exists. We do not feel this is consistent with the intent in providing for modification of the secondary treatment requirement.

A more detailed explanation of these comments is attached in triplicate. We hope that our initial comments and suggestions will assist you in developing final regulations. We submitted these comments early to give you ample time to evaluate these points. We shall, later in the comments period, submit additional comments directed at the more technical issues. We would be happy to meet with you and other Pacific Coastal states to attempt to resolve the differences which appear to exist.

LARRY F. WALKER, Executive Director, Water Quality.

HUMBOLDT BAY WASTEWATER AUTHORITY,
Eureka, Calif., March 9, 1978.

Ms. LISA FRIEDMAN,
U.S. Environmental Protection Agency, Office of General Counsel, Water Quality
Division, Washington, D.C.

DEAR Ms. FRIEDMAN: At the EPA public hearing concerning subject ocean discharge regulations held in San Francisco on February 22, 1978. I gave a short oral presentation of some of the concerns of the Humboldt Bay Wastewater Authority. I was informed that followup written comments would be accepted in your evaluation process prior to promulgation of regulations. This letter is to add further comments.

So that you may have a better understanding of the reasons for our concerns, a bit of background concerning our regional project is in order. The area to be served by this regional project includes about 70,000 population surrounding Humboldt Bay in northwestern California. The project is to be constructed by a joint exercise of powers authority consisting of the County of Humboldt, the City of Eureka, the City of Arcata, the McKinleyville Community Services District and the Humboldt Community Services District. All of these agencies are currently treating and discharging into the estuarine waters of Humboldt Bay through eight separate discharges, which are currently in violation of state and federal requirements. Building construction moratoriums and limitations have been imposed on most of the communities around the bay.

A regional project was designed and a waste discharge permit acquired (NPDES No. CA0023817) in May of 1975. A year of extensive ocean monitoring was conducted, concluding in November of 1976. Plans and specifications have been completed and approved. The Step III construction grant has been approved. Bids were taken in May 1977 for the total regional system, consisting of a series of long interceptors, pump stations, activated sludge secondary treatment plant and an ocean outfall. However, opposition to the project from some local groups resulted in litigation delaying construction of the project. It is not expected that litigation will be concluded until late summer or fall of this year. A major item of concern of those who have opposed the project has been the activated sludge method of secondary treatment, which is a relatively high-cost, energy-intensive treatment method considering the limited environmental benefits which might be achieved in our specific circumstances. Therefore, the Humboldt Bay Wastewater Authority and the member agencies which have created it are convinced that some modifications of the treatment method must be considered in order to reduce costs and energy use, or there will be no chance to develop a system that would be supported by our people.

Two possible design revisions which have been suggested are: change to use of trickling filters and reduction of treatment level of high but dilute wet-weather flows. Change to trickling filter would appear to reduce the level of treatment by a small amount while achieving significant reduction in electrical energy use. Because we have high peak wet-weather flows compared to our average dry-weather flows (40 MGD peak versus 7 MGD average dry weather flow) some reduction in treatment of these dilute peak, wet-weather flows appears warranted. Our existing design is based upon adhering to the extremely rigid requirements in effect prior to the 1977 Act amendment which will allow such modification.

It should be further noted that the Humboldt Bay Wastewater Authority system will receive only domestic waste. There is no significant industry tributary to this system. The only industrial discharges to the system will be small in size consisting of fish processing plants and local meat packing. Since the constituents of their discharges are similar in nature to normal domestic wastes, the usual problem of toxics contributed by industry is not present in our case. We will firmly control discharges to our system to prevent the entrance of toxic pollutants.

Our extensive ocean study program, carried out under the guidance and control of the California Water Resources Control Board, has provided valuable evidence of receiving water conditions. Study of the nature of turbulent coastal current conditions at our site and the relatively small size of our discharge has shown that domestic wastes such as ours can be effectively diffused and assimilated without causing environmental problems. Therefore, absent the problem of toxics, it seems reasonable to allow limited relaxation of strict biological secondary

treatment requirements in order to achieve major reduction in energy use and operating costs while also simplifying and improving operational reliability.

On the basis of the background information submitted above, we wish to state several specific concerns and requests to take into consideration in promulgating regulations on ocean discharge modifications:

1. We are supportive of the proposals and comments submitted by the California Water Resources Control Board, and believe that the "Water Quality Control Plan for Ocean Waters of California," as amended in 1978, provides proper criteria and guidelines for achievement of the degree of treatment needed at each specific ocean discharge. We believe that water quality standards which regulate surrogate parameters such as D.O., turbidity, light transmission, etc., should be allowed to be used to show compliance.

2. In cases such as ours, where a regional system to provide a single, controlled ocean discharge is being constructed to eliminate several unacceptable discharges to an enclosed bay or estuary, our ocean discharge should be considered to be "existing." We already have an NPDES ocean discharge permit. This type of situation should be taken into account in interpreting such phrases as "existing deep marine discharges" and "no new or substantial increase."

3. The term "deep" is a relative term. We do not believe that any fixed depth should be established as a basis for acceptance or rejection of a treatment modification request. In our coastal conditions we can achieve 100-to-1 dilution at a 60-foot depth with our relatively small discharge.

4. We do not believe that any minimum "length" of outfall should be set as a criteria for approval or disapproval. In our case, with no significant recreational use of the waters and beaches, and little environmental change with increased distance beyond the present design diffuser location, no significant benefit is achieved with increase in length.

5. A fixed percent removal of BOD and suspended solids should not be a limiting criteria. This can cause treatment which is not cost effective in cases such as ours, where large amounts of wet-weather infiltration to the system causes a very dilute or weak sewage.

6. The requirement that "the applicant has established a system for monitoring the impact of such discharge on a representative sample of aquatic biota, to the extent practicable" should be construed to allow application if a firm commitment is made by a discharger to establish such a system. In our case we have conducted the initial ocean studies to develop baseline data. The required ongoing monitoring program will be established in cooperation with and under the control of the California Water Resources Control Board.

7. The law should *not* be interpreted to require that the concentration of toxic pollutants in the discharge granted a modification be no greater than the concentration which would occur with secondary treatment. In a case such as ours, of essentially domestic waste, and with the contribution of toxics to the system being very small, it might preclude a small reduction in strict secondary requirements which would allow an energy-saving and cost-effective design change from activated sludge to trickling filter method of treatment.

8. Compliance with Section 301(h)(5) should *not* require a publicly-owned treatment works to have an enforceable pretreatment program at the time of the application. Instead, a firm commitment should be required to establish such a program. In our case, such an enforceable program shall be adopted to coincide with the shift from multiple bay discharges by several local agencies to a single ocean discharge controlled by the Humboldt Bay Wastewater Authority.

In summary, most of our concerns relate to our specific situation of having a new ocean discharge which is replacing several unacceptable discharges to Humboldt Bay. Until the adoption of the 1977 Amendments we had based our design upon strict interpretation of secondary discharge requirements. This has resulted in major local opposition by those who believe that an activated sludge method of treatment does not produce environmental benefits commensurate with the required high cost and high use of energy. By very limited modification of strict secondary requirements and change to more flexible and rational controlling criteria, changes can be made which are consonant with national objectives for achieving energy conservation and cost effectiveness.

Sincerely,

JOHN R. STRATFORD,
General Manager and Chief Engineer.

THE CITY OF SAN DIEGO,
DEPARTMENT OF WATER UTILITIES,
San Diego, Calif., May 23, 1978.

HON. RAY ROBERTS,
Chairman, Subcommittee on Water Resources,
House of Representatives, Washington, D.C.

DEAR SIR: It is our understanding your subcommittee is receiving testimony on May 24 and 25, 1978 concerning the waiver from secondary treatment provided for in Public Law 95-217 adopted on December 27, 1977, which amended Public Law 92-500.

The San Diego Metropolitan Sewerage System, which serves 1,500,000 people in sixteen (16) surrounding cities and agencies in the County of San Diego, with additional emergency flow from the City of Tijuana, Mexico, discharges its primary treated effluent 2½ miles through an ocean outfall in the Pacific Ocean at a depth of 220 feet below sea level. Digested sludge is not discharged but is mixed with sand and seaweed and utilized as a soil amendment by the City. The ocean area surrounding the discharge outfall has been monitored since 1963, which was a year before the plant was put into operation. All monitoring data is computer filed with the California Regional Water Quality Control Board, San Diego Region.

This data has been reviewed and studied along with numerous other reports, studies and investigations that have been made by scientists and engineers over the years. All individuals involved have concluded that the effect of the discharge has not been adverse. In fact, testimony shows an increase in some cases of diversity and numbers of species.

These studies, amounting to over \$1,000,000 worth of investigation and reports, referred to many times and on file and submitted to various governmental agencies, were performed by:

Holmes, Narver and Montgomery,
Brown and Caldwell,
Southern California Coastal Water Research Project,
Research Management Associates,
Lowry and Associates,
California State Water Resources Control Board.

Further, as an example of a very recent presentation in February 1978, the California Regional Water Quality Control Board, San Diego Region, (our regulatory agency) received testimony from their own consultant, Dr. Gerald T. Orlob, on the impacts of the San Diego Metropolitan Sewerage System discharge on the ocean. A copy of the presentation is attached as Exhibit "A". (Please note that the consultant is a marine and ocean authority of note.)

After reviewing the scientific and technical data in the presentation, one should carefully note page 20 which reports the questioning of Dr. Orlob by the Regional Board Chairman, Mrs. Scheuneman:

Question. "Dr. Orlob, you mentioned the outfall is working very well. As the flow increases do you think secondary treatment will be required?"

Answer. "Well, as I see it now, there are no indications that secondary treatment would be a solution to the problem. The difficulties are, I think, more readily solvable by improving the overall capacity of the plant. I think it can be demonstrated that the benefits derived from taking that big additional step to go to secondary treatment are not commensurate with the costs."

Such testimony from scientists and experts, including the National Research Council, which has been affirmed by environmental and ecological interest groups such as the San Diego Coastwatch, Coordinates for Century 3 (who assisted the Citizens Committee studying our needs) are all a part of the 201 phase of our efforts as required by Public Law 92-500. This testimony is reaffirmed by statements from regulatory agencies such as California Department of Water Resources, the State of California Water Resources Control Board and John Rhett, Deputy Assistant Administrator of the Environmental Protection Agency, who said that:

"If all the cities had followed the excellent example of The City of San Diego in disposing of wastewater and pollutants, there never would have been a need for Public Law 92-500."

It seems to us that this is overwhelming documentation, that the City of San Diego does not need secondary treatment as defined in the public statutes at this time.

Thomas C. Jorling, Assistant Administrator, PEA, stated in his prepared comments at the San Francisco, California, February 22, 1978 meeting regarding modifications to secondary treatment requirements:

"The (statutory) criteria require that the modifications will not interfere with the attainment of maintenance of that water quality which assures the protection of public water supplies and the protection and propagation of a balanced, indigenous population of fish, shellfish and wildlife, and allows recreational activities in and on the water."

This statement by Mr. Jorling is a repeat and practically a word for word quote of the goal of Public Law 92-500, Section 101(a) (2).

We are in complete agreement with this position. However, we feel the scientific and technical documentation has already been presented. It attests to the attainment of that goal by The City of San Diego. In addition, when one simply sails into the ocean off Pt. Loma, sees and photographs sailing, recreational and commercial fishing, kelp harvesting, lobster beds, surfing, and skin diving right down to the ocean outfall (where photographs show plant and animal life in abundance), we submit that the 1983 goal of the law itself is already attained.

EPA has given the City an enforcement order to hire a consultant and prepare plans and specifications to build secondary treatment to discharge the *present* and future effluent into the ocean. The construction costs are estimated at \$427,000,000. With primary treatment as our standard, the same capacity would cost approximately \$52,000,000. Thus, we believe secondary treatment is a needless waste of taxpayers' money.

Mayor Pete Wilson stated this in his June 22, 1977 testimony to Senator Muskie and the Environmental Pollution Subcommittee. Mayor Wilson reiterated San Diego's long range desire to implement resource recovery of effluent by recycling the effluent into the City's water supply system, using innovative and new technology to do so. We are engaged in such work with out 10-year research on reverse osmosis and application for funding for a 1 MGD aquaculture water hyacinth project as developed by NASA. By such an approach we feel we are fulfilling Senator Muskie's statement in the December 15, 1977 Congressional Record, Page S19640:

"The Conference agreement emphasizes the need to use alternative technologies instead of conventional secondary treatment plants and encourages the development of new and innovative systems. To accomplish this the bill requires republication of cost effective guidelines to effect the long-term benefits of recycling and reclaiming—in order to make use of nutrients in the waste waters."

While research is being completed on these new technologies, capacity in our present plant is being approached and probably will be exceeded before the institutionalized paper flow process will allow construction to commence. We urge therefore that a waiver of secondary treatment requirements and the expansion of our primary plant to our next increment of capacity be granted. In the interim, we propose to perfect aquaculture technologies and set up a plan and schedule to proceed with resource recovery. The studies we have completed to date on such systems show them to be cost effective to us. Resource recovery systems use less energy than presently required systems and lead to something about which all of us can be proud. To be mandated into expending some \$400,000,000 for secondary treatment facilities in the face of the body of evidence indicating that it is unnecessary is a waste of our monetary and physical resources.

Once again, The City of San Diego is pleased to be given the opportunity to make this presentation. We stand ready and available, either through written or personal presentations, to answer any questions we may be asked or to provide any documentation requested.

Thank you,

R. W. KING,
Water Utilities Director.

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD, SAN DIEGO REGION

[Presentation given by Dr. Gerald T. Orlob of Resource Management Associates on Impacts of Domestic Wastewater Discharge on the Ocean Environment off Point Loma, Calif.]

ITEM 3—CONSULTANT'S REPORT ON ANALYSIS OF CITY OF SAN DIEGO MONITORING DATA

Chairman SCHEUNEMAN. Mr. Burtman, would you introduce this item please?

Mr. BURTMAN. Thank you Mrs. Scheuneman.

To provide a little background for this item: When the city of San Diego applied for waste discharge requirements for their metro discharge, a very significant monitoring program was required of the city as the operator of the system. The city began collecting data about 15 months before the discharge was initiated. As time went by, the volume of data that came into the regional board office made it almost impossible to review. Because of this, the board has had consultants to review this data every two years or so for the simple reason that looking at the data was like "trying to memorize the Los Angeles telephone book"; it was so voluminous.

The most recent reviews of this data have been done by Dr. Gerald Orlob who is both a consulting engineer and a member of the faculty of the University of California, initially at Berkeley and now at another branch. Dr. Orlob is rather well noted for his use of electronic data processing machines for solving some rather complex problems in the field of engineering. He has done several of these studies for the regional board. As a matter of fact, he has also done this as part of the study for the San Diego 201 plan. He has done this in cooperation with a number of other people, also of rather large repute in the field, including Dr. Robert Cooper of the University of California, school of public health. I think with that brief introduction it would be proper to call upon Dr. Orlob to present the findings of his latest report.

Dr. ORLOB. Madam Chairman, members of the Board, it is indeed a pleasure to be here once again. Actually, I met some of you previously, but there are some new members of the board and I would welcome the opportunity today to brief you on some of the background material that has been developed over the years on the San Diego outfall and its performance.

To facilitate our discussion, I have chosen to go back a little farther than just the most recent examination of the performance of the outfall. I have included some illustrative material that extends back to a previous study which was conducted as a part of the facilities planning effort of San Diego. So I will refer to the performance of the outfall, not only as far back as 1963, but for the last three years or so. Unfortunately, I won't report on the current status of the outfall since our study was commissioned to cover the data through mid-1976, but I suppose the performance in the recent year or so has not been greatly different. There may have been some changes which you will hear about, but what might be more interesting to you I think will be the overall performance of this outfall. Information obtained from studying this outfall may be used as an example of what might be anticipated at other locations along the coastline. In my judgment and in the minds of many others in my field, the Point Loma outfall is unusual in that: (1) it has a well-conceived and executed monitoring program; (2) it was well designed; and (3) it has experienced very unique episodes in its existence which have allowed us to evaluate some things that might not have otherwise been possible.

I have assembled transparencies for your reference. These include the major exhibits which have been prepared as figures in the most recent report and a few from the prior report to the city of San Diego.

First of all I think it would be appropriate to give you a few factual points. First, the Point Loma treatment facility was placed in operation in August of

1963 as a primary treatment facility. Primary treatment removes such materials that settle to the bottom of the clarifiers or that can be skimmed as floatables from the surface, and the effluent after that degree of removal is discharged directly to the outfall. With a little additional treatment, on occasion, there have been some efforts to provide chlorination to reduce coliform bacteria. This plant at its inception had, and still has, at least for the period covered by this report, a design capacity of about 80 million gallons per day. That capacity was reached in the late 60s and early 70s. In my most recent evaluation, 1976, the flow was 120 million gallons per day on the average; roughly 50 percent above the intended designed capacity. For quite a period of time there has been a gradual, but steady, increase in the discharge flows from the plant. In the last half dozen years or so it has increased at a rate of about 6 million gallons per day each year and that trend doesn't seem to have changed very much. So the prospect is that today, even a year or so later, there may have been some additional increases depending on the rate of growth of the service area tributary to the plant.

It is possible also since we've gone through a drought that maybe there's been a little letup in the total flows, but not as much as experienced in northern California. I am sure we have experienced a decline simply from the lack of water infiltrating into the system. Occasionally the capacity has been far exceeded when we have excessive runoff or rainfall in the area—runoff recharging the groundwater table, and of course raising those groundwater tables in some cases above the flow line of the sewer system which feeds the main interceptor and outfall. The result is that when these episodes occur, real peaks appear. Flows may be double the designed capacity for short periods of time. Of course this would be initially detrimental to the performance of the system simply because the hydraulic loading is far exceeding that for which it is designed, and of course we would expect lower treatment efficiency associated with that kind of event.

Turning to the outfall itself, I have said before and I think others will agree with me, that this ocean outfall is perhaps unique among those along the Pacific coast. It is certainly an excellent example of designer's art, both in design and construction. It was fortuitous for the city of San Diego because it has a unique site off Point Loma and projects a relatively short distance from shore. The outfall has a steep profile so it is able to discharge within two miles of the shore at a depth exceeding 200 feet from the surface. This is a very favorable situation, to say nothing of the fact that the outfall itself was carefully designed by Dr. Brooks at Cal Tech with the aid of physical model studies. The outfall was designed in accordance with the latest understanding at the time of how such facilities should be designed. It has performed well since its installation. I might say also that it was designed with future capacity of the system in mind so it has a capacity of about 230 million gallons per day. Up to the present it hasn't changed that capacity; except perhaps up to about 70 percent during periods of excessive infiltration of the system. It is also designed to provide maximum dispersion of the waste into the environment so that by the time that material rises toward the surface, as it does, it has achieved adequate dilution. Nominally that should be 100 to 1 within a reasonable distance of the outfall. This outfall and operation of the treatment plant by about 15 months. This provides a

The monitoring program is unique as I've mentioned for several reasons. One of them is the fact that it actually started in advance of the installation of the outfall and operation of the treatment plant by about 15 months. This provides a baseline to tell us a little bit about the effects of the discharge of wastewater to the marine environment, and what has transpired in a period of something like 14 years since the outfall first went into operation. We are able with the aid of this background material to follow the trend somewhat more reliably. So that 1962-63 survey, let's say about a year or maybe 15 months long, included many observations. We don't take all of them now because we found that it's probably not efficient to do so. The information derived was not worth the cost of collecting those samples, but we have modified the program to collect some additional bits of information that we didn't earlier on.

Observations generally required of the monitoring program are those of the wastewater flow itself, its quality, and a variety of different constituents. This information is provided regularly by the city to the regional board. The receiving water quality was rather intensively monitored at the outset but has been of less importance recently except in the matters of coliform bacteria, transparency, and temperature. Because the outfall is fairly efficient and provides good dilution, we don't find evidences in the receiving water quality due to the waste discharge that are anywhere near the requirements imposed by the regional board.

Perhaps more informative is the knowledge of bottom sediment characteristics. The organic content in particular turns out to be rather informative as to the general performance of the outfall. Also the benthic animal population inhabiting this thin upper layer of the ocean floor tells us a lot about what changes might have taken place during the period of operation.

We have in addition to monitoring stations around the outfall itself, some 35 different sampling locations, many of which are situated right on the shoreline. Of course these are areas of water use which we like to monitor from the point of view of the people who come into contact with that water. The most important measurement there is that of the bacterial concentrations.

We have been reviewing this data periodically and I have been fortunate enough to have participated in that review program. It started back in the mid-60s with an effort on the part of Marine Advisors, a local oceanographic group charged by the board to collate the mass of information, to code it for computer analysis, and to set up a program for evaluation of benthic animal populations. Since that time my consulting organization and I have evaluated that data and updated it with the aid of Dr. Cooper of The University of California and have revised the program somewhat from time-to-time. It has been suggested that the board follow suggestions for revision of the program.

Here's the monitoring pattern: It consists, although it's been modified somewhat, of a number of stations situated around the outfall diffuser in the shape of a square, roughly two miles on each side. A year or two after the outfall went into operation the city added more stations closer to the outfall for the simple reason that at the periphery of this square, we weren't able to detect very many significant changes. So we moved a little closer to get more background information: Particularly information on the distribution of substances that respond to the environment with respect to distance from the outfall.

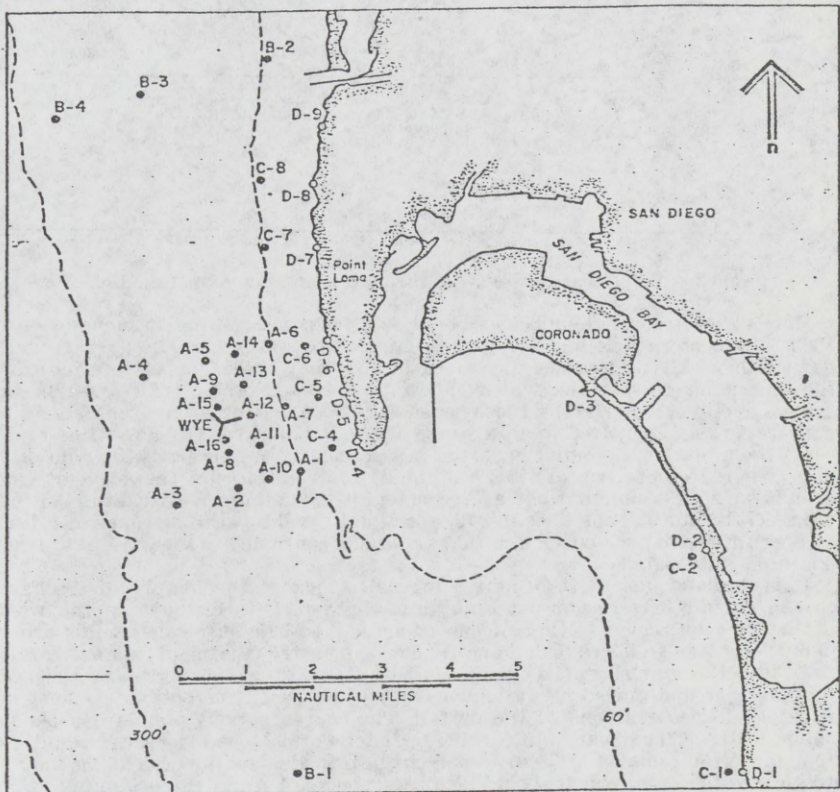


FIGURE 1. Point Loma outfall monitoring stations.

To compare the performance of this outfall to something that would be representative of a natural background, a number of so-called control stations were selected. Here's one to the south opposite San Diego which we find currently is perhaps not a good choice for a control station for other reasons that we might talk about later, but distant enough from the outfall that we feel that the Point Loma discharge itself does not influence the station. Likewise to the north are three offshore control stations, or "B" stations. The two seaward stations, A3 and 4 here, in the vicinity of the outfall are also what we regard as control stations for bottom deposits because they seem to be little affected by the pattern of any deposition near the outfall. Along the shore we have shore-line sampling stations, particularly in front of the outfall, and to the north, and in various locations along the waterfront where swimmers would come in contact with that possible dilution of the discharge.

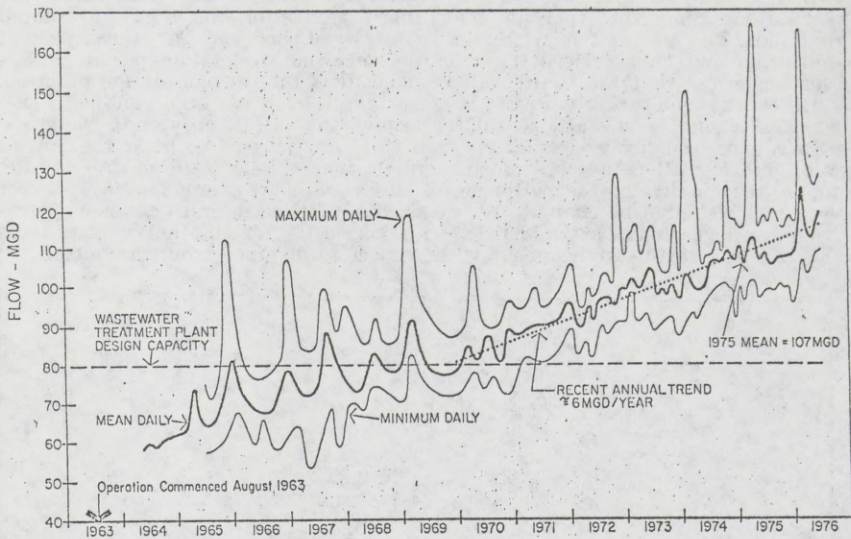


FIGURE 2.—Wastewater discharge through Point Loma outfall, 1963-76.

Here's a pattern of the efficiency of the outfall since it went into operation in 1963. The heavy black line along the center of this sketch is the average daily flow with yearly and seasonal variations also shown. The upper line indicates the maximum daily value which shows peaks of excessive infiltration in the system due to storms. Lately these peaks have been getting up to over 160 million gallons per day compared to an average of about 120 or so. The lower line represents the minimum flow that is sort of a baseline. On a daily basis it would probably be representative of very minimal contribution to the system from groundwater. The fluctuations are representative of the same pattern. You can see recently, since about 1969 and 70, a gradual trend upward, perhaps at a little steeper rate than previously, and that trend has continued to the present at about 6 million gallons daily.

It is perhaps just as informative for us to look at the history of discharge to the outfall in terms of an important characteristic included in the waste discharge requirements: that of suspended solids. The suspended solids are by definition those solids that don't settle out of primary treatment and are carried over into the marine environment. Potentially, they are separable if they can flocculate or find quiescent water where they can reach the bottom, as some apparently do near the end of the outfall. The concentrations of these suspended solids in the effluent vary quite widely. Under normal operations we would like to achieve the removal of 50 to 70 percent in primary treatment, leaving the rest to go into the ocean. That would mean, as you see here in the beginning of our historic period, a suspended solids concentration on the order of about 100 mg/l, and this was at a time when the plant was underloaded, hydraulically at

least. It was performing well at startup the first year. More recently this value has averaged over long-term periods about 140 to 150 mg/l which is still pretty good for an overloaded primary plant. But what you see in the discharge is evidence of a failure of the sludge transfer line from Point Loma over to an island in Mission Bay. Digested sludge from the plant is mixed with sand to make it suitable for growing grass. The sludge line failed because of the corrosive effects of digested sludge. Well, one can't simply continue to let the sludge accumulate in the plant. It has to go somewhere and in this case it had to go to the ocean outfall. That digested sludge, although it represented the modicum of treatment through the digestive process, was diverted into the outfall for about two years and it shows up here as an increase in the suspended solids concentration through the outfall (1964-1976).

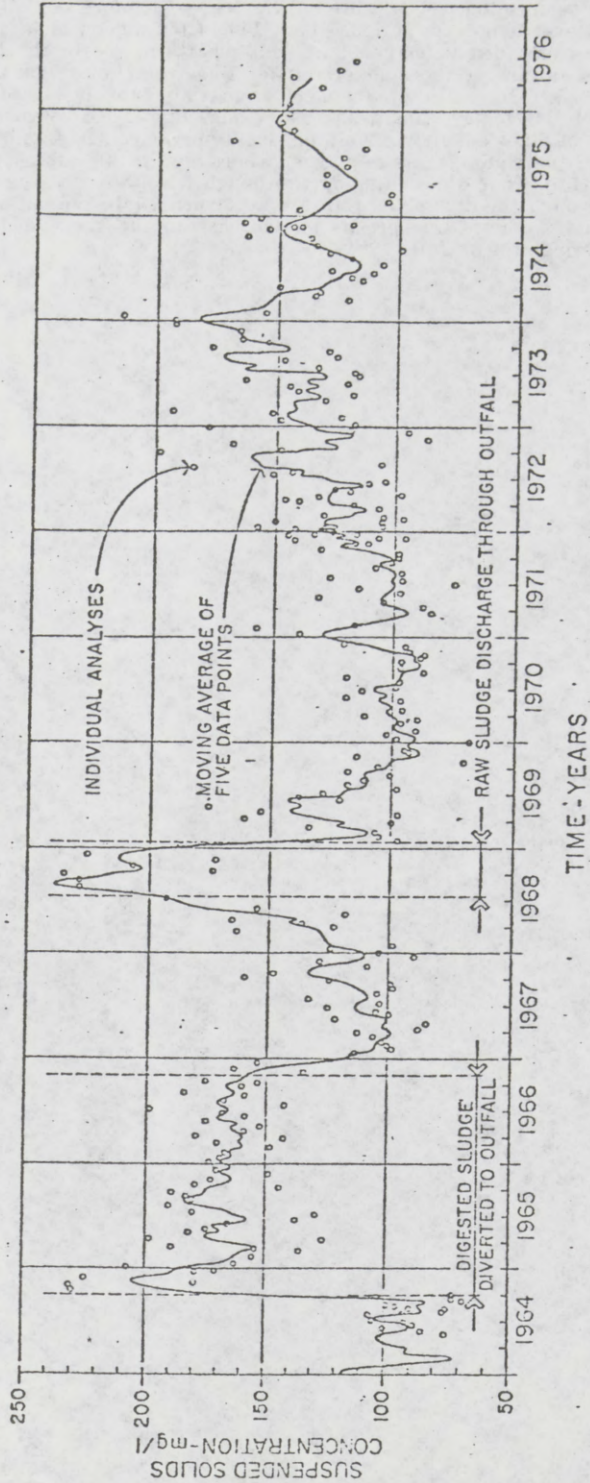


FIGURE 9.—Suspended solids concentrations, Point Loma discharge, 1964-76.

At this point I became associated with the project because I was asked to evaluate effects on the environment from that digested sludge. We estimated, rather crudely at the time, how much of the ocean floor might be affected by this material. But after about two years the plant was put back into operation and resumed more of a normal pattern. Unfortunately, due to accumulation of sand in the digesters associated with infiltration problems, the digesters became ineffective and a portion of the digesters' capacity was removed from service. That meant there was no place to put the sludge. It had to go through the outfall as raw sludge for six months while the digesters were being cleaned. This had an impact shown here in the fluctuations of suspended solids (1968). Those episodes were quite useful for us because it told us something about how the environment could respond to the changes.

I have some recent data on effluent quality between 1973 and the middle of 1976. From the figure you can see slight annual variations in suspended solids concentrations but no upward trend from year to year. The concentration runs about 150 mg/l through 1976; a removal of approximately 50 percent but not quite as efficient as we would like. Biochemical oxygen demand also shows slight variations but is somewhat proportional to plant efficiency. Grease concentration values in the effluent fluctuate widely, due partly to the difficulty of making accurate analytical determinations using the test for grease and oil. In the past, values were more erratic; so if anything, there has been a slight decrease in concentrations of grease in the effluent. Finally, total heavy metals have not changed much. You may recall the maximum has been set at about 2 mg/l.

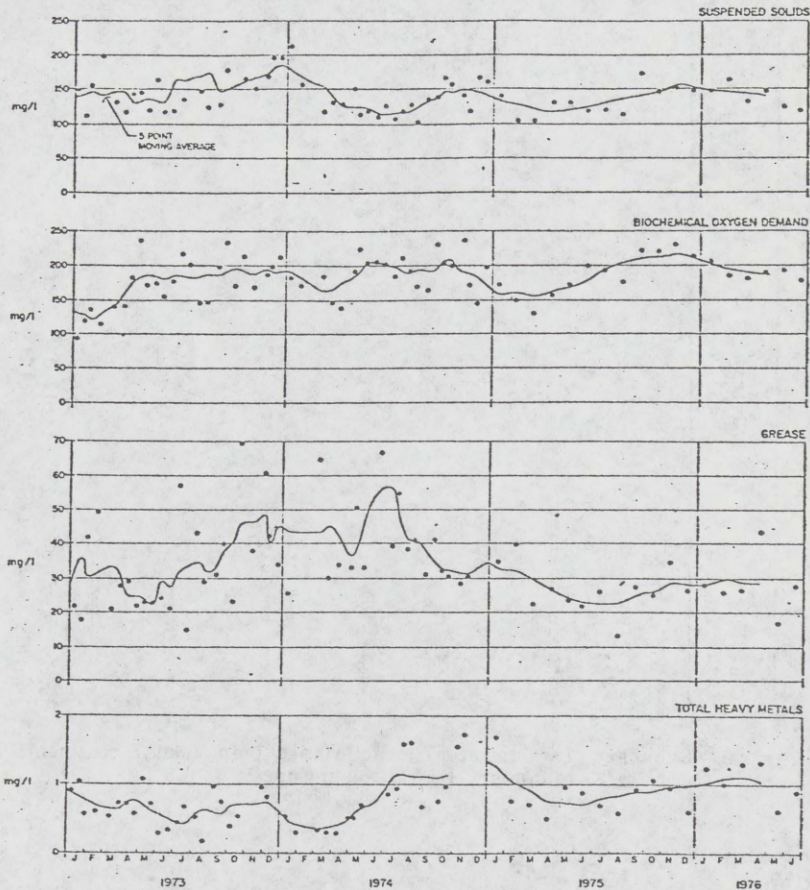


FIGURE 3.—Wastewater quality, Point Loma outfall effluent, 1973-76.

I might point out that there have been a few violations, although these are relatively few and are primarily associated with the requirements for the mass emission of suspended solids through the outfall.

Constituent or Parameter	Units	Concentration			Exceeded Standards	Trends	
		min.	mean	max.		Seasonal	Annual
Discharge (daily mean)	MGD	94.0	109.8	162.5	continuous above design	yes	increasing
Suspended Solids daily	mg/l			316	27 x >200	yes	increasing
monthly	mg/l	104	134.2	170	2 x >150	yes	steady
Daily mass load	lb/dx10 ³			346,800	17 x >200	yes	increasing
Monthly mass load	lb/dx10 ³			173,900	2 x >150	yes	steady
BOD daily	mg/l			325	-	yes	steady
monthly	mg/l	130	185.8	231	-	yes	steady
pH	-	7.28	7.41	7.54		no	steady
Grease and Oil semi monthly	mg/l			67	<75	yes	decreasing
monthly	mg/l	13	27.1	43	<60	yes	decreasing
Volatile Solids monthly	mg/l	69	105.5	135	-	yes	steady
Heavy Metals semi monthly	mg/l			1.38	<5	no	steady
monthly	mg/l	0.60	0.93	1.33	<2	no	steady
Daily mass load	lb/dx10 ³				<5	no	steady
Monthly mass load	lb/dx10 ³				<2	no	steady

TABLE 3.—Summary of wastewater characteristics, Point Loma Treatment Plant, January 1975 through June 1976.

Here's a summary of violations from January 1975 through June 1976. I have shown the various requirements along with the number of times the requirements have been exceeded as well as recent trends. During this year and a half period, daily requirements issued by the board for suspended solids were exceeded on 27 days. Monthly requirements during this same period were exceeded twice. Of all the constituents shown, only suspended solids were increasing in the discharge. This was to be expected of course because of the hydraulic overloading experienced: the plant simply did not have enough capacity. This situation has now been remedied and we should find an overall improvement in compliance with the suspended solids requirement. Even so, the data shows the outfall has performed well.

One of the unique characteristics of this site is that the ocean waters become stratified for much of the year, especially during the summer. This means that essentially a lid is put on the diffuser with a strong zone of stratification occurring at something like 30 to 50 feet below the surface. For example, in August 1972, the surface temperature was about 20°C but only 12°C at a depth of about 50 feet. The consequence is that wastewater discharged from the outfall on the ocean floor rises up, encounters the zone of more stable water and refuses to rise higher, particularly if the discharge has become diluted on the way up. It just disperses laterally and we essentially have improved the overall performance.

There are times during winter months when because of the cooling of the waters and more intensive mixing, the surface and bottom temperatures are about the same. At those times it would be possible for the effluent discharge at the bottom to reach the surface simply from the buoyancy of the wastewater, but this happens very rarely. When it does, there is still enough mixing with seawater as it disperses laterally.

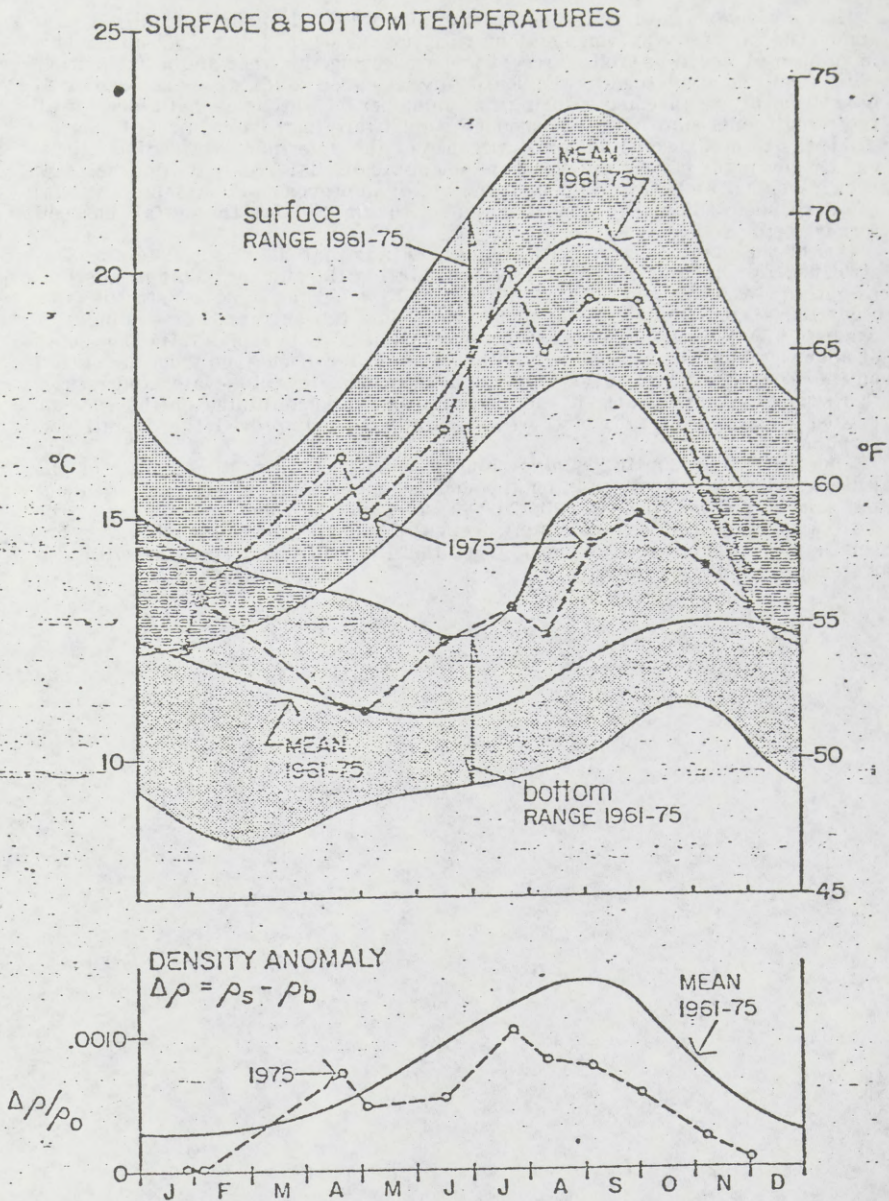


FIGURE 4.—Seasonal temperature difference in the water column off Point Loma.

But temperature stratification is very beneficial. In general, most people who come into contact with seawater may be found on the surface, but we find very little evidence of an outfall down there 200 feet below us. Here's a summary of some of this historic information: we are interested really in the difference between top and bottom density differences due to temperature. These differences are generally rather significant throughout most of the year except during the winter months when there is little difference between top and bottom. Otherwise there is a high degree of thermal stratification as shown here for the last year and a half covered by this most recent evaluation.

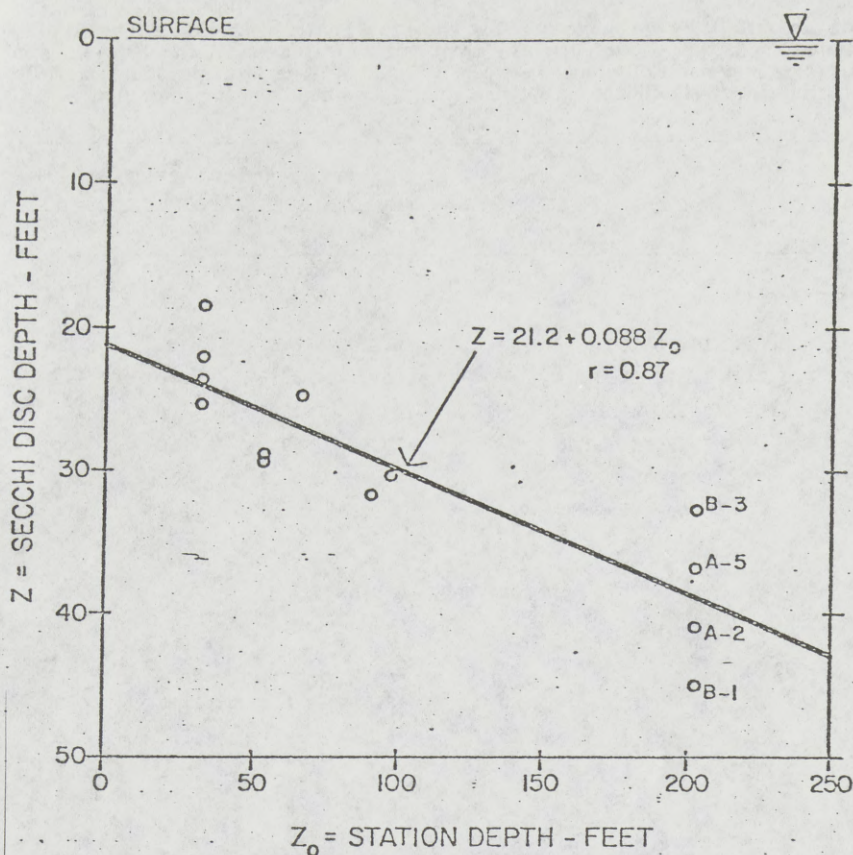


FIGURE 5.—Variation in Secchi disc depth with water depth off Point Loma.

Another characteristic of importance, perhaps more from aesthetic reasons than others, is the transparency of the water as measured from the surface downward. Here we have the Secchi depth which is determined by watching a little black and white disc lowered from the boat to a point where it is no longer visible to the naked eye. The Secchi depth is determined by moving the disc up and down so that you can just barely see it. If the water is very turbid that depth would be very low. On the other hand, we would be able to see perhaps 50 or 60 feet below the surface well offshore. Early in the investigation we used more sophisticated techniques such as hydro-photometers that measure light characteristics through one meter of water, but we found by analyzing that data that there was very little evidence that there were strong statistical variations of the clarity of the water around the outfall. What we did find in analyzing this was a difference in the transparency depending on the distance from the shoreline. Water along the shoreline area is well mixed with suspended material from biological growths along the shoreline, so generally the turbidity is a little higher in close to shore than it is offshore. In the early study conducted there was a slight indication that perhaps there was some increase in the turbidity in the vicinity of the outfall, but it is pretty hard to pin that down. I think we would be hard pressed to show that in any statistical analysis of a little more rigorous sort. More recently we looked at this problem again with the aid of computerized statistical techniques. As shown in the figure we found the general trend that Secchi depth increases as you go offshore. In deeper water you notice quite a lot of variations but this line has a rather high correlation, 0.87, which indicates that statistically the trend is pretty reliable. It tells us that the variation is largely associated with proximity of the shoreline rather than with proximity

of the outfall. So we haven't really had any violations of transparency limitations. Nor is there apparently any great cause for concern. Without dwelling on it, there is a small difference between 1975 and 1976 performance, but not really anything very significant except that due to distance from the shoreline.

		No.	FREQUENCY PERCENT			
			MPN/100 ml			
			<10	≥10	≥100	≥1000
SURFACE SAMPLES						
GROUP I.	DIFFUSION	-	n.d.*	n.d.	n.d.	n.d.
II.	DISPERSION	90	66.7	33.3	10.0	1.1
III.	INSHORE-DISP.	54	87.0	13.0	0.0	1.1
IV.	INSHORE-NORTH	34	70.5	29.5	8.9	3.0
V.	CONTROL	35	85.8	14.2	5.6	2.8
VI.	SHORE	<u>269</u>	57.2	42.8	8.2	0.4
Total		482				
BOTTOM SAMPLES						
GROUP I.		-	n.d.	n.d.	n.d.	n.d.
II.		80	28.8	71.2	47.4	16.3
III.		45	68.9	31.1	4.4	0.0
IV.		31	38.8	61.2	45.1	16.1
V.		<u>27</u>	74.1	25.9	11.1	13.7
Total		183				

*n.d. - no data

TABLE 5.—Frequency of coliform (MPN) counts, Point Loma and vicinity, all stations, 1975 to June 1976.

What is of more immediate concern is the potential for exceeding limits for coliform bacteria. We find very few instances in which the coliform bacteria concentration exceeds the limit of 1,000 per 100 ml. What might be significant as an effect from the outfall however is the difference between surface samples in those closer to the bottom. That is the zone which we said we would probably contain the sewage after it is discharged. Most of these values here at the surface correspond to a single observation in each location for which the concentration was in excess of 1,000 organisms per 100 mg. Of course the percentage is far less than the 20 percent that would be permissible under state requirements.

What I have just shown you corresponds to most of the stations in the vicinity of the outfall where we have not yet necessarily achieved 100 to 1 dilution. But what might be important is to look more specifically at the areas where water contact is immediate in the shoreline areas at shore stations D1 through D9. Only one coliform sample out of 269 samples in the year and a half period was in excess of the limit of 1,000 per 100 ml. Such an excellent record was also exhibited in previous years.

So far it might seem that there is little to indicate that this outfall is in any way detrimental but I suppose it would be difficult for us to pin this down statistically. Perhaps we have to resort to qualitative interpretations. One thing we have found are changes that have taken place in a rather significant way; whether these changes are beneficial, detrimental, or what, we can't really say. We use the concentration of decomposable organic material measured by bio-

chemical oxygen demand or BOD of the sediments. The BOD shows a very characteristic pattern around the outfall which is usually elliptical in form. The pattern moves up and down and changes somewhat in concentration with time and has shown a response to the episodes of sludge discharge. We should initially find high BOD levels in the sediments. If we then cleaned up the discharge the BOD levels would eventually readjust to lower levels. The concentrations we found around the Point Loma Outfall are probably not much different than what we would find at the mouth of a stream discharging organic material naturally but they are above background values, about 0.5 milligrams per kilogram.

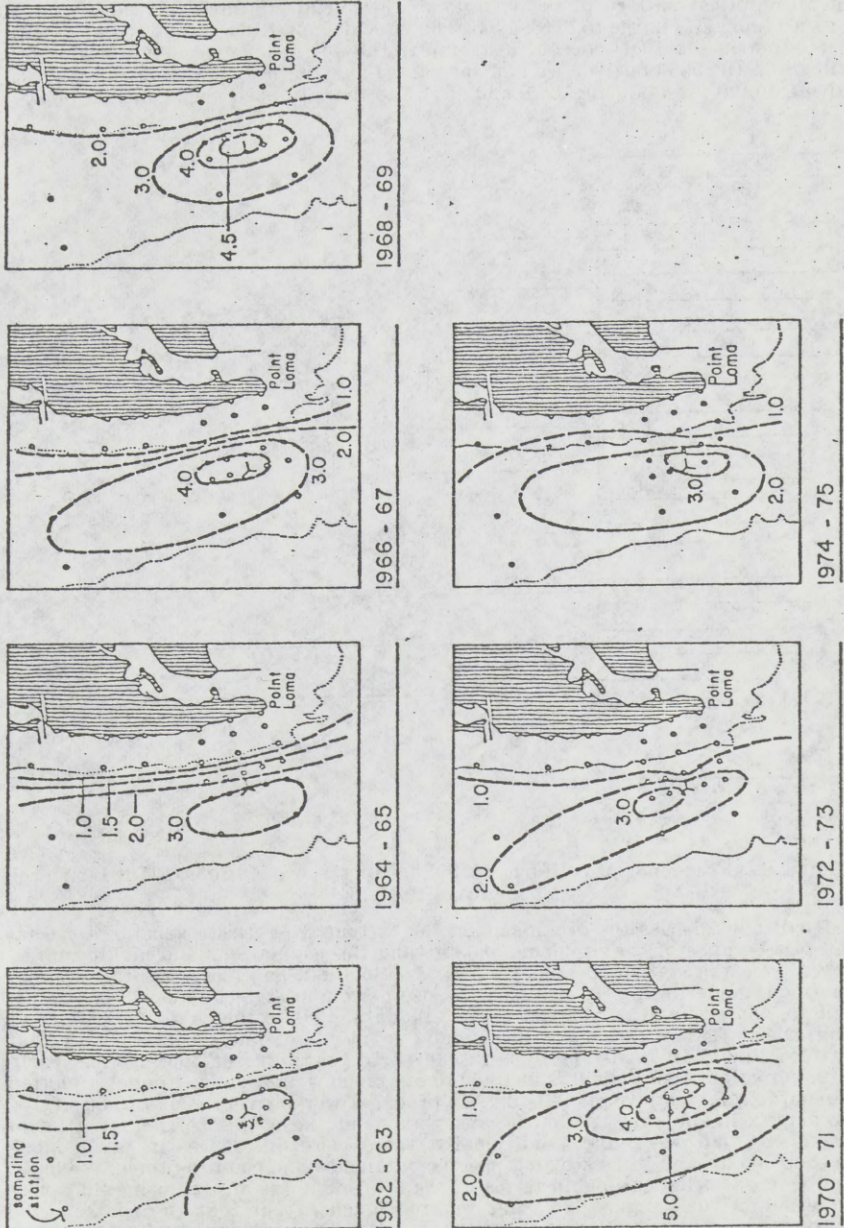


FIGURE 10.—Biochemical oxygen demand of sediments vicinity of Point Loma Outfall, 1962-75.

In the period 1973-1974 the pattern of BOD values in the sediments was very similar. The concentration center moved up and down a little bit but perhaps that is not so significant. The inshore area is kept clean of organic material simply because of the mixing due to long-shore currents which carry this material away from the shoreline. Offshore there is a tendency for material to settle out but the open ocean tends to modify the impact of any of the suspended material on the local environment.

The overall experience of this outfall has shown a series of changes that have taken place. At the beginning in 1962-1963 we had hardly anything that could be identified as a pattern of organic material on the bottom. The first appearance of an elliptical pattern in the vicinity of the outfall appeared at the beginning of the sludge discharge in 1964-1965. The effects showed up rather strongly with a big increase in BOD concentrations near the outfall of over 4 milligrams per kilogram. In 1968 and 1969 we had the raw sludge discharge. Sediment BOD was at maximum levels during 1970 and 1971 and then dropped back considerably.

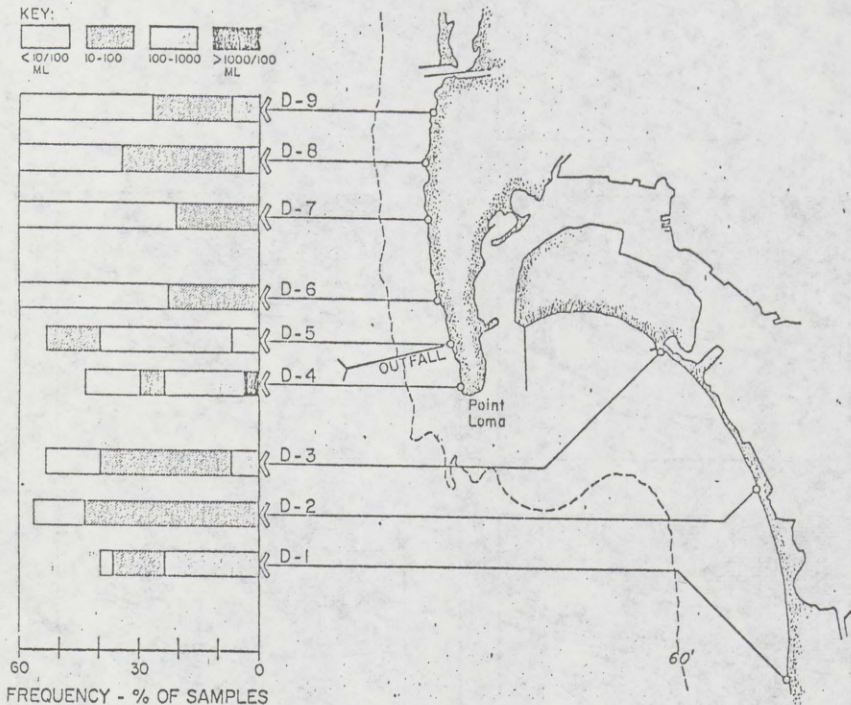


FIGURE 6.—Frequency of coliform (MPN) counts, shore stations, Point Loma and vicinity, 1972-75.

I will now discuss the organisms on the bottom. These have generated special interest because of the problems of assessing the populations and making inferences from the statistical evidence. As Mr. Burtman has indicated, this was an enormous undertaking. It required the use of computer techniques to assemble, collate, analyze, and summarize all of this data. It is to the credit of the city of San Diego that efforts have been made to develop some consistency in that pattern that didn't exist perhaps in the early years. If you look at this early data you might be a little less inclined to put much weight on it although I plotted the data from whatever it tells us. We probably weren't very good at classifying organisms in the early period because taxonomic keys didn't exist for a lot of organisms that we found. Additionally, there were differences in taxonomists in their acuity and in picking out specific organisms and counting them. We have, however, some indications in terms of the total numbers of organisms that were collected in the sample. We can't say too much except that the controls and stations near the outfall changed pretty much in the same pattern in this period.

But it did appear after some time that there was a difference in the dispersion zone (close to the outfall), the diffusion zone (adjacent to the outfall), and the controls (comparatively unaffected by the outfall itself). This pattern shows that the total numbers of organisms in the samples rose to a certain level, and with some minor fluctuations, has remained somewhat constant since about 1968 or 1970. The total number of organisms of course are not all together meaningful. We wondered how big the organisms were, what class of organisms we found, and how many different species; so we looked at different ways of interpreting these data.

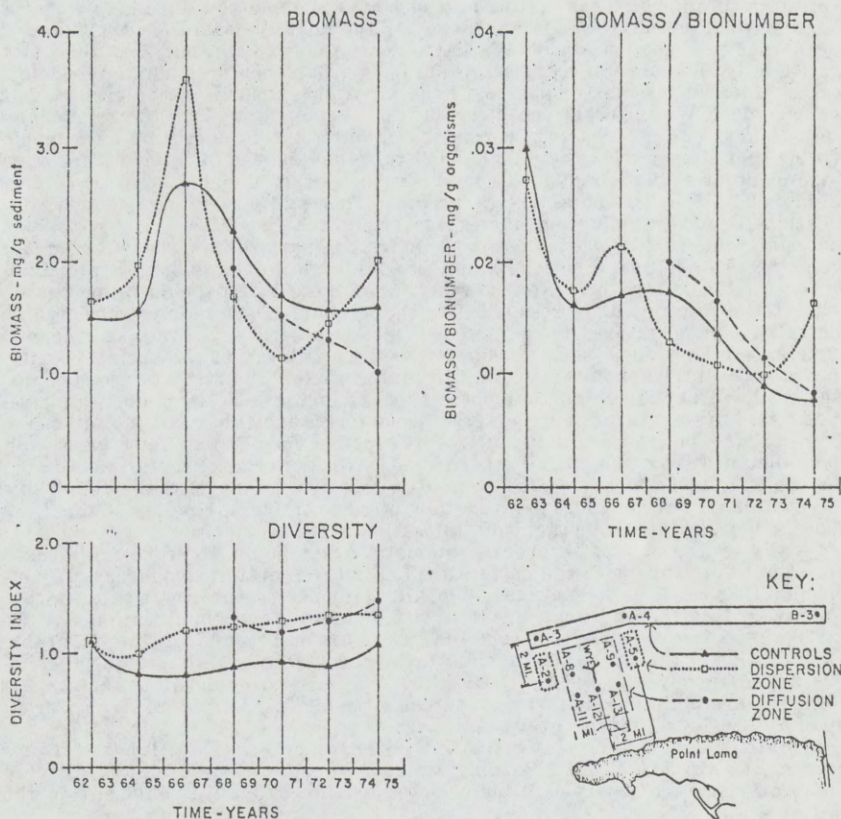


FIGURE 12.—Benthic animal biomass and diversity, vicinity of Point Loma outfall, 1962–75.

We have the biomass of the organisms per unit of sediment in milligrams per grab of sediment. Here we can see some episodes that at least appear to be significant. For example, in 1965 to 1966 we have a big peak in the biomass per unit of bottom sediment, indicative of that episode of enriching the environment with the discharge of digested sludge. It stimulated growth and organisms of certain species proliferated. Other species perhaps didn't do so well. We would like to differentiate between those.

We have looked at measures of the diversity of the organisms; that is, the relationship between the number of organisms and the number of species that would be present. Ordinarily it has been thought that if you have both a large number of organisms and a large number of species in ecosystems, the environment is healthy. There have been some misgivings, however, of using that particular criterion in the ocean environment, particularly where you have a limited substrate that may support only particular kinds of organisms. But we followed this diversity index along and haven't really seen any significant changes in the period since the outfall went into operation. By itself, this is

useful information because it indicates there have not been radical changes in the overall composition of communities of organisms in the outfall areas. On the other hand, since we did have some changes in biomass it looks like there might have been some competition for available organic material or food as the organisms became smaller.

Finally, we turn to the question of species. Now we have a taxonomic key with about 450 species of organisms found in the bottom sediments off Point Loma. It becomes almost impossible to organize these in a way to make gainful interpretations from individual species. In fact you have a problem sampling. If you were to swim down to the bottom and pick up a sample you are likely to get a large starfish on one occasion and none for the next 100 samples. What does it mean that you got one once? We have some problems in analyzing this data statistically. What we have chosen to do is to group them by similar physiological characteristics and responses to the environment. The major groups that we have dealt with are (1) crustacea such as shrimp, animals with skeletons on the outside; (2) polychaetes, worms that inhabit the bottom such as tubificid worms that simply stick their little shell tubes up and feed at the surface from organic material that goes by; (3) mollusks such as small clams; and (4) echinoderms such as brittle stars or sea urchins. These groups do give us some indications. For example, polychaetes are organisms that like a lot of organic material that settles on the bottom. Sludge discharged into the environment which settles out to the bottom would provide such a desirable substrate. Indications are that over the years the numbers of these organisms have increased; that is, the worms simply responded to the available food supply from organic material. The crustacea have increased or decreased depending on the circumstances. They show some sensitivity to the proximity of the outfall because they are less prevalent near the outfall and are more abundant in the controls. But we have kept in mind the controls are changing also. Organisms that respond rapidly to the presence of organic material are the small mollusks, the clams. These proliferate abundantly close to the outfall, but don't grow well some distance from the outfall where they have less organic material. Finally, the echinoderms, which are rather sensitive organisms, show that they don't like the outfall very well. There are very few of them in close, but lots of them up-shore. They are difficult organisms to sample accurately.

Finally by the way of an overall summary, a few points could be made based upon our experience with the outfall itself. First, the outfall is hydraulically efficient; that is, it is a very good outfall, it disperses the wastewater rather effectively into the environment. It is situated in a favorable location and we rarely expect to see the material on the surface because of the favorable stratification. Frankly we do not find evidence of the outfall or that turbidities are adversely affected by the outfall. There is no obvious adverse impact from the aesthetic point of view. You can't see the discharge unless you are a diver and go down to inspect the outfall.

Overall, the receiving water quality objectives of the board have always been met with this outfall. Bathing waters are generally of high quality in all locations by comparison to many other locations that we could cite in the state.

However, effluent quality requirements have not always been met. The frequency with which they have not been met is increasing somewhat because of the hydraulic overloading of the plant. It seems that unless something gets done these violations are likely to continue.

Organic accumulations on the bottom are continually being modified. They tend to be in some kind of equilibrium with the rate of supply of that organic material through the outfall. As the supply increases, so does the bottom respond by an increase in the evidence of that organic accumulation. The amount of this accumulation goes up and down with performance of the outfall to some extent but there isn't any way that we can see that this is really harmful to the environment.

Some organisms respond but others move away. But we can't pin down whether to call the changes unfavorable or not. Benthic animal populations have been stimulated in some cases. Other populations have preferred to just simply live elsewhere.

That summarizes the experience of the last several years in evaluating the performance of this outfall. We have a well-designed outfall and diffuser line. The performance record has been pretty good with the exception of the hydraulic overloading which could be corrected by some redesign. I will be glad to answer any questions.

Mrs. STOCKWELL. I would just like to commend Dr. Orlob on his presentation, and I enjoyed reading his excellent report.

Mrs. SCHEUNEMAN. Dr. Orlob, you mentioned the outfall is working very well. As the flow increases do you think secondary treatment will be required?

Dr. ORLOB. Well, as I see it now there are no indications that secondary treatment would be a solution to that problem. The difficulties are, I think, more readily solvable by improving the overall capacity of the plant. Secondary treatment might change the nature of the material that goes into the environment. That is, it transforms some suspended materials or organic dissolved material, but I don't think that would remedy anything detrimental that we can see in the environment, actually I don't see even at the present time any serious consequences of increased load other than that we're at the threshold of an incipient failure. It could happen. We could overload the plant to the point where it would fail in a way it failed in the early 60s. But to just increase the degree of treatment, I think not. I think it can be demonstrated that the benefits derived from taking that big additional step to go to secondary treatment are not commensurate with the costs.

Mr. BURTMAN. Dr. Orlob, during the episode when a lot of suspended material was discharged, your pictures indicated that there was an increase in the sediment bod clear up into the reference station. Do you feel this would indicate that the reference station should be moved farther north because of this?

Dr. ORLOB. It is very difficult to get a good reference station. At station B1 in the south there are some indications, for example, that something else is affecting it besides Point Loma, perhaps south of the United States-Mexican border, I don't know. But whatever the effects, sometimes we can't pick them up. We don't know enough about the normal behavior of the environment. Perhaps episodes of upwelling on the bottom influence all stations, but we haven't discerned those effects. I think it would be desirable to reconsider the location of some of those stations and in the way in which they are sampled. We have a number of suggestions along those lines included in the report. One of these is that we might look more carefully at the replication of results that were obtained at some of these stations. Perhaps the stations should be farther away, but if we go farther north we may run into the influence of other outfalls. Land effects are also of concern. We notice large variations at control stations away from the shoreline, and don't really have a good explanation for that. We've been using two offshore stations near the diffuser for biological comparisons because they look more stable.

Mr. BURTMAN. There's a strong feeling among numbers of people that attachment of heavy metals to particulate matter is a matter of physical reality. Yet based on your analysis, this is apparently not the case; that is, the distribution of settleable material is not borne out by the distribution of metals found in the environment.

Dr. ORLOB. Well, I have a partial explanation for this although I think perhaps it is an area that requires additional inquiry. The adsorption of heavy metals on organic particulates is preferential to the particles of smallest diameter. For a small unit mass of material, you have the largest surface area for metals to attach. These small particles go the farthest away from the outfall, so the chances are that any complexing by organic material of heavy metals would result in their being transported large distances away from the outfall. We haven't been able to discern any particular pattern in the heavy metals in the sediments. They're uniformly distributed to about what you would find in background levels elsewhere and I think this has been the experience of the bigger outfalls to the north. There's been some difficulty identifying the impact in relation to a specified source: the dispersal into the environment is so great. I have had occasion to work recently with copper, a heavy metal specifically associated with the power industry. Copper has a 10,000 to 1 preference for the ions to be adsorbed on the surface of suspended particles or to be complexed with organic material, as opposed to staying in ionic form in solution. But in all of these mechanisms, because everything stays in suspension, there's relatively little interaction with the sea bed. So I don't see that as an immediate problem, but I might in some cases in the future. The biggest problem is probably toxicity to sea life from the uptake of complexed heavy metals in the dissolved organics and free heavy metals ions such as copper.

Mrs. STOCKWELL. Madam Chairman, I would move that the board accept the report by Resource Management Associates presented by Dr. Orlob.

Mr. BUTTERFIELD. I second it.

Mrs. SCHEUNEMAN. Any discussion? All in favor say 'aye'. The motion was unanimously approved.

Thank you, Dr. Orlob. This was a very interesting report.

Mr. BUTTERFIELD. Madam Chairman, I have a general comment. It appears as though from this data we can conclude that the Point Loma outfall was very well designed and is a very efficient outfall. Even though the city of San Diego has experienced much tougher times with the heavy hydraulic loading on the plant itself, the outfall seems to have compensated for many of the plant's deficiencies.

COUNTY SANITATION DISTRICTS
OF ORANGE COUNTY, CALIF.,
May 26, 1978.

Hon. RAY ROBERTS,
*Chairman, Subcommittee on Water Resources, Committee on Public Works
and Transportation, House of Representatives, Washington, D.C.*

DEAR MR. CHAIRMAN: I understand that your Subcommittee is conducting a set of hearings on the Marine Secondary Treatment modification provision contained in the Clean Water Act of 1977. Orange County Sanitation Districts have long supported the concept of authorizing alternative processes to secondary treatment when a case can be made that the environmental effects are comparable or superior to that of secondary treatment and where the unnecessary expenditure of public funds (Federal, State, and local) can be avoided.

We have participated, together with other sewerage agencies, in providing comments to the Environmental Protection Agency and were pleased to learn of the hearings you have scheduled in Washington.

In connection with our review of the "Preliminary Concept Paper" circulated by the EPA, we asked one of our agency's consultants to examine the document with a view to determining how the agency could go about preparing an application under the draft regulations. I think that the effort by Mr. Kris Lindstrom of J. B. Gilbert & Associates, Sacramento, California, is instructive. I understand that the regulations proposed by EPA in the Federal Register on April 25 are substantially the same as those that were contained in the "Preliminary Concept Paper". It occurs to me that the Subcommittee and its staff would be interested in Mr. Lindstrom's run-through and in his commentary. Accordingly, I am enclosing the document which he prepared and I hope that it will be of use and have no objection to it being included in the transcript of your hearings. If there are any questions that you would like to have directed either to me or Mr. Lindstrom, we would be more than pleased to provide additional information.

Sincerely,

FRED A. HARPER,
General Manager.

J. B. GILBERT & ASSOCIATES,
PLANNING & ENGINEERING CONSULTANTS,
Sacramento, Calif., March 27, 1978.

Mr. FRED A. HARPER,
General Manager, County Sanitation Districts of Orange County, Fountain Valley, Calif.

DEAR FRED: During the past several days, we have reviewed EPA's proposed regulations dated March 17, 1978 for modifications of secondary treatment requirements for marine discharges. This review has included the input of your staff, SCCWRP, the State Board staff, and our discussions with others including Tom Jorling.

Attached is a package of material for your use in formulating the Districts' responses. Included are (1) basic criteria that must be met in order to apply for a waiver; (2) a list of key issues and a discussion of each; (3) recommendations for changes and additions; and (4) an annotated appendix which summarizes the information required for submittal of an application for modification.

If you would like additional information or amplification, we will be glad to provide it.

Sincerely,

KRIS P. LINDSTROM.

Attachment.

PROPOSED REGULATIONS FOR WAIVER OF SECONDARY TREATMENT REQUIREMENTS

BASIC WAIVER CONDITIONS

1. There are applicable State water standards which are met for the pollutant for which the modification is requested.
2. The modification of NPDES requirements will not interfere with the attainment or maintenance of water quality which assures protection of public water supplies, recreational activities, and a balanced indigenous population of marine life.
3. Ocean monitoring is maintained.
4. No additional waste discharge requirements will be placed on other point and nonpoint sources.
5. All applicable pretreatment requirements will be enforced.
6. A nonindustrial source control program is developed and enforced to the extent practicable.
7. No increase in pollutant emissions from that specified in modified permit.

EXISTING DISCHARGE CRITERIA

Issue

The proposed Regulation includes increases in design capacity only if approved prior to September 1978. Additional treatment facilities for improving quality which have been planned or designed, or are under construction prior to the date of the filing of the application, are not considered as "in place". This also applies to adopted source control provisions or pretreatment facilities which have not been fully implemented.

Proposed Change

For both capacity and quality purposes, existing discharge should be defined to include all facilities which have been proposed or approved under Step I, II, or III EPA grants prior to the date of application. This would provide for consideration of capacity increases already planned or approved as well as interim improvements or construction of secondary treatment facilities which have not yet been put into operation.

The Regulation should also allow existing facilities to include proposed improvements that have been delayed as a result of Step I planning (EIS activities) under review by the State or EPA at the time of waiver.

SPECIFICITY OF CRITERIA AND TERMS

Issue

The Regulation contains criteria, terms, and requests for information that are imprecise and unclear.

Discussion

Criteria.—The criteria for an existing discharge, the depth requirements for a discharge, and the reasons for rejecting a waiver should be clarified.

If a criterion for minimum dilution is required (i.e., 50:1 or 100:1 minimum dilution), why not clearly state it rather than determining it is equivalent to that achievable through an outfall that extends "200 or greater feet"?

Terms.—There are numerous terms such as "stressed coastal waters", "balanced indigenous population", "edge of the zone of initial dilution", "adversely effect", "initial mixing", etc., which are not clearly defined. They must be, if an application is to be "complete" as requested.

Information.—Some of the information requested exceeds that needed to make appropriate technical evaluations. For example, if information is needed on currents and where they transport the wastewater field, it should be clearly stated rather than requesting continuous wind data, a cross-spectral analysis of winds and currents, etc. What is actually needed is the ambient current data used in the outfall design.

Proposed Changes

Criteria.—The Regulation should specify minimum dilution requirements under worst case conditions which an applicant must achieve. The marine waters for which modified permit applications will not be accepted should be defined.

Terms.—Terms used in the Regulation need to be more specifically defined, and there should be a table of terms cross-referenced as to subject, page, or regulation number so that one can determine in what context the term is being used.

Requested Information.—Rather than requiring lengthy volumes of material, the appendices should contain technical summaries of the basic information required to support the conclusions provided. Cross-referencing to published studies or inclusion of abstracts thereof, should be sufficient to document conclusions. If this is not sufficient, EPA should request additional data and set time requirements for response by the applicant.

TOXIC POLLUTANT REMOVAL REQUIREMENTS

Issue

The Regulation states that the applicant must (1) meet EPA marine water quality criteria under ambient seawater concentrations or (2) the level of effluent quality obtainable by secondary treatment, whichever is the most stringent.

Discussion

EPA criteria for ocean water quality have not yet been published and hence, the applicant cannot now assess the information needs for application. Also, if background levels of a substance are higher than the water quality criteria, the proposed Regulation states that after mixing, the discharge should meet ambient seawater concentrations. This is not possible since any addition, even from a river flowing into the sea, would change the concentration of many constituents.

Proposed change

The Regulation should contain a list of the proposed EPA water quality criteria or specify effluent limitations for man-made substances. This will provide necessary specifics for applicants to assure protection of the marine environment.

REQUIRED ACTIONS BEYOND THE CONTROL OF THE APPLICANT

Issue

Failure to file a complete application prior to September 24, 1978, is grounds for denial of the modification requested. Many of the required actions, certifications, letters, and analyses required to be submitted by the applicant are to be completed by other State, Federal, or governmental agencies. In addition, State or Federal delays in approving or reviewing Step I, II, and III work may prevent the applicant from having the facilities needed to increase capacity or provide treatment which would otherwise be considered in determinations of design flow or removal efficiency determinations.

Proposed Change

The regulation should allow for a conditional waiver or an extension of time for filing certain specified information if it can be demonstrated that the time delay was caused by circumstances beyond the applicant's control.

MEETING STATE STANDARDS ON DATE OF APPLICATION

Issue

Will the discharge meet applicable State water quality standards at the time of application, and can the State of California provide the required certification letter?

Discussion

This cannot be determined because EPA has not certified the Ocean Plan as amended. As of this date, the SWROB has received no indication from EPA that they intend to certify the Ocean Plan and no time schedule has been established. SWROB has sent a letter to EPA in response to the Section 301(h) Regulations asking if the Ocean Plan, as amended, will meet EPA's needs for surrogate parameters for water quality standards for BOD and SS.

TIMETABLE FOR REVIEW OF MODIFICATION APPLICATION

Issue

The Regulation contains no time limits for review. There is no sense of urgency and no information to allow the applicant to schedule his ongoing improvement program.

Proposed change

The proposed Regulation should contain specific dates or time limitations for EPA's review, hearings, collection of hearing material, decision making, and appeals. A tight time frame of approximately six months should be set forth to expedite the process and make final determinations on secondary treatment re-

quirements. This will minimize the costs associated with inflation, reduce the existing discharge of pollutants, and avoid the possible loss or reduction of State or Federal grant funding.

BEST PRACTICABLE WASTE TREATMENT TECHNOLOGY

Issue

The preamble to the proposed Regulation states that granting a waiver of the requirements of Section 301(b) (1) (B) of the Act does not change the responsibility for complying with the requirements of Section 201(6) (2) (B)—the adoption of best practicable wastewater treatment technology (BPWTT) by July 1, 1983.

Proposed change

The Regulation should specify that BPWTT has not been defined for ocean discharges and that should a modification be granted any discharger, that the conditions specified in the modified NPDES permit would constitute BPWTT for that particular applicant's discharge.

PROVISIONS FOR EXAMINING THE TRADEOFFS INVOLVED IN GRANTING A MODIFICATION

Issue

There are no specific provisions for providing a technical evaluation of the tradeoffs involved in granting a modified permit compared to full secondary treatment. These include savings in grant funds, (local share), labor and material resources, energy, and other items.

Discussion

The supplementary information section contains a discussion of the need for addressing the true economic costs of applying for a waiver, but makes no provision for similar analyses on alternative treatment levels or toxic pollutant control costs.

Section 233.21(b) of the Regulation address an Alternative Funding Program to be included as a yet unspecified appendix. In this appendix it would be appropriate to include a summary of proposed wastewater management alternatives (including pretreatment alternatives, source control, and treatment methods) for meeting the modified permit requirements which should be defined as best practicable wastewater treatment technology.

In Congress' setting of national *goals* of protection of indigenous population and pollutant elimination, consideration of economic factors was not excluded.

Proposed change

Appendix V should be added, entitled "Modified Wastewater Management Program". It would describe the facilities and procedures necessary to achieve the modified permit requirements and their comparative costs and resources requirements compared to construction of secondary treatment facilities.

The appendix would contain a summary of a detailed program which includes a schedule for plan, design, construction, and implementation of all facilities, ordinances, regulations, pretreatment facilities, monitoring programs needed to comply with the modified permit changes requested, and for meeting all other applicable water quality standards.

PROCEDURAL MATTERS

Issue

The procedures specified for application review and hearing are cumbersome and complex.

Discussion

Since EPA is acting as the sole reviewer and decision maker, such complex procedures are unnecessary. If the intention is to discourage applicants, this should be achieved through clear technical requirements. Review time limits should include: minimum time requirements for requesting additional information, supplying that information, length of the hearing and appeal procedures, and deadlines for making decisions. Since applicants in any state or region will be submitting similar information and perhaps using the same group of experts or data base, it would make sense to hold consolidated hearings at which each applicant's case could be considered. This would save time, money, and staff time.

Also, one consolidated regional hearing would: simplify notices and other procedural matters, assure efficient use of review experts, and avoid duplication. It would assure the attendance by top officials, scientists, and other technical persons whose input is required in evaluating each application.

Proposed changes

Procedures should be simplified, consolidated regional hearings considered, time schedules established for the completion of the various steps involved in decisionmaking.

SUGGESTED CHANGES TO PART 233—MODIFICATION OF EFFLUENT LIMITATIONS BASED ON SECONDARY TREATMENT FOR DISCHARGES INTO MARINE WATERS¹

SUBPART A—GENERAL

Sec. 233.1—Definitions

(g) The term "balanced indigenous population" means that ecological community of organisms which (1) might reasonably be expected to repopulate the area within 500 meters of the boundary of the zone of initial dilution from adjacent unpolluted waters if the waste discharge were terminated or the discharge of toxic pollutants were reduced.

Add Section (U) or clarify Section (V) to include the term initial mixing. Is there a difference between the area subject to initial mixing and the zone of initial dilution?

Discussion

The term "initial mixing" is used in Sections 233.12 and 233.14(a) and in Part 1, Question 1-9 of the Application Form. Does this term refer to what occurs within the zone of initial dilution or does it refer to the continued mixing and dilution with seawater which occurs outside this zone in a zone of transition? Within one of these zones it is probable that pollutant concentrations will become so small that they will become analytically indistinguishable from naturally occurring concentrations. Hence there will be no distinct identifiable boundary of distinguishable influences on marine organisms or water quality but rather a gradient effect.

Question.—Should there be some criterion for determining a specified distance from the outfall diffuser at which adverse effects should not be detectable?

Sec. 233.1—Definitions

Add section (W) which defines "edge of the zone of initial dilution" which states:

"(W) The edge of the zone of initial mixing is defined as that portion of the water column and sea floor lying between the outer boundary of the zone of initial mixing and a 500 meter distance extending beyond the boundary."

SUBPART B

Sec. 233.11—Existing discharge into marine waters

Sec. 233.11(a) (2) (A) (i) Rapid dilution of partially treated wastes, of the order achieved by existing multiport ocean outfalls discharges at depths of approximately 200 feet or greater or if the discharge is in shallower waters, demonstration that initial dilution of at least 50:1 is achieved.

Sec. 233.12(a) (1) (B)—Suggested Revision

(B) For suspended solids, a state water quality standard or standards for turbidity, light transmission, light scattering, color, or other parameters which are designed to insure adequate maintenance of the photic zone; and

Sec. 233.14(d) (2) (B) (V). The extent to which the applicant's discharge has caused or may cause at any time over the life of the applicant's treatment works, alterations in the natural structure, function of biological communities, or reproductive potential of populations. Such alterations shall include changes in species composition, standing crop, diversity, feeding relationships, seasonal succession, direction of community development, and disease incidence.

Sec. 233.19—Elimination of toxic pollutants from nonindustrial sources

(b) Development of control program. Suggest changing to account for the fact that control of many of the nonindustrial sources listed are beyond the

¹ Ordering of sections in text does not match index starting with Section 233.15 through Section 233.22.

control of a local sewerage agency (i.e., streets and gutters, use of fertilizers and pesticides, etc.). The schedule of "activities" for development of a control program should specify that the control strategies and analyses required may be beyond the applicant's ability to perform due to institutional, economic, or legal constraints.

Sec. 233.22—Compliance with ocean discharge guidelines, state water quality standards and other requirements

(a) *Ocean dischargers.*—If the applicant discharges into the territorial seas or contiguous zone, the applicant shall demonstrate in application (Appendix not specified) that its discharge meets all EPA ocean discharge guidelines. If the applicant's discharge exceeds these guidelines at the time of application, the applicant must demonstrate that it now has a program (i.e., Step I, II, or III projects) to meet the guidelines or can do so by employing other means.

RECOMMENDED CHANGES TO PROPOSED APPLICATION FORM

PART 1: COMPLIANCE WITH BOD AND DO

Special Instructions for Question 1-2: Change last sentence to read:

"Applicants should enter the values for the flows indicated and compute the time of flow between the *last treatment unit of the treatment facility* and the diffuser ports."

Question 1-4: Point of clarification—Does a criterion level have to be a specific numerical value or can it be a criterion such as stated in the Water Quality Control Plan for Ocean Waters of California which contains the following:

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

Question 1-9: Point of clarification—Does the analysis requested ask for mathematical calculations, laboratory studies, or actual field data?

Question 1-10: Point of clarification—What is really needed here? Is it a request for an assessment of ocean or discharge conditions during which dissolved oxygen levels are below water quality standards?

Part 2: No change.

PART 3: SUSPENDED SOLIDS

Question 3-8: Point of clarification—Why is the first part of this question necessary if water quality criteria for toxic pollutants must be met? Is this to assess the effects of the type and level of treatment on the form and amount of toxic pollutants available for uptake by marine organisms?

PART 4: PHYSICAL

A. Initial Dilution

Question 4-3: Omit part of first sentence stating "for the conditions listed above". Density gradients are for the ocean itself, the discharge conditions don't apply.

B. Ocean Discharge—Suggested Changes

Discussion.—The data requested appears to be unreasonable given the reasons for which such data is normally collected.

For example: An outfall 5 miles offshore would require that one monitor salinity 5 miles further offshore. Obviously the 10 mile offshore data would be meaningless in terms of measuring any effects from the addition of freshwater to the marine environment. To determine effects, data collection should be much closer to the outfall. Similarly, data on winds and the relationship between winds and currents is not meaningful once an outfall is constructed, since it is the currents which have the greatest influence on wastewater dilution and dispersion.

If the intent of Appendix K is to provide data on the ultimate fate of effluent, the mixing it receives, and what onshore areas are possibly effected, it should be clearly requested.

Suggested Changes:

Question 4-11: If the discharge is to the ocean, provide in Appendix K an oceanographic report including:

Seasonal measurements of the current speed and direction, and salinity representing continuous profiles (where possible) in transects paralleling either side of the outfall from the shoreline to a reasonable distance beyond the outfall terminus. Sampling stations should be spaced at distances equal to about one-fourth the pipeline length. Data should also be provided for stations around the diffuser. These stations should encompass an area encircling the discharge area whose diameter is equal to approximately three times the length of the diffuser based upon the center of the circle being the centroid of the diffuser or diffusers.

Depending on the specifications of applicable water quality criteria and monitoring requirements, additional measurements should be made simultaneously at the same stations. Light transmission, pH, dissolved oxygen and suspended solids measurements are possible minimum requirements.

Records of current speed and direction at two depths near the diffuser must be provided.

Effects of direct freshwater runoff from coastal areas will be determined, as will any effects of estuarine discharges.

PART 5: MARINE BIOLOGICAL ASSESSMENT

Suggested change in Questions 5-6 and 5-12: Strike out the word "adversely" in question 5-6 and "adverse" in 5-12. The determination of the nature and importance of certain ecological changes or effects is a value judgment which cannot be answered on a "yes" or "no" basis.

For example: Is an increase in fish abundance near an outfall beneficial or adverse? It would depend on the types of fish, their general health, their influence on other trophic levels, their value as fishery resources, and if they are in any way contaminated by toxic pollutants.

CHANGES IN APPENDICES

Do additional appendices need to be added to include provisions for including the analysis of alternative wastewater management programs as specified in Section 233.21(b) and certification that the discharge complies with any applicable approved coastal zone management plan as specified in Section 233.22(c)?

APPENDIX A

IMPACT ON BIOCHEMICAL OXYGEN DEMAND (BOD) ON DISSOLVED OXYGEN (DO) DEMAND RESULTING FROM DISTURBANCE OF BOTTOM

This appendix is to contain an analysis showing that BOD exerted *after* initial mixing will not result in subsequent depletion of DO below applicable criteria for DO. It is also to contain a description of the oxygen demand resulting from disturbed and undisturbed sediments under the most critical three months of the year.

APPENDIX B

EVALUATION OF BIOSTIMULATORY EFFECTS DUE TO BOD

This appendix is to contain an assessment of the effects on overall environmental quality and marine organisms as a result of the biostimulatory effects of BOD. The analysis should include: aesthetic conditions, increased turbidity, increases in undesirable organisms, effects on food webs, community structure, and ecological relationships between various marine communities.

APPENDIX C

DESCRIPTION OF MORE CRITICAL DO SITUATION

(Not Needed, Omit)

APPENDIX D

OTHER CONSIDERATIONS RELATIVE TO PH

(Not Needed, Omit)

APPENDIX E

DESCRIPTION OF MOST CRITICAL IMPACTS OF SUSPENDED SOLIDS

(Probably Not Needed, Can Be Omitted)

Needed only if the range of conditions created under average daily dry weather and average daily wet weather flows and under maximum day loadings do not reflect the most critical environmental case with regard to oceanic effects from suspended solids. If achievement of applicable water quality criteria used for suspended solids is not met under certain circumstances due to natural conditions (i.e., red tide, stormwater runoff from Santa Ana River, etc.), it should be documented here.

APPENDIX F

SUSPENDED SOLIDS AND LIGHT TRANSMISSION DATA

This appendix is used to support Questions 3 through 5 of the application. Data contained in this appendix will support conclusions regarding the impacts of diluted suspended solids on criteria applicable to water clarity and if the discharge will comply with the criteria under the waiver.

A letter from the Regional Water Quality Control Board should be included giving their concurrence that suspended solids in the water column are not found at concentrations which exceed background levels.

APPENDIX G

DESCRIPTION OF EXPERIMENTAL PROCEDURE USED TO COMPUTE AMOUNT AND AREAL EXTENT OF SS ACCUMULATION ON SEABED

This appendix will document all the existing work on ocean monitoring related to water column and benthic sampling to determine if organic material is, has, or will accumulate on the bottom near the CSDOC outfall. Included will be an analyses of suspended solids in the water column, sediment sampling for COD, volatile SS, video tapes of outfall, and 35 mm photographs. Data and analyses on settleable solids will also be included.

APPENDIX H

RELATIONSHIP BETWEEN SS LEVELS AND THE CONCENTRATION OF TOXIC POLLUTANTS AND PATHOGENIC MICROORGANISMS IN THE WATER COLUMN AND ON THE SEABED

This appendix is to contain a description of how an alteration of the suspended solids criteria will affect the amount of heavy metals, persistent synthetic organics, and pathogenic microorganisms in the water column and benthos.

Information contained in this appendix *must* demonstrate that each of the 65 toxic pollutants listed in Section 233.1(t) will, for naturally occurring substances, meet EPA water quality criteria after allowance for initial mixing or to be the same as that obtainable through application of full secondary treatment. For synthetic substances (such as PCB, acrolein, etc.), EPA criteria would be the same as that achievable through application of full secondary treatment without allowance for mixing.

This section must also demonstrate that an increase in suspended solids will not cause an increase in the distribution and survival of pathogenic microorganisms compared to the application of full secondary treatment.

APPENDIX I

DESCRIPTION OF METHOD USED TO COMPUTE INITIAL DILUTION

This appendix must contain calculations which show the rate of initial dilution achieved at the outfall diffuser under average and worst-case conditions taking into account that *no increase in dilution is attributable to ambient currents*. These calculations or those developed using EPA's PLUME model, will determine a zone of initial dilution for use in making the water quality assessments specified in other sections.

This section must also contain data demonstrating that coastal circulation processes continuously supply a volume of seawater equal to 1.77 times the calculated average dilution multiplied by the volume of treated wastewater.

APPENDIX J

OCEANOGRAPHIC DATA

Data on oceanographic data regarding currents that may influence shape, trajectory, and entrainment in the plume (or plumes if multiple diffusers are included).

APPENDIX K

OCEANOGRAPHIC REPORT

(Data on Ocean Discharge)

I. Current measures:

Seasonal Measurements

Continuous records of current speed and direction at two depths near the diffuser must be provided.

Seasonal measurements of speed and direction.

II. Salinity Measurements: Continuous profiles (where possible) in transects from the shore to at least one pipeline length greater than the outfall distance offshore, spaced at distances of one-fourth of the pipeline length at two stations on each side of the diffuser.

III. Light Transmission, pH, D.O., and SS at Same Stations

IV. Wind Data: Continuous wind data representative of the outfall area must be provided for a significant historical period.

V. Correlation of Currents and Wind: Correlate current speed and direction.

APPENDIX L

DATA ON ESTUARINE DISCHARGE

(Not Needed, Omit)

APPENDIX M

MARINE BIOLOGICAL ASSESSMENT

I. Biological Communities (Presence, Characteristics, Distribution):

Demersal Fishes

Pelagic Fishes

Macrofaunal Benthos

Phytoplankton

Zooplankton

Macroalgae

Intertidal Assemblages

Areas of Special Biological Significance (Marine Sanctuaries)

Subsections of the Above

1. The identity and relative abundance of the dominant and subdominant species of each community.

2. The presence or potential for commercial or recreational fisheries.

3. The presence of distinctive habitats of limited distribution such as kelp beds, coral reefs, or sub- or intertidal rock outcroppings, etc.

II. Assessment: The extent to which the applicant's discharge *has caused or may cause at any time over the life of the applicant's treatment works*, alterations in the natural structure, and function of biological communities or reproductive potential of populations.

Such alterations *shall* include changes in the following:

Standing Crop

Diversity

Feeding Relationships

Seasonal Succession

Direction of Community Development

Disease Incidence

III. Biological Conditions Summary:

1. Conditions which exist at the edge of the zone of initial dilution.

2. Conditions which exist in nearby unpolluted waters of comparable depth, substratum composition, temperature, salinity, and hydrographic regime.

3. Conditions which would be expected to exist at the edge of the zone of initial dilution if the applicant's discharge received full secondary treatment.

The summary shall be included as Appendix M of the applicant's application for a modified permit.

APPENDIX N

INFORMATION ON WATER QUALITY WHICH ASSURES PROTECTION OF PUBLIC WATER SUPPLIES

I. Background Discussion of Past and Future Planning:

A. Exact location of each planned or existing desalinization plant seawater intake which is or will be utilized by a desalinization plant producing water for public water supplies which is or will be located within 10 nautical miles of any outlet port of the applicant's outfall.

B. Detailed Impact Analysis (Discharger Effect On)

1. Quality of Seawater

2. Level of Treatment Needed

3. Comparison With No Discharge and Full Secondary Treatment

Analysis shall include:

1. Effects of intake water quality and travel time, currents dilution, etc.

2. Quality of water produced for public supply assuming no additional treatment.

3. How discharge will affect quality and extent of the level of treatment.

APPENDIX O

INFORMATION ON WATER QUALITY WHICH ALLOWS RECREATIONAL ACTIVITIES

I. Background Conditions (Detailed Discussion):

A. Recreational Fishing:

1. Finfish

2. Shellfish

(Surrounding outfall within three-mile radius)

Off shorelines or along beaches adjacent to outfall location and length as determined by analysis of prevailing currents and tides.

B. Any State, Federal, or Local Restrictions on Consumption of Fish Within A Three-Mile Radius:

1. Limitations on concentrations of toxic pollutants or other substances in fish or shellfish tissue if imposed and compliance therewith.

- C. Recreational Boating and Swimming :
 - 1. Includes underwater diving (three-mile radius).
- D. State, Federal, or Local Restrictions or Limitations on Water Contact Sports (three-mile radius).
- E. Recreational Swimming, Wading, and Picnicking Along Adjacent Shorelines and Beaches.
- F. Analysis—Evaluation of Recreational Activities.
 - 1. Impact on existing and potential recreational activities in the vicinity of the outfall.
 - 2. Comparison with activities which might be expected to take place if there were no discharge or full secondary treatment was implemented.

APPENDIX P

MONITORING SYSTEM

- I. Monitoring to Determine Compliance With Effluent Limitations :
 - Toxic Pollutants
 - Sampling Techniques
 - Frequency
 - Methods of Analysis
 - Alternatives
- II. Monitoring to Determine Compliance With Pretreatment Standards :
 - Industrial User Monitoring
 - Treatment Plant Monitoring
 - Sampling Techniques
 - Frequency of Sampling
 - Method of Analysis
 - Alternatives
- III. Monitoring of Water Quality :
 - Selection of the Sampling Area
 - Sampling Techniques
 - Frequency of Sampling
 - Methods of Analysis
 - Alternatives
- IV. Impact of Discharge on Indigenous Population :
 - Laboratory *in situ* Bioassays (acute, chronic, liquid, SS, and solid phase)
 - Reconnaissance and Field Studies
 - Selection of Sensitive Marine Organisms
 - Selection of Sampling/Testing Area
 - Selection of Control Areas
 - Sampling Testing Techniques
 - Frequency of Sampling/Testing
 - Method of Analysis/Alternatives
- V. Resource Analysis I Through IV Above :
 - Economic
 - Personnel
 - Technical Capability

APPENDIX Q

POINT AND NON-POINT SOURCE REQUIREMENTS CHANGES

This appendix is to contain an assessment of whether a change in the waste-load allocation from the change in requirements will result in any additional treatment, pollution control, or other requirement on any other point or non-point sources.

To support these findings a letter from the Regional or State Water Quality Control Board is needed which contains a "detailed analysis" of the facts and other considerations supporting any conclusions.

APPENDIX R

PRETREATMENT REQUIREMENTS

1. Evidence that an approvable pretreatment program which meets the requirements of Appendix R has been established at the time of application.
2. All resource requirements of Appendix R . . . satisfied with one year of approval.
3. Schedule of compliance for implementing 18 months after issuance of modified permit.
4. Identification of all industrial users.
5. Dissemination of notice of pretreatment requirements to industries.
6. Submission of the list (Item No. 4) to EPA.
7. Characterization of wastewater from users on list (Item No. 4).
8. Characterization of wastewater from undesignated industrial users—compatible or incompatible to applicant's treatment system.
9. Submission of State certification (or other form of approval) pretreatment program conforms to all applicable Federal and State laws and requirements.
10. Implementation of a monitoring program to determine the concentration of each pollutant which may be in the plant effluent, based on Item Nos. 7 and 8.
11. Dissemination of notice of the scheduled date of promulgation of any pretreatment standard.
12. Establishment of appropriate monitoring and reporting requirements for industrial users.
13. Development of schedules of compliance for industrial users.

APPENDIX S

TOXICS IN NONINDUSTRIAL SOURCES*

This appendix is to contain a schedule of activities, to commence no later than one year after issuance of a modified permit, designed to eliminate the introduction of toxic pollutants from nonindustrial sources into its treatment works. This includes a discussion of available data on toxic pollutant and discharges from these sources, and a program for identifying and monitoring these sources. A control program is also requested which includes the following:

1. An analysis of control technologies and their effectiveness.
2. An analysis of utilizing controls on the use handling and ultimate disposal of toxic pollutants to prevent their input into the treatment facility.
3. Pesticide control measures.
4. Resource analysis of the proposed five-year program. This is to include economic, institutional arrangements, personnel, technical, and other needed resources to carry out a control program.

(California State Water Resources Control Board, Sacramento, Calif., Larry F. Walker, Executive Director, Water Quality)

COMMENTS REGARDING PROPOSED REGULATIONS MODIFICATION OF
SECONDARY TREATMENT REQUIREMENTS*Introduction to the Proposed Regulations*

1. The following statement is made:

"Because secondary treatment incidentally removes toxic pollutants along with suspended solids, a POTW applying for a modified permit under Section 301(h) must demonstrate that it has reduced the concentrations of these toxic substances in its discharge to at least the level which would have been with secondary treatment. . . . This will require at least primary treatment in the case of POTW's

*Includes but is not limited to medical and dental offices; hospitals, schools, research, educational and commercial laboratories; warehouses; streets and gutters; shopping centers; carwashes; paint stores; residential, commercial, and public uses of pesticides and fertilizers; gas stations; and septage collection and disposal.

with wholly domestic influent and more than primary treatment for POTW's with industrial inputs."

We feel the basic concept in requiring this equivalency is in error. This point is described in detail in the comments regarding the basic policy associated with the proposed regulations submitted earlier in the comment period. Nonetheless, it is in error to imply anything less than full secondary treatment applied to either domestic or mixed wastes can possibly achieve the equivalency in terms of toxic substance removal required by the proposed regulations.

2. Only a small number of communities potentially qualifying for the Section 301(h) modification asserted that they had *all* possible environmental data at hand to conclusively prove to EPA that such a modification should be granted. Furthermore, the amount of data required to make a meaningful demonstration is not a fixed level of necessary information. If an applicant discharging 300 mgd into the Pacific Ocean at the 200 foot depth can successfully make the demonstration, the data required by an applicant discharging 5 mgd into the same water at the same depth should and could be substantially reduced. The proposed regulations, however, do not recognize the transferability of data for making reasonable projections of environmental effects. To conclude that because a minority of communities asserted that the data was presently in hand, that the data requirements should not be onerous for many applicants is a misrepresentation. As a matter of fact the data requirements will be very burdensome to even the largest entities and will in all likelihood effectively preclude successful application by smaller communities.

3. We are pleased that the Agency has provided for submission for additional data, information, and interpretation after the September 24, 1978 application date.

4. Unfortunately, BPWTT has not been formally defined by EPA in the Agency's regulations. We think that it is imperative that the Agency formally define this required treatment level at the earliest possible date. At present, it is essentially impossible for a discharger making a 301(h) modification request to evaluate the impact that the BPWTT requirement will have. EPA appears to be implying that any modification will be only for a short time because of the necessity of complying with BPWTT. It is necessary that the Agency directly face this issue by formally defining BPWTT and seeking comments in an open forum.

5. EPA asks the question whether the regulations should provide for the special problems associated with small native villages in the Pacific Trust Territories, Puerto Rico, and Alaska. We feel the Agency should do everything in its power to make sure that the Act is applied in an effective and reasonable fashion even if this results in additional burdens upon EPA. We certainly see how the proposed regulations would effectively preclude modifications for small native communities where it is easily recognized that secondary treatment is neither a viable or necessary technology. In such cases, EPA should provide for reasonable technical projections rather than actual field measurements and also provide technical assistance in preparation of applications. This same consideration should also be afforded small mainland communities which similarly can have very severe economic and technical problems.

Proposed Regulations

*Subpart A—Section 233.1—*A definition of "industrial source" to a community sewer system should be included.

Subpart B—Section 233.11(a)(2)(i)

The criteria for "rapid initial dilution" is unnecessarily vague. A community discharging 10 mgd at an 80 foot depth can achieve the same or greater initial dilution as another community discharging 300 mgd at a 200 foot depth. However, the smaller community certainly would not achieve the initial dilution that it would if the outfall extended to the 200 foot depth. To prevent confusion we suggest EPA define "rapid initial dilution" in quantitative terms to be determined using a standard procedure. The EPA "PLUME" model which provides for no cross current considerations could be utilized and an appropriate minimum dilution would be approximately 50:1 (using this very conservative model).

*Section 233.11(a)(2)(iv)(B)—*An explanation of the meaning and determination of "stressed marine organisms" should be included.

*Section 233.11(b)—*The term "existing discharge" should include all those facilities which are approved for Step I, II, or III of the construction grant program. Our previously submitted comments present an expanded discussion of this point.

Section 233.12(a)(1)—The explanation of this section states:

"Only state water quality standards approved by EPA prior to October 28, 1972, shall be considered water quality standards. No new or revised water quality standard may be utilized to determine compliance with this section unless it is approved by EPA prior to September 24, 1978."

It would be less confusing if the September 24, 1978 replaced the October 28, 1972 date in the first sentence and the second sentence was eliminated.

Section 233.14—This section is a critical section in the proposed regulations. We have early in the comment period discussed at some length our comments related to the use of the equivalency of toxic substance removal, compliance with *all* water quality standards, and the question of applying the water quality criteria for synthetic toxicants directly to the effluent. We remained convinced that these criteria prohibit any successful request for modification.

Data is presently not available as to the concentrations of the 65 toxic substances listed in the NRDC consent decree. It will be impossible to generate that reliable data prior to the date of application. The performance of secondary treatment with regard to each of these 65 substances is not documented and hence criteria prohibit any successful request for modification.

Section 233.14(c)(ii)—There is an error in the statement:

(B) Dilution water is continuously supplied in an amount equal to the wastewater flow times the dilution water.

Only if one strikes the word "water" from the end of the sentence, does the statement make sense. The statement then becomes the definition of dilution.

Section 233.14(d)(2)(ii)(F)—There are certain elements in the proposed regulations, such as determining feeding relationships, seasonality, succession, and direction of community development, which extend beyond the realm of standard outfall monitoring and are more relevant to a major research project. Feeding relationships, succession, community metabolism, and the direction of community development represent individual processes which are not understood in detail but which are integrated in the overall patterns of species distribution and abundance. The distribution and abundance of species represents the physical end product of all natural and human influence on communities of organisms. With the addition of short-term phenomena (fish kills, algal blooms) and evidence of qualitative impacts (disease, abnormalities, and adverse bio-accumulation of toxicants) the biological evaluation should be limited to consideration of seasonal patterns of distribution and abundance of species without losing any important information.

In discussing this section, EPA requires that a radial pattern of transects be utilized. The radial pattern of transects is seldom the most effective sampling station array. Sampling patterns reflecting the prevalent dispersion patterns, bathymetry, and bottom sediments are much more informative. Therefore, because effective sampling geometry is essentially site specific, we suggest EPA not attempt to make any uniform criteria for location of sampling stations.

In viewing the concept of initial dilution in relation to its application by regulatory agencies for marine outfalls, one must be cognizant that there are two different objectives being approached. The first is to apply a relative tool for simulating the performance of an outfall diffuser. In this application it is important to maintain a conservative estimate to ensure for the lack of understanding of chronic toxicity effects of municipal wastewater. Yet it needs to be of a simplistic formulation to be used for the different types of outfalls under a standardized format. With this objective in mind, the PLUME model provides an adequate approach.

However, this model is not applicable to the second objective, which is to present, as realistic as possible, the movements of the outfalls' wastefield to ensure than an effective monitoring program can be implemented. This intent is presented throughout the Concept Paper, but is not supported by the recommended techniques of initial dilution calculation. The limitations of the PLUME model are that, (1) it does not consider influences of lateral currents; (2) it does not consider the finite length of diffusers and the formation of a line source; and (3) it does not consider the finite thickness of the sewage field. The simplistic geometry simulated by the PLUME model does not produce adequate understanding of the temporal and spatial variability in the wastefield movements. There are several existing models which, in conjunction with results of recent investigations, could resolve many of these deficiencies. Examples of the models are Sotil (1971) for a slot jet in stratified conditions, Koh and Fan (1970) and Davis (1975) for a row of equally spaced buoyant jets. All of these models are for the case of no ambient crossflow and do not account for near field dispersion and the effect of

the finite thickness of the wastefield. Work by Kotsorinos (1975), Wu and Koh (1977), Roberts (1977), and Wright (1977) should assist in presenting a more realistic simulation of the wastefield. (See list of references)

It is important to understand the temporal variations in the physical oceanographic conditions that can induce significant changes in the areal coverage in which initial dilution occurs; e.g., the frequency and duration of different current speeds and directions that will influence the rise of the plume in different directions at different rates, or changes in the vertical density structure that can result in shifting between a surface and subsurface wastefield. Understanding the time scales in which these events occur enables the marine scientists to include monitoring techniques that evaluate impacts on responsive time scales. This evaluation of dynamic plume behavior will be more useful than what has been referred to as "the edge of the zone of initial dilution."

Section 233.15—A detailed quantitative inventory of recreational activities (and also potential effects on water supply) appears unnecessary unless there is a reason to believe the discharge may have some effect on these activities as evidenced by violation of applicable water quality standards.

Section 233.16(b)(4)—Unfortunately, at the present time there does not exist a standard method for conducting *in situ* bioassays for liquid, suspended solids, solid fractions. Furthermore, there is no uniform procedure for determining the relative impact of liquid, suspended, and solid phases. In the absence of a conceptual scheme for evaluating the meaning of this data, we feel it would not be productive to require such research type information to be developed, if indeed it will be possible to develop meaningful data. This type of effort would be exceedingly difficult for a small community.

Section 233.17(b)—In a state such as California numerous state and local agencies are empowered to act in an advisory capacity with regard to the determination of appropriate effluent limitations. These agencies include the Regional and State Coastal Commissions, State Department of Conservation, State Lands Commission, State Department of Fish and Game, State Department of Health, local health and planning departments, and 208 planning agencies. However, only a single agent, the Regional Water Quality Control Boards, are empowered to actually impose effluent limitations. To require that each appliance obtain statements from each of the numerous advisory agencies is an unnecessary, burdensome, and duplicative effort. We suggest that such a statement should only be furnished by the agency which is empowered to establish the water quality requirements.

Section 233.18(c)(6)—Because state concurrence is required to formally enact any modification, it appears to be redundant to require a separate state certification of the adequacy of pretreatment programs. We suggest this certification procedure be eliminated and permit the State to review compliance with applicable pretreatment requirements as part of its general concurrence authority. The suggested procedure would serve to consolidate the state review rather than fragment such review.

Section 233.19(b)—Storm water control and pesticide control which appear to be required are often outside the specific enabling legislation of the sewerage entity. A sanitation district does not have authority to impose restrictions on storm drainage practices or pesticide application practices. Furthermore, in large urban areas it is common to find that the operating entities of sewage treatment facilities and the sewer system may be within different governmental jurisdictions. Because of these unique and varying circumstances, we feel it is essential to have flexible guidelines regarding the practicability of nonindustrial source control.

Section 233.20—Our earliest comments address the major policy issues associated with this section in detail.

Section 233.22—It is unclear who is required to provide the certifications. It does appear that it would be desirable to include such a certification into the overall state concurrence procedure rather than fragment the state review process.

Section 233.32(d)—Because state certification and concurrence are required by the regulations, the applicant should be required to submit a copy of the applicant to the certifying and concurring state agency.

Subpart C—Section 233.32(a)(2)—Because of the great deal of information required by these regulations, it is highly unlikely that communities will be able to complete their applications much before the September 24, 1978 filing date. Thus, the State would be forced to make the decision regarding certification prior to evaluating the completed application.

Furthermore, in accordance with the federal regulations, the certification process contains requirements for public notice which require additional lead time. In light of all these complicating factors and the severe time constraints, the states may be forced to waive such certification in accordance with Section 401 of the Federal Act.

We favor combining all the required, separate state certifications into the single state concurrence process. This process would reduce duplicative reviews, speed up the application filing, and application review.

Section 233.45—Because the permit will be formally issued by EPA, a discussion of the further administrative disposition of the permit should be included to prevent subsequent confusion regarding the responsible agency for any additional permit modifications, monitoring, and any necessary enforcement. We suggest that administrative jurisdiction over any federally modified permit be returned to the approved state and feel that such a procedure is consistent with the Congressional policy outlined in Section 101(b) of the Act.

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