TIME - STRESSED COASTAL ENVIRONMENTS: ASSESSMENT AND FUTURE ACTION

PROCEEDINGS

of

SECOND ANNUAL CONFERENCE

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THE COASTAL SOCIETY
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New Orleans, Louisiana

November 17 - 20, 1976

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Thursday, November 18, 1976

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RELATIVE SIGNIFICANCE OF CONTEMPORARY DREDGING IMPACTS IN SAN DIEGO BAY, AN HISTORICALLY STRESSED ENVIRONMENT

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Abstract

For nearly a century prior to 1963, San Diego Bay was heavily stressed by four types of man's activities: (1) diversion and damming of all principal tributary drainages, with virtual elimination of fresh water input to the bay; (2) dredging and filling so extensive that only 17-18% of the original bay floor remains undisturbed; (3) discharge of: (a) sewage and primary effluent, (b) industrial wastes, and (c) power plant cooling water to the bay; and (4) intensive urbanization of adjacent lands.

In light of this historic setting, the environmental impacts of contemporary dredging activities would appear to be of relatively minor significance. However, since the 1960's dredging projects have been rigorously regulated and widely opposed by environmental groups. Specifically, in recent years, institutional constraints brought to bear through Federal and state regulatory processes have become key determinants in the authorization of dredging projects in California. Dredging permit procedures require review by numerous Federal, state, county, and municipal agencies as well as citizen interest groups. Opposition to a project by an agency or group may result in costly delays, possible project modification, or even cancellation.

A current dredging project in San Diego Bay provides a "real world" case history illustrating how environmental considerations and associated institutional constraints can modify dredging practices, delay project schedules, and increase costs, even in an historically stressed environment.

INTRODUCTION

The intent of this paper is to: (a) examine qualitatively the significance of contemporary dredging impacts in San Diego Bay, in light of the heavily stressed environmental conditions which obtained in the bay for nearly a century prior to 1963; (b) review the complex procedural mechanisms for regulating contemporary dredging work, using San Diego Bay as an example; and (c) illustrate the major time and cost consequences of these regulatory controls by means of a current San Diego Bay case history.

The paper incorporates excerpts from papers presented by one or both of the writers at the Third International Estuarine Research Federation Conference in Galveston, Texas, October, 1975; and the Seventh World Dredging Conference in San Francisco, July, 1976 (see Smith and Graham, 1976; and Smith, 1977).

SAN DIEGO BAY

Located in the extreme southwest corner of the United States, just north of the U.S.-Mexico border, San Diego Bay is one of the finest natural harbors in western North America. The bay is a moderate-sized, landlocked estuary about 22.5km long, ranging from 0.4 to 4km in width. Except in the 7.5 to 20m deep channel, depths range from generally deeper than 9m in the north bay, from 3 to 4.5m in the central bay, and from 0 to 3m in the south bay. The extreme range of tides within the bay is 3.2m.

In 1857, the bay was undisturbed by man, as is shown in Figure 1. By contrast, the bay now is surrounded by metropolitan San Diego, with a population of more than a million (see Figure 2). In addition, the bay is the site of one of the largest naval establishments in the country.

Since the 1870's, the bay has been subjected to a succession of man-induced environmental stresses that undoubtedly have had major effects on habitat, water quality, and biological communities in the bay. These stresses included:

(a) diversion and damming of principal tributaries, which all but eliminated fresh water input;

(b) extensive dredging and filling;

(c) bay discharge of sewage and other waste; and

(d) intensive urbanization of the land areas ringing the bay, with attendant introduction of urban contaminants.

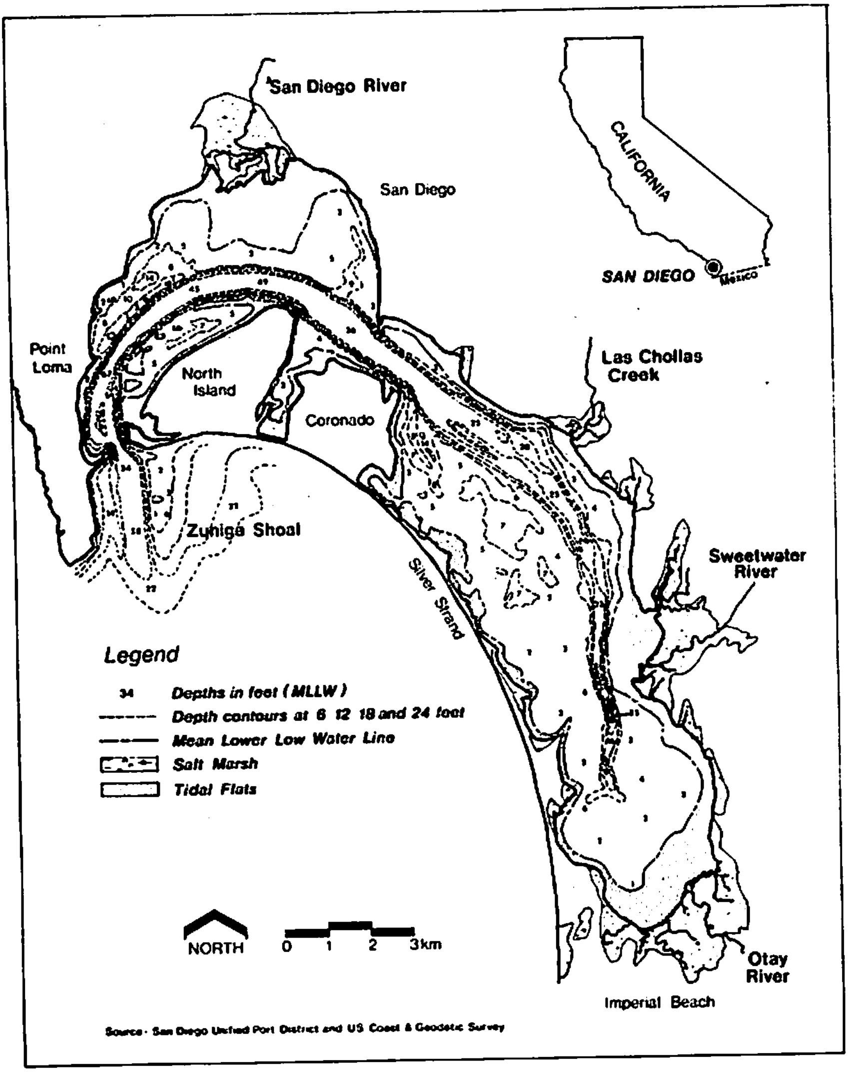

Figure 1. Configuration and bathymetry of San Diego Bay in 1857.

Although the above-mentioned stressed undoubtedly had a major effect on water quality in the bay from the 1870's onward, there was no scientific mention of these effects until the 1930's, and no technical documentation was initiated until shortly after World War II. Thus, the scientific record of the bay's response to man-induced stresses is limited to the post-war period.

In the absence of comprehensive historical data on the effects of these stresses, definitive judgments on the extent and degree of such effects cannot be made. However, based on assessments of the limited historical data available (presented in following sections), it seems clear that the effects of these stresses were substantial in terms of changes in the habitat, water quality, and biological communities in the bay. A brief examination of the principal stresses and their effects follows.

DIVERSION AND DAMMING

As presented in detail in Smith (1977), the principal tributaries to San Diego Bay (figure 3) prior to man's intervention were the San Diego, Sweetwater, and Otay rivers, and a number of smaller streams; the drainage basins tributary to the bay totalled about 2,330 km^2. As late as the 1850's, the prominent delta of the San Diego River was building in northern San Diego Bay (see Smith, 1977, Figure 1), as were the deltas of the Sweetwater and Otay rivers in the south bay. The presence of these deltas is strong evidence that natural sedimentation (primarily fluvial deposition) was gradually filling the bay. Beginning in the 1870's, however, fresh water input and fluvial sediment influx were greatly reduced as a result of: (1) the 1875-77 diversion of the flow of the San Diego River away from San Diego Bay and into nearby Mission Bay (Rambo and Speidel, 1969; and USACE, 1975b), and (2) construction of water storage reservoirs on the Sweetwater and Otay rivers in 1888 and 1919, respectively (see Figure 3). Diverting the San Diego River terminated fresh water and sediment contribution and, and shown in Smith (1977), constructing the reservoirs reduced the fresh water and sediment input from the Sweetwater and Otay rivers by about 75 percent. The other tributaries to San Diego Bay (Las Chollas Creek and the creeks in the North and South Bay groups - see Figure 3) historically have contributed insignificant amounts of fresh water and sediment to the bay (USACE, 1975b; Smith, 1977).

Based on Smith (1977) and the sources cited therein, the total fluvial sediment delivered to San Diego Bay

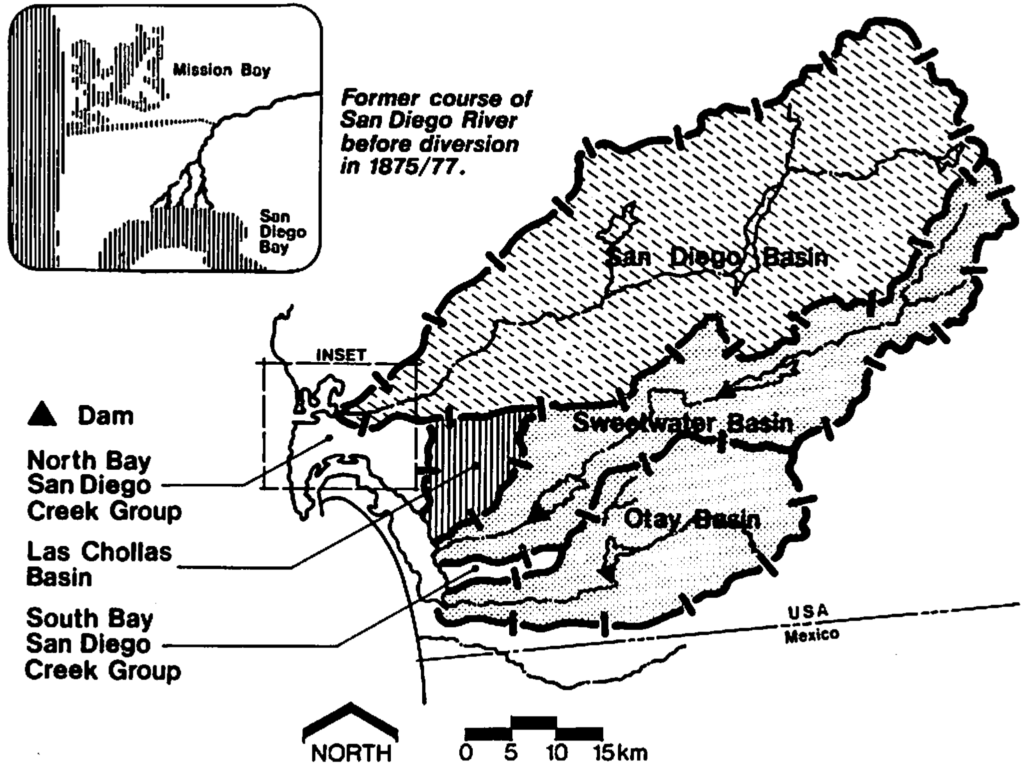

Figure 3. Tributaries and drainage basins contributing runoff and sediment to San Diego Bay. Reproduced from Smith (1977) by permission of the Academic Press, Inc.

annually prior to man's intervention was probably on the order of 0.8 to 1.1 x 10^6 m^3. Following diversion and dam construction, the annual fluvial sediment contribution dropped to 1.4 to 1.9 x 10^5 m^3; roughly this rate apparently has obtained for the last 55 years. In short, according to USACE (1976b), fluvial sediment contribution to the bay is minimal because: (1) few major drainages enter the bay, (2) many of these drainages are partially controlled by dams, and (3) stream velocities downstream from the dams are generally non-scouring.

DREDGING AND FILLING

As presented in Smith (1977), San Diego Bay is one of the most extensively dredged and filled estuaries in the United States. The history and extent of dredging and filling in San Diego Bay are unusually well documented (see Mudie, 1970; Gautier, 1972; Peeling, 1974; USACE, 1975b; and Smith, 1977). According to USACE (1975b),

> "Starting near the beginning of this century the channels in the north and central parts of the bay were straightened, widened, and deepened to facilitate navigation; and practically all of the marshlands in the north bay were filled to create lands for airfields, highways, docks, shipyards, parks, tourist and recreational facilities, and other uses.

> "...Extensive dredging since 1940 has...altered the character of /much of/ the bay floor. ... the bay floor mud layer has been removed exposing the underlying sandy strata."

EXTENT OF FILLING

Prior to major filling activities, San Diego Bay had an area of 54 to 57km^2, as defined by the mean high tide line of 1918 (see Gautier, 1972). Filling activities, primarily using dredged material, began in 1888 (Peeling, 1974) and intensified markedly shortly before and during World War II. As illustrated in Figure 4, approximately 15.5km^2 of the bay, amounting to about 27 percent, have been filled.

EXTENT OF DREDGING

The areal extent of dredging in the bay is illustrated in Figure 5. Approximately 31km^2 of the 1918 bay floor, amounting to 55 percent, have been dredged. As evident in Figure 5, except for an area of about 10km^2 in the extreme south bay area, most of the bay floor has been dredged.

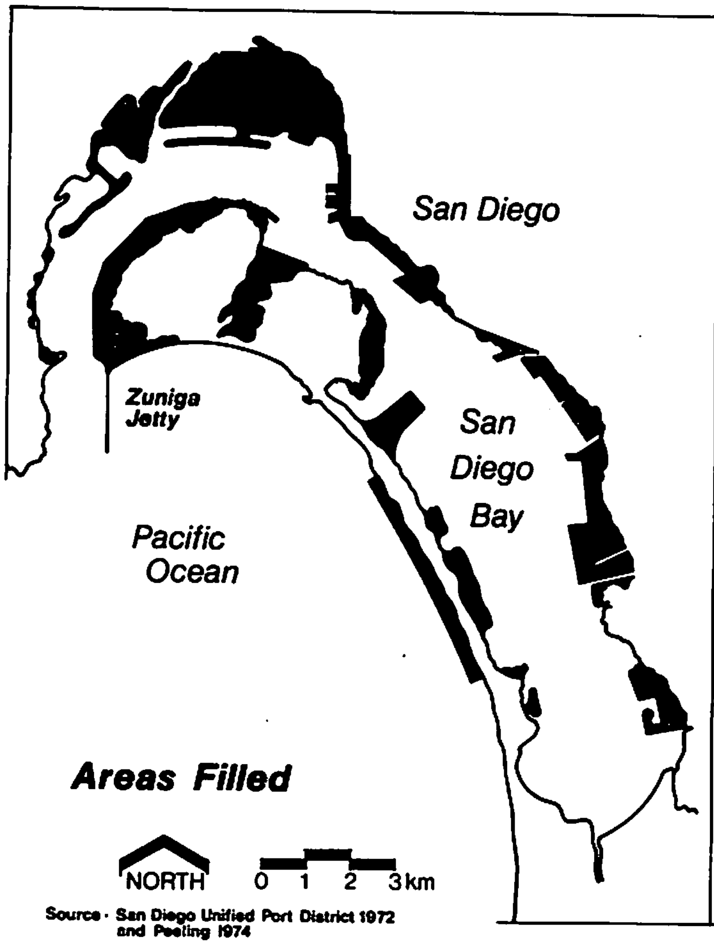

Figure 4. Areas filled in San Diego Bay during the period 1914-1971. Reproduced from Smith (1977) by permission of the Academic Press, Inc.

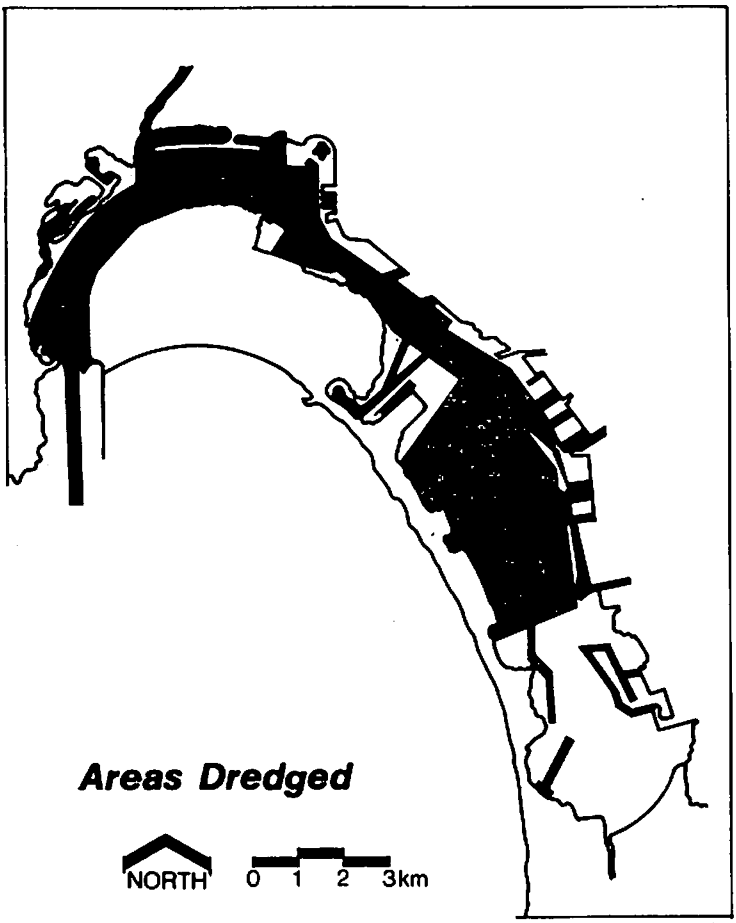

Figure 5. Areas dredged in San Diego Bay during the period 1936-1971. Reproduced from Smith (1977) by permission of the Academic Press, Inc.

Further, this dredging has virtually doubled the depth of most of the shallower portions of the north and central bay.

If dredging and filling both are considered, only about 17 to 18 percent of the bay area represented by the 1918 mean high tide line remains undisturbed. More than half of this dredging and filling was associated with World War II naval activities.

VOLUMES MOVED

As to the volumes moved, it is estimated (Smith, 1977) that dredging has shifted about 100 to 140 x 10^6 m^3 of bay floor sediment approximately as follows: (a) about 2 x 10^6 m^3 to deep water ocean disposal sites by mechanical dredging and transport[1/], (b) about 22 x 10^6 m^3 to Silver Strand as beach replenishment by pumping (Peeling, 1974), and (c) roughly 75 to 115 x 10^6 m^3 to bay marginal areas as fill by pumping[1/], as illustrated in Figure 4. By comparison, (1) the present water volume of San Diego Bay is about 230 x 10^6 m^3, and (2) the San Diego River, the former chief tributary to the bay before diversion in 1875-77, is estimated to have delivered about 3.8 to 5.3 x 10^5 m^3 to the bay annually.

Clearly, damming and diversion, and past dredging and filling produced major changes in the physical characteristics of this estuary (see Smith, 1977), and probably in the biological communities living therein. Assessing the environmental significance of these changes, however, must also take into account the lengthy history of waste discharges to the bay.

WASTE DISCHARGES

Past and present waste discharges to San Diego Bay include: (a) metropolitan sewage and primary treatment plant effluent, (b) industrial wastes, (c) power plant cooling water, and (d) various other wastes.

The nature and effects of these various waste discharges are discussed in some detail in San Diego Regional Water Pollution Control Board (1952), Newman (1958), Ford (1968), Parrish and Mackenthun (1968), Ford et al. (1970, 1971, 1972), Dodson (1972), Gautier (1972), Browning et al. (1973), Ford and Chambers (1973, 1974), and Wagner (1976). A brief discussion of the principal types of these discharges follows.

SEWAGE AND TREATMENT PLANT EFFLUENT

According to Dodson (1972), San Diego's raw sewage was discharged to the bay from 1885 to 1943, and the bay received effluent from primary treatment plants from 1943 to 1963.

1/Based on review of data with Mr. D. R. Forrest, SDUPD, who has extensive knowledge of San Diego Bay dredging projects.

Thus, this type of stress on the bay environment persisted for almost 80 years.

More specifically, in 1885 the city of San Diego installed its first sanitary sewers, which delivered untreated sewage wastes to the bay (Dodson, 1972). The metropolitan population grew rapidly after the turn of the century and the municipal sewage discharges increased proportionately, as did waste discharge from industry and from vessels in the bay, with resulting marked deterioration in water quality and "...a marked reduction in the variety and abundance of organisms which dwelt within or visited the bay seasonally" (Browning et al., 1973).

The early water quality history of the bay is not documented nearly as well as the history of dredging and river diversion (discussed above). Dodson (1972) reported that, with San Diego's leap in population to 250,000 between 1935 and 1940 (a 40 percent growth), polluted bay waters became a public health hazard and hydrogen sulphide from sludge on the bay bottom was ruining paint on Navy ships. To remedy this situation, a 32km long interceptor sewer and primary treatment plant were built in the early 1940's; the unchlorinated effluent was discharged into the northern part of the bay. "By 1943, only seven raw sewage outfalls continued to discharge to tidal waters in the metropolitan area" (Dodson, 1972).

By 1947, the metropolitan population had grown to 350,000; the bayshore sewage treatment plants were overloaded and the "...bay was again showing signs of abuse" (Dodson, 1972). The principal treatment plant was rebuilt with improved treatment equipment but by 1950 the population had soared to 450,000; about 225 million litres per day of sewage and industrial wastes were being discharged (SDRWPCB, 1952), and the bayside treatment plants were again overloaded.

Concern for water quality problems led to establishment of the California Regional Water Quality Control Board in 1950. The San Diego Region of the Board has since documented conditions in the bay, and evolved a program to replace all bay discharge of sewage (Figure 6) with ocean discharge via a single outfall. The resulting sewerage system, completed in 1963, is shown schematically in Figure 7.

As detailed in California RWQCB-SDR (1966) and summarized in Browning et al (1973):

> "...by 1963, 80 percent of the bay had dissolved oxygen concentrations below the levels necessary for continued sustenance of fish and wildlife. Water clarity...was low...due to discoloration

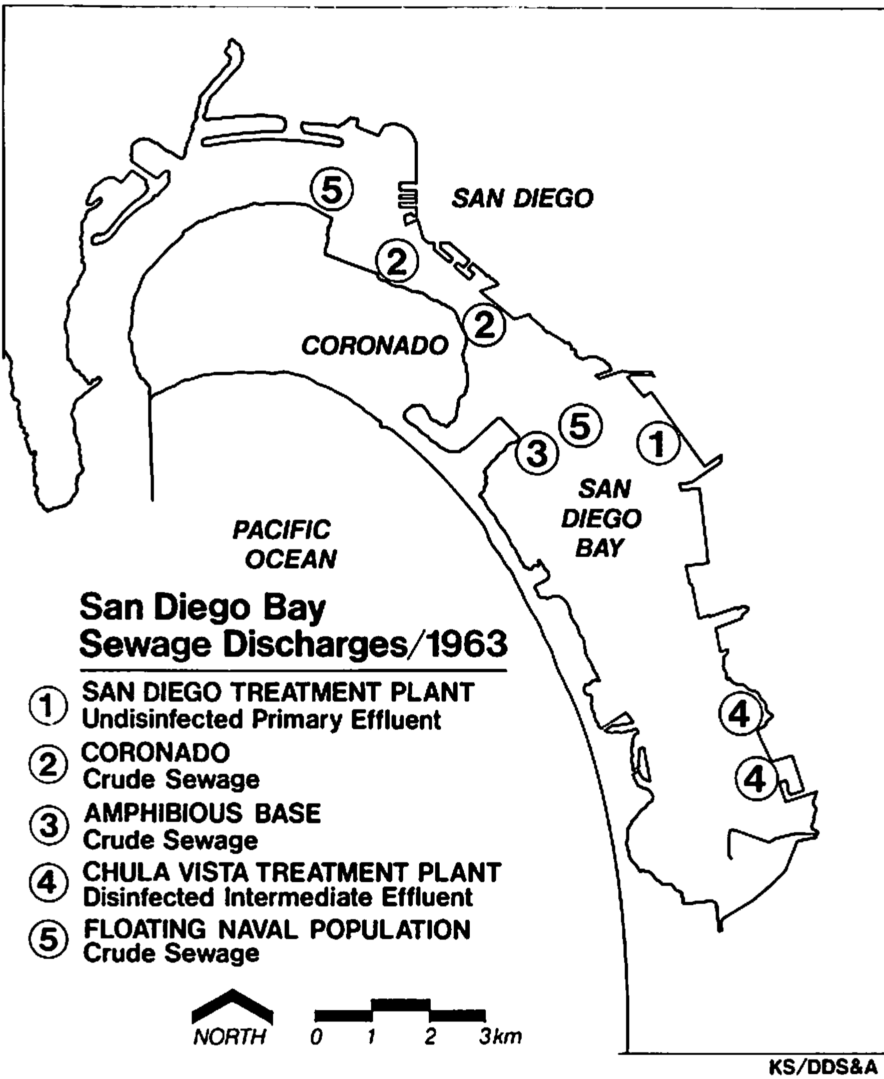

Figure 6. Sewage discharges to the bay in 1963, prior to completion of the San Diego Metropolitan Sewerage System.

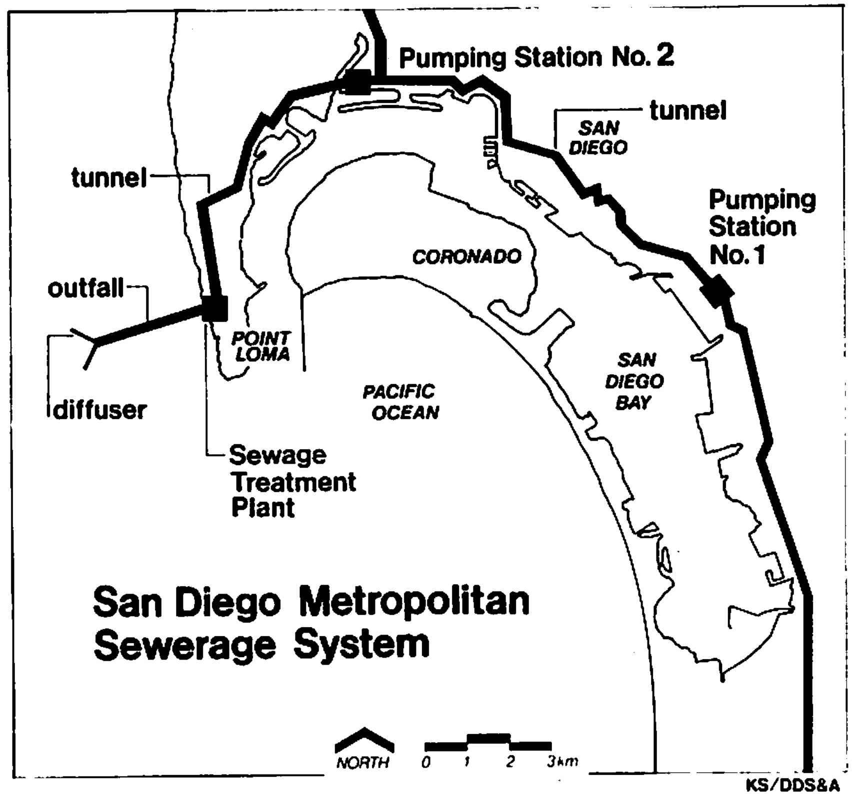

Figure 7. San Diego Metropolitan Sewerage System built in 1963.

and plankton blooms caused by nutrients from waste discharges, storm runoff, and other sources. Bacterial counts were excessive and forced closure and quarantine of many beach and water areas. Extensive sludge deposits (800 yds. wide by 9,000 yds. long) blanketed bay bottoms around the U.S. Navy installation and waterfront area. This deposit reached seven feet in thickness at some points."

As presented by Browning et al. (1973):

"With the installation of the S.D. Metropolitan Sewerage System in August 1963 municipal waste discharge to the bay were terminated. Improved water quality conditions were noted in a very short time. Water quality sampling in the late 1960's revealed dissolved oxygen concentrations generally between 4-7 mg/l, Secchi disk readings of 6 to 12 feet, and bacterial counts acceptable for water-contact sports. Conditions acceptable to fish and wildlife existed in about 80 percent, or 7,600 acres, of the bay area. Several military and industrial activities, located along the bay front, continued to discharge waste until 1970, and discharges from the North Island NAS continued until July, 1972."

According to Dodson (1972):

"From an almost hopeless community disgrace in 1963, San Diego Bay has made a phenomenal recovery. By 1964 the surface was displaying a long-forgotten sparkle. Game fish began to appear throughout the 22-mile length of the bay. Sludge banks in the vicinity of the now-abandoned bayside treatment plants rapidly stabilized and began to recede. Bow-waves of passing ships were white - not dull green. Fishing and recreational boats no longer had scummy hulls. Fifty years of abuse had disappeared in less than two years."

INDUSTRIAL WASTES

Prior to completion of the sewerage system in 1963, all industrial wastes were discharged to the bay (Parrish and Mackenthun, 1968). In 1952, these included the wastes from five fish canneries, a kelp processing plant, a fish and animal reduction facility, aircraft industries, and a number of other, less significant discharges. The nature and volumes of these wastes are detailed in SDRWPCB (1952).

Major industrial discharges to San Diego Bay at the time the metropolitan sewerage system was completed in 1963 are illustrated in Figure 8.

Although military and shipyard wastes are not called out in the reports just cited, Browning et al. (1973) state:

Military Wastes

> "For many years, navy ships like others in the bay, were an important source of oil, grease and chemicals that found their way into bay waters. Highly toxic industrial wastes also came from the North Island Naval Air Station. ...
>
> ".../Although/ for many years RWQCB-SDR protests against continued discharges from naval sources were ignored... ...during the summer of 1972, the Navy ended the discharge of all industrial wastes into the bay."

Shipyard Wastes

Privately owned commercial shipbuilding and repair facilities have increased substantially in recent years as the result of the closing of the U.S. Naval Repair Facility in 1964. Building and repair of naval vessels is now a major industry. There are more than 20 shipbuilding and ship repair firms located around the margins of the bay (Browning et al., 1973).

Concerning shipyard wastes, an estimated 625,000 lbs. of copper, zinc, and lead-based paints were discharged annually to the bay (California WRCB, 1976). Field investigations by the California RWQCB-SDR (1972) showed that heavy metal concentrations in bottom sediments were substantially higher near shipbuilding and repair facilities than in other parts of San Diego Bay. The highest concentration of heavy metals recorded was found in the Commercial Basin area of the north bay.

The report concluded that marine paints (which contain substantial quantities of mercury, arsenic, and tin), when removed by sandblasting and washed into the bay, pose a threat to water quality. A subsequent investigation by EPA of bay floor sediments adjacent to shipyards (EPA, 1974) confirmed the findings of the RWQCB-SDR, which resulted in establishing a program that would reduce substantially this type of pollution.

POWER PLANT COOLING WATER

Heated cooling waters are discharged to the bay from

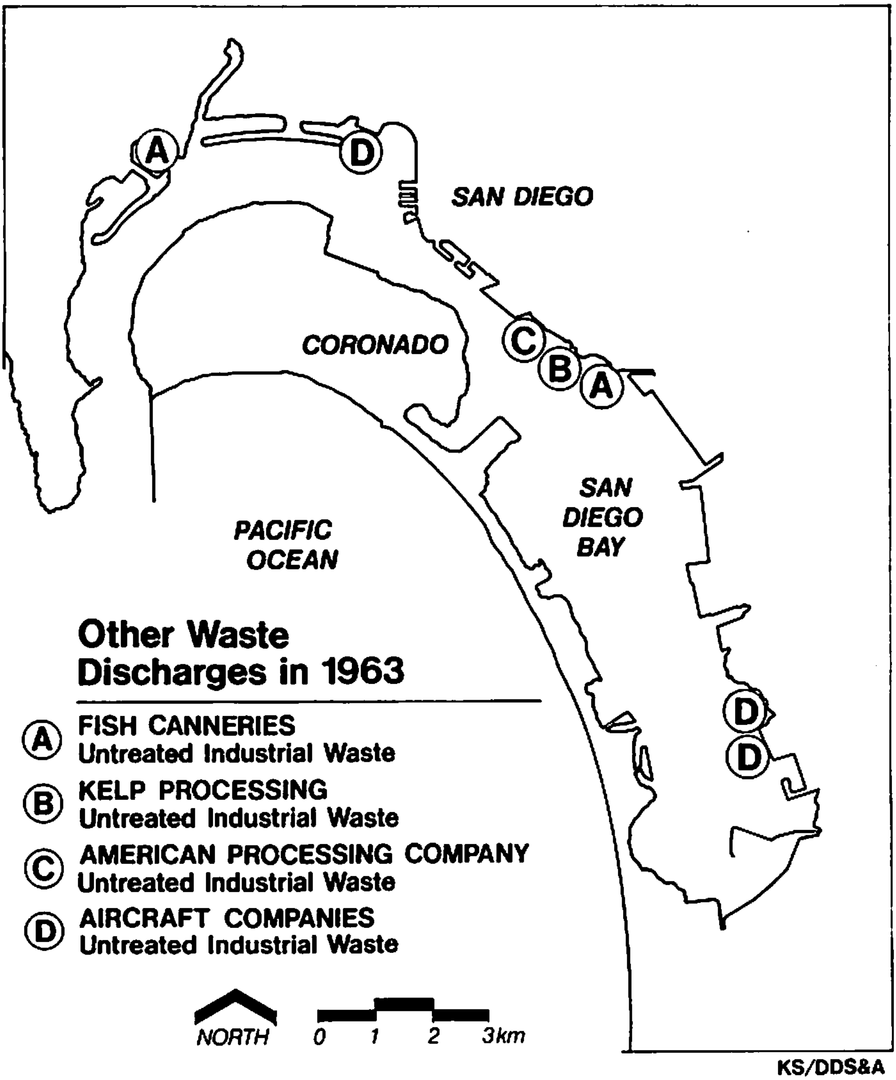

Figure 8. Major industrial discharges to the bay in 1963.

three San Diego Gas & Electric Company steam electric generating stations located at intervals along the eastern shore of the bay.

The Broadway plant in downtown San Diego was built in the 1920's, the Silvergate plant went into operation in 1941, and the South Bay Plant began operating in 1960.

The cooling water throughput of the three plants is approximately as follows: Broadway - 377 litres per month, Silvergate - 795 litres per day, South Bay - 2,500 litres per day. The Silvergate and South Bay plants operate more or less continuously but the Broadway plant is operated only in periods of peak demand.

In compliance with the CWRCB bays and estuaries thermal plan (1970), intensive studies of the effects of these thermal discharges have been conducted by various investigators under sponsorship of the utility. A detailed discussion of the results of these studies (see Smith and Wright, 1975, for pertinent references) is outside the scope of this paper. The discharges from all three plants comply with the limits set by the Board's thermal plan. For a number of reasons, the areas affected by the thermal plumes from the Broadway and Silvergate stations are limited in extent. The much larger volumes of water from the South Bay plant generate a plume which extends over a considerably larger area; further, this heated water discharge is located in the very shallow southern portion of the bay which has limited circulation.

Studies of benthic fauna in the vicinity of the South Bay plant have been carried out almost yearly since 1968, primarily during the summer months when the heated waters would have the most adverse effects (Ford, 1968; Ford et al., 1970, 1971, 1972; Ford and Chambers, 1973, 1974). These studies have not shown any major adverse impacts on marine life beyond 600 feet from the discharge point, but were not sufficiently comprehensive to evaluate properly the impact of thermal discharges on the ecology of South Bay (Browning et al., 1973).

According to Browning et al. (1973),

"The impact of the thermal effluent on marine habitats is much greater in the South Bay than it is in the north and central portions.

"...As a result /of the South Bay plant discharge/ waters in a substantial area of the South Bay are frequently 7°-9° F warmer than the waters in the rest of the bay. Many temperature-sensitive organisms may not be able to tolerate the high temperatures which occasionally occur in South Bay."

OTHER DISCHARGES

Various other discharges have contributed wastes to San Diego Bay in the past. These include: (a) sewage and other wastes discharged from naval and commercial vessels, and from recreational craft, (b) effluent from a desalination plant, and (c) a number of smaller intermittent discharges such as aircraft industry wastes which reach the bay via storm drains (see discussion in SDRWPCB, 1952).

Vessel Sewage

The FWPCA (1969) study of vessel pollution in San Diego Bay concludes:

"1. Areas of San Diego Bay having intensive vessel activity are adversely affected by waste from watercraft. The most serious adverse effects are reflected by total and fecal coliform densities and the presence of Salmonella organisms and floating sewage solids in and on bay waters. Salmonella bacteria can readily be isolated from the waters of San Diego Bay in areas of concentrated vessel activity. The presence of such pathogenic bacteria is a hazard to the health of persons coming in contact with these waters.

"2. Floatable materials such as sewage solids, trash, garbage and oil discharged to San Diego Bay by ships create aesthetically offensive conditions. Most oil observed in San Diego Bay results from carelessness in fueling and fuel transfer operations onboard ships and between ship and shore. Pumping of bilges in violations of rules and regulations is also a probable source of oil in the bay. Carelessness of individuals of the waterborne population in San Diego Bay brings large amounts of floatable trash and garbage into the bay.

"3. Bottom deposits of decomposed and actively decomposing sludge resulting in part from settleable vessel wastes may be found in areas of concentrated vessel activity in San Diego Bay. These deposits upset the normal ecology of the bay by diminishing the diversity of benthic biota."

Four years later, Browning et al. (1973) reported that although all municipal waste discharges to San Diego Bay had been terminated, the waters continued to receive sewage and other discharges from ships and boats. According to this reference, in 1971 the U.S. Navy embarked on a five year program which would eventually result in termination of sanitary waste discharges from all naval vessels.

Recreational boating in the bay contributes some sanitary wastes, which probably are not significant volumetrically except in the various marina areas where there are large concentrations of boats, including many "live-aboards." State laws requiring installation of sewage retention facilities in recreational craft are reducing the volumes of sanitary wastes from boating.

Desalination

The Senator Clair Engle Desalting Plant was operated in the South Bay for a period of about five years ending in 1972 (Smith and Wright, 1975). The results of a study of the effects of this discharge were reported by Environmental Engineering Laboratory (1972) to which the interested reader is referred.

URBAN RUNOFF

As illustrated in Figure 2, the bay is surrounded by an intensely urbanized matropolitan area with a population in excess of one million.

Although there is literature dealing with the effects of urbanization on the chemical character of urban runoff (see Sartor and Boyd, 1972; Whipple, 1975; and sources cited therein), to the writers' knowledge, no work has been published on the specific effects of urban storm runoff on San Diego Bay. This subject is treated in general terms by Browning et al. (1973), who state:

> "In addition to silt, clay and organic materials, storm and drain waters can introduce a variety of other pollutants into bay waters. Oil and grease from city streets, agricultural pesticides, and lead particles that owe their origin to air pollution and the combustion of high octane gasolines, all enter the bay through runoff. And, large volumes of fresh water which cause rapid changes in salinity that some sedentary marine species cannot tolerate, also can be considered a kind of 'pollutant.'
>
> "Fine silts and clays smother many bottom organisms

> and increase turbidity, thus decreasing the amount of penetrating sunlight necessary for growth of flora living in the bay waters or on the bottom. Organic materials introduced with runoff utilize oxygen from the water, thus decreasing supplies vital to all aquatic fauna. It only takes trace amounts of some highly toxic pollutants (trace metals and synthetic organic compounds) to directly or indirectly affect the viability of bay habitats."

Intuitively, it seems likely that urban runoff would have a measurable effects on some segment of the biota in the bay because of a number of factors, including the bay's moderate size, the extent of adjacent urban areas, the highly seasonal character of the rainfall, among others. Perhaps future work can test this speculation.

IMPROVEMENT IN BAY WATER QUALITY

As documented in Dodson (1972), Browning et al. (1973), and Wagner (1976), installation of the San Diego Metropolitan Sewerage System in 1963 terminated municipal waste discharge to the bay, and improved water quality conditions were noted in a very short time. As summarized by Browning et al. (1973):

> "Largely through the efforts of the Regional Water Quality Control Board - San Diego Region, the water quality in most areas of the bay has continued to improve during recent years. Turbidity has decreased, dissolved oxygen values have increased, and surface scums, oil slicks, and floating debris occur less frequently as a result of waste discharge regulations imposed by the RWQCB-SDR, improved oil handling procedures (resulting in fewer accidents) and improved clean-up procedures. The sludge beds that formerly covered much of the bay floor have been dispersed by tidal currents and dredging projects, or reduced by oxidation. Bay waters have become clearer, and healthy fish and invertebrate populations again flourish in many areas. Eel grass beds have re-established on some of the shallow dredged bottoms and several other ecologically desirable marine plants have begun to grow on pilings and rock structures. At the same time, the vast algal mats which previously covered the bottom in some areas of the central and southern bay areas have been greatly reduced; these mats are generally considered ecologically undesirable."

SUMMARY OF PRINCIPAL MAN-INDUCED EFFECTS ON THE BAY

The marked (some even term them "dramatic") improvements just described are certainly both significant and highly commendable. On balance, however, the point remains that for almost a century prior to the mid-1960's, the bay was a heavily stressed environmental system. Recapitulating, the principal adverse environmental effects of the various stresses discussed or listed above include: conversion of what probably was a brackish estuary to an entirely saline water body; destruction of 80 percent of the bay marginal salt marshes by filling; doubling of average depth as a result of dredging; buildup of sewage waste deposits and associated algal mats on the bay floor, with massive reduction in the benthic and pelagic biological communities; conversion of mud bottom to sandy substrate by dredging, and local contamination of bottom sediments with trace metals from shipyards and industrial discharges.

When contemporary dredging activities are viewed in this historic context of roughly a hundred years of environmental stresses (including the World War II episode of massive dredging and filling), environmental impacts of current dredging projects would appear to be of relatively minor significance. However, since the later 1960's, dredging projects in San Diego Bay (and throughout much of the U.S.) have been rigorously regulated and widely opposed by environmental groups.

REGULATION OF DREDGING

In recent years, institutional constraints brought to bear through Federal and state regulatory processes have become key determinants in the authorization of dredging projects in California. Dredging permit procedures require review by numerous Federal, state, county, and municipal agencies as well as citizen interest groups. Opposition to a project by an agency or group may result in costly delays, possible project modification, or even cancellation.

Environmental and legal controls on dredging projects (Smith, 1975; Boerger and Cheney, 1976) stem from regulatory policies specified in various Federal and state laws.[1/]

[1/] Pertinent Federal laws include the River and Harbor Act; Federal Water Pollution Control Act; National Environmental Policy Act; Marine Protection, Research, and Sanctuaries Act; and the Coastal Zone Management Act. Examples of pertinent California state laws include the Porter-Cologne Act; the California Environmental Quality Act; and the Coastal Zone Act.

The specific requirements of the Federal laws (and the complicated regulatory procedures for implementing them) generally are set forth as detailed regulations and guidelines published in the Federal Register (USACE, 1975c; Smith, 1976). At the state level (in California, for example), the detailed regulations are issued by the appropriate regulatory boards and commissions. Generally, the pertinent regulatory procedures require issuance of permits for specific acts such as dredging, discharge of dredged material, placement of fill, etc.

PRIMARY CONTROL

Primary regulatory control of dredging projects is the responsibility of the Federal government. This responsibility is vested in the Secretary of the Army and is exercized by the Corps of Engineers.

Federal regulatory control of dredging, construction, and related actions in U.S. navigable waters dates back more than 75 years. The River and Harbor Act of 1899 requires that a "Work in Navigable Waters" permit be obtained from the Department of the Army, Corps of Engineers, for virtually all structures or work in navigable waters of the United States. More recently, Corps and EPA regulations (33CFR and 40CFR) require a "Dredged Material Permit" for discharge of dredged material into the territorial sea.

SECONDARY CONTROLS

Additional, secondary or quasi-regulatory controls on dredging projects are exercized by environmental and conservation agencies and organizations as they function in a review capacity during the permit application processing procedure (see Smith, 1976, Figure 2). For example, Corps of Engineers "Work in Navigable Waters" and "Dredged Material" permit application processing procedures for a dredging permit provide for review of a permit application and supporting certifications by as many as two dozen Federal, state, county, and municipal agencies, and perhaps a dozen or more citizen interest groups (Smith and Graham, 1976).

HOW ENVIRONMENTAL CONSIDERATIONS FUNCTION AS CONSTRAINTS

During the review process, these agencies and/or citizen groups may oppose part or all of a given project at one or more of the several check points in the Corps' permit review procedure (USACE, 1974; Smith, 1975, 1976), with resulting costly delays and possible project modification or even cancellation. When issues cannot be resolved, opposing sides commonly invoke local, state, and Federal political pressures and, in some cases, resort to litigation.

The following abbreviated case history of the San Diego Harbor Navigation Improvement Project is a near-classic, real world example illustrating: (a) how environmental considerations functioned as constraints on a major dredging project, and (b) the effects these constraints had on project schedule and cost.

SAN DIEGO HARBOR NAVIGATION IMPROVEMENT PROJECT

As described in detail in the Corps of Engineers' General Design Memorandum (USACE, 1975a), the San Diego Harbor Navigation Improvement Project will widen, deepen, and extend existing channels to allow larger and deeper draft vessels to use the present commercial facilities in the harbor. More specifically, these jointly funded improvements (Federal: 95.9 percent; local, 4.1 percent) will involve cutterhead hydraulic suction dredging of more than 5.5 million m^3, and clamshell dredging of about 765,000 m^3. The hydraulically dredged material will be delivered via pipeline to various disposal sites discussed below; the mechanically dredged material will be barged to an EPA approved ocean disposal site.

The project as originally proposed involved dredging about 9 million m^3 of material and, when authorized by Congress, was estimated to cost about $8 to 10 million, with work to commence in 1972. However, a series of institutional constraints (primarily of an environmental nature) caused substantial changes in the project design and a three year delay in schedule.

When finally approved in 1975, the project had been reduced in size to about 6.5 million m^3 and the estimated cost had escalated to about $16.3 million. When the contract was awarded in August 1975, the actual price was $18.7 million.

CHANGES AND DELAYS OWING TO INSTITUTIONAL CONSTRAINTS

The principal changes in the project and the specific institutional constraints that were largely responsible for the changes and associated delays are discussed in detail in Smith and Graham (1976). A brief synopsis of that discussion follows.

During development of the General Design Memorandum (from July 1970 to December 1974), the Corps had more than 48 meetings (including a formal Public Hearing) with 17 Federal, state, and local agencies to ensure that the concerns of each were considered fairly in the final design. In addition, some 26 letters of comment on the General Design Memorandum were received from Federal, state, and local agencies and firms between January 1972 and January 1975; it is noteworthy that all but four of these addressed disposal of dredged material.

In the course of this protracted interaction between the Corps and various agencies and public interest groups, institutional constraints (primarily, conservation agencies acting to protect environmental resources they believed to be threatened by disposal of dredged material) were responsible for: (a) substantial modifications in the dredged material disposal plan, (b) elimination of most associated landfill sub-projects, and (c) delay in project approval of about three years. Specifically, the proposed southerly incremental extension of the channel was shortened by about 40 percent, the volume of the project was reduced by almost 30 percent, and major changes were made in the dredged material disposal plan, including: (1) deletion of a series of nearby, low cost landfill disposal sites for dredged material, (2) addition of several distant sites requiring high pumping costs, and (3) costly ocean disposal of about three-quarters of a million m^3 originally scheduled for bay marginal disposal sites.

Because of escalation in dredging costs during this three year period, and the added costs in meeting environmental restrictions, the eventual \$18.7 million contract cost was almost \$8 million higher than the estimated cost of \$10.9 million at the time the project was initially funded in 1973. According to Ackerman (1975), about \$5 million of the cost increase resulted from: (a) institutionally imposed environmental restrictions, and (b) the escalation in dredging costs during the time required to work through the institutional constraints just discussed.

In summary, the San Diego Harbor Navigation Improvement Project illustrates clearly how environmental constraints can lengthen the authorization process, modify project design, and substantially increase design and construction costs.

EPILOGUE

As detailed in this paper, San Diego Bay has been heavily stressed since the 1870's as a result of several types of man's activities. Although quantitative data on the bay's response to these stresses is limited, the historical record is clear on the following past impacts: fresh water and natural sediment input to the bay were all but terminated as a result of river diversion and damming; the bay's physical characteristics were significantly altered by massive dredging and filling; sewage and other waste discharges adversely affected water quality and biological communities; and what once was a natural, pristine aquatic environment has been significantly altered and modified as a major metropolitan population has grown up around it.

Although the question of which stress (or stresses) was most significant cannot be determined scientifically owing to incomplete data, it appears from the available data that in the long term, the most adverse impacts to the bay resulted from sewage and other discharges, which caused a reduction in water quality and consequent deterioration in the biological health of the bay; these discharges have since been terminated or substantially reduced.

In light of the magnitude of these stresses and the lengthy period during which they occurred, contemporary dredging activities per se would not appear to be the cause for a high level of environmental protest. As shown in the case history, however, significant delays were involved during the review and approval process of the proposed dredging project as a result of public concern for the bay environment. Associated project costs skyrocketed. Was this delay and associated increase in cost justified? In some respects, probably; in others, probably not. What seems clear is that the project was not reviewed within the perspective of the previous hundred year period of man-induced impacts. Nor were the projected results of project completion evaluated in terms of terrestrial projects of equivalent magnitude.

It is the writers' belief that much of the objection to this dredging project, and undoubtedly to other dredging projects elsewhere in the country, stem from a fear of the unknown and lack of historical perspective on the part of the layman.

ACKNOWLEDGMENTS

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REFERENCES

Ackerman, Samuel M., 1975, Personal communication regarding project costs attributable to environmental restrictions. Los Angeles District, Corps of Engineers, Dec. 2.

Boerger, Frank C. and Michael H. Cheney, 1976, Economic impact of dredging regulations. In Krenkel, P. A. et al., eds., Dredging and its Environmental Effects, p. 408-417, Amer. Soc. Civil Engineers.

Browning, B. M., J. W. Speth, and W. Gayman, 1973, The natural resources of San Diego Bay, their status and future. Calif. Dept. Fish and Game, 105 p.

California Regional Water Quality Control Board-San Diego Region, 1966, Water quality control policy, San Diego Bay. As cited in Corps of Engineers, Los Angeles District, Draft Environmental Statement, San Diego Harbor, San Diego County, California, March, 72 p.

California Regional Water Quality Control Board-San Diego Region, 1972, Staff report on wastes associated with ship-building and repair facilities in San Diego Bay. June. 46 p.

California Water Resources Control Board, 1970, Policy regarding the control of temperature in the coastal and interstate waters and enclosed bays and estuaries of California. State of California.

California Water Resources Control Board, 1976, California waterscape, v. vii, n. 3, July.

Dodson, Roy E., 1972, Clean up of San Diego Bay. Civil Engineering-ASCE, March, p. 62-63.

Environmental Engineering Laboratory, 1972, A study of the effects of water discharge to South San Diego Bay from the Clair Engle Desalting Plant. Tech. Rpt. for Office of Saline Water, SD-9-73, Oct., 60 p.

Environmental Protection Agency, 1974, Guidelines for the control of shipyard pollutants, Draft report to San Diego Regional Water Quality Control Bd. Nat'l. Field Investigation Ctr., Denver, July 1.

Federal Water Pollution Control Administration, 1969, Vessel pollution study - San Diego Bay, California. Dept. of Interior, FWPCA Pac. SW Region, 66 p.

Ford, Richard F., 1968, Marine organisms of South San Diego Bay and the ecological effects of power station cooling water discharge. Environmental Engineering Lab., Tech. Rpt. C-188, for San Diego Gas & Electric Co., 278 p.

Ford, R. F., R. L. Chambers, and J. Merino, 1970, Ecological effects of power station cooling water discharge in South San Diego Bay during August 1970. Environmental Engineering Lab., for San Diego Gas & Electric Co.

Ford, R. F., R. L. Chambers, and J. Merino, 1971, Ecological effects of power station cooling water discharge in South San Diego Bay during February-March 1971. Environmental Engineering Lab., for San Diego Gas & Electric Co., 92 p.

Ford R. F., R. L. Chambers, and J. Merino, 1972, Ecological effects of power station cooling water discharge in South San Diego Bay during August 1971. Environmental Engineering Lab., for San Diego Gas & Electric Co., 50 p.

Ford, R. F. and R. L. Chambers, 1973, Biological studies at the South Bay Power Plant during the period September 1972-April 1973. Final Report, v. 5A, Biological measurements, May. Environmental Engineering Lab., for San Diego Gas & Electric Co., 188 p.

Ford, R. F. and R. L. Chambers, 1974, Biological studies at the South Bay Power Plant during the period September 1972-July 1973. Final report, v. 5C, Biological studies, Aug. Environmental Engineering Lab., for San Diego Gas & Electric Co., 189 p.

Gautier, Roland G., 1972, Natural physical factors of the San Diego Bay tidelands. Part of Master Plan revision program, San Diego Unified Port District, Planning Dept., Jan., 88 p.

Mudie, Peta J., 1970, A survey of the coastal wetland vegetation of San Diego Bay. For Calif. Dept. Fish and Game, contract no. W26 D25-51, June.

Newman, William A., 1958, Sedimentary and biological characteristics of San Diego Bay floor in 1958. State of Calif. Water Pollution Control Bd. 1957-58 Standard Agreement No. 12D-19; with Marine Advisers, Sept., 38 p.

Parrish, L. P. and K. M. Mackenthun, 1968, San Diego Bay, an evaluation of the benthic environment, October, 1968. U.S. Dept. of Interior, FWPCA, Cincinnati, 22p. and appendices.

Peeling, Thomas J., 1974, A proximate biological survey of San Diego Bay, California. Naval Undersea Ctr., Rpt. No. NUC TP 389, June, 83 p.

Rambo, Charles E. and William C. Speidel, 1969, A case study of estuarine sedimentation in Mission Bay-San Diego Bay, California. For Dept. of Interior, FWPCA, Contract No. 14-12-425 by Marine Advisers, La Jolla, CA, Feb., 58 p.

San Diego Regional Water Pollution Control Board, 1952, Extent, effects and limitations of waste disposal into San Diego Bay. State of Calif., San Diego, CA, 95 p.

Sartor, James D. and Gail B. Boyd, 1972, Water pollution aspects of street surface contaminants. U.S. Environmental Protection Agency Office of Research and Monitoring, EPA-R2-72-081, Nov.

Smith, David D., 1975, Disposal of dredged material - a key environmental consideration in the construction of major nearshore and coastal marine facilities. ASME Winter Annual Mtg., Houston, Nov. 30-Dec. 4, 8 p.

Smith, David D., 1976, New Federal regulations for dredged and fill material. Environmental Science & Technology, April, v. 10, p. 328-333.

Smith, David D., 1977, Dredging and spoil disposal - major geological processes in San Diego Bay, California. In Wiley, M., ed., Estuarine Processes, v. II, p. 150-166, Academic Press, N.Y.

Smith, David D. and Michael W. Wright, 1975, Environmental impact report for the Chula Vista boat basin/wildlife reserve. For San Diego Unified Port District, Nov., 117 p.

Smith, David D. and Katherine F. Graham, 1976, The effect of institutional constraints on dredging projects: San Diego Bay, a case history. In Dredging: Environmental Effects and Technology. Proc. WODCON VII, San Pedro, CA. p. 119-141.

U.S. Army Corps of Engineers, 1974, Applications for Department of the Army permits for activities in waterways. Office of the Chief of Engineers, EP-1145-2-1, Oct., 26 p.

U.S. Army Corps of Engineers, 1975a, General design memorandum for San Diego Harbor, San Diego County, California. Los Angeles District, Feb., 80 p. and appendices.

U.S. Army Corps of Engineers, 1975b, Final environmental statement, San Diego Harbor, San Diego County, California. Los Angeles District, Feb., 84 p. and appendices.

U.S. Army Corps of Engineers, 1975c, Navigable waters procedures and guidelines for disposal of dredged or fill material. Fed. Reg. v. 40, n. 88, part II, May 6, p. 19766-19794.

Wagner, Dennis, 1976, San Diego Bay: a long battle up from pollution. Coronado Journal, Dec.

Whipple, William, Jr., ed., 1975, Urbanization and Water Quality Control. Amer. Wtr. Resources Assoc., Minneapolis.

IMPACT OF DREDGING IN THE TAMPA BAY ESTUARY, 1876-1976

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ABSTRACT

Tampa Bay is an estuary located on the west coast of Florida. One-sixth of the state's population lives in the three counties bordering its shores.

During the last 100 years four major types of dredging have impacted the bay: channel deepening, maintenance dredging, shell dredging, and dredging for landfill construction. These impacts range from the economic benefit provided by channel and port construction for what is now the eighth largest port in the nation to the environmental damage caused by dredging to create over 5,000 ha of landfill in the bay for residential, commercial, and dredged material disposal use. These landfills have resulted in the loss of 44% of the original marine wetlands bordering Tampa Bay.

Recent environmental concerns have halted landfill dredging and severely restricted maintenance dredging. Research on shell dredging in the bay indicate minimal impact if carefully controlled. New channel deepening and open water disposal of 55,000,000 m^3 of dredged material is planned as part of the Tampa Harbor Deepening Project, now in progress. This project has undergone intensive review and modification as a result of environmental concern by both citizens and scientists.

During the 1960s, the population of Florida increased 37% from 4.9 million to 6.8 million, while the United States as a whole showed only a 13% increase. Three out of four of these new residents migrated from other states. The 1976 population is estimated to be 8.7 million with 74% of this number living on 28% of the land area, the coastal zone (Division of State Planning, 1976). Of the 40 estuarine study areas examined by McNulty et al. (1972) Tampa Bay is second only to the Florida Bay system in size (Fig. 1). One-sixth of the state's population lives in the three counties bordering the bay, Hillsborough, Pinellas, and Manatee.

Tampa Bay is divided into six sub-areas (Fig. 2): Old Tampa Bay, Hillsborough Bay, Upper Tampa Bay Proper, Lower Tampa Bay Proper, Boca Ciega Bay, and Terra Ceia Bay. Representative physical and chemical parameters for these sub-areas are also given in Figure 2. Olson and Morrill (1955), using as a basis a 1943 chart, determined the total area of the bay to be 90,500 ha with a shoreline of 320 km. As noted by Simon (1974) alterations to the bay since that time have made these figures obsolete. For example Olson and Morrill (1955) list the shoreline of Boca Ciega Bay as 42.3 km while Simon (1974) using a 1971 chart found it to be 199.6 km. The author is presently updating the work of Olson and Morrill (1955) using 1976 charts. These same authors noted

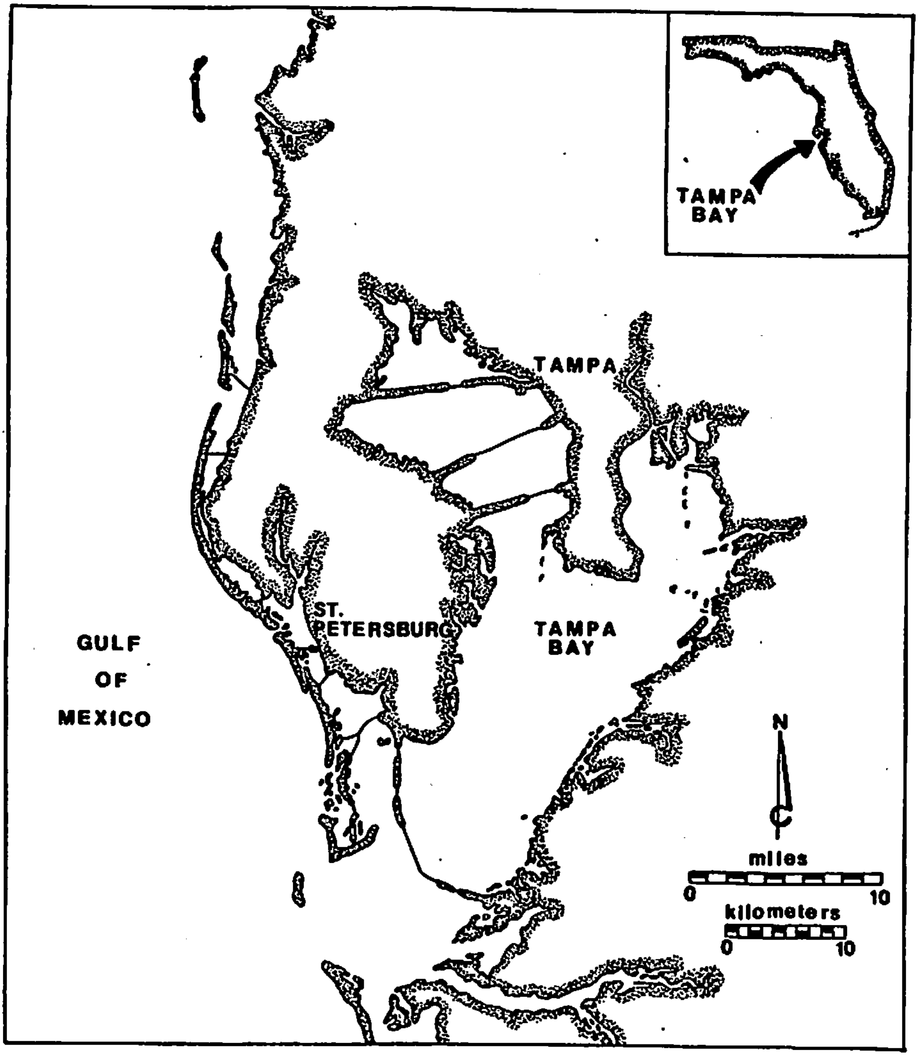

Figure 1. The Tampa Bay Estuary, Florida.

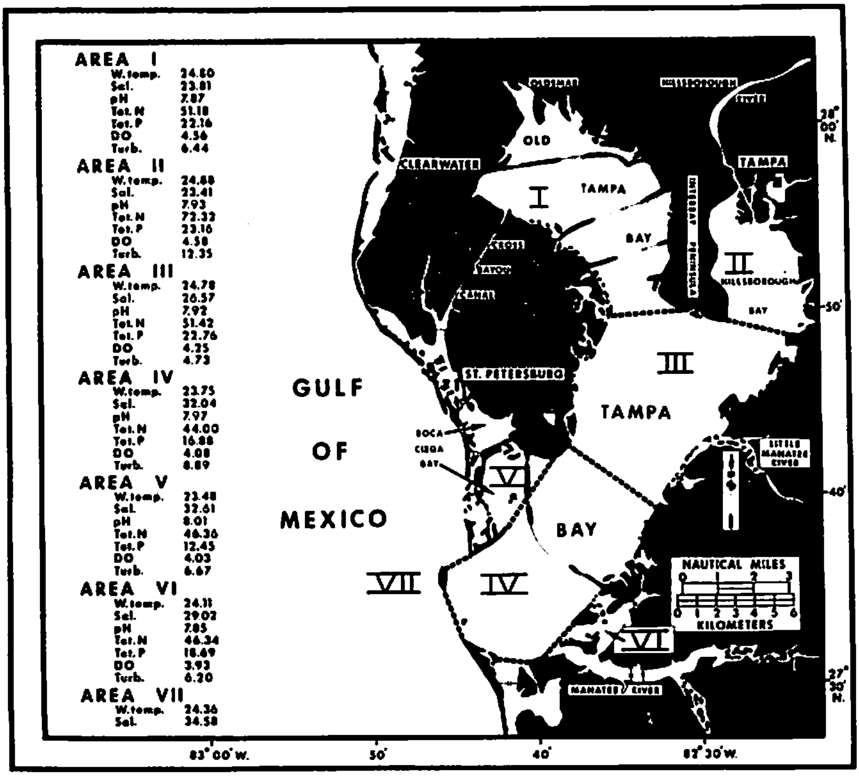

Figure 2. Hydrographic measurements for different areas of Tampa Bay and adjacent waters of the Gulf of Mexico, January 1965 through August 1967. Water temperature, °C; salinity, p.p.t.; pH; total nitrogen, μg at/l; total phosphorus, μg at/l; dissolved oxygen, ml/l; turbidity, J.T.U. (Original map slightly modified from Bureau of Commercial Fisheries Circular 313, 1969).

that "Tampa Bay may readily be classed as a shallow body of water since the modal depth is but 9.7 ft and 90% of its area has a depth less than 22 ft" (9.7 ft = 3.0 m, 22 ft = 6.7 m).

The subtropical climate of the Tampa Bay area supports both tropical mangrove forests and temperate tidal marshes along the shores of the estuary. Latest measurements, made with the assistance of the U.S. Geological Survey, Tampa office, show 5,630 ha of these intertidal marine communities remaining in the bay. This represents a 44% decline from those present in 1876 (Lewis, unpublished). The value of these communities in the production of detritus and their role in marine productivity in south Florida estuaries has been well documented by Heald (1971), Odum (1971), and Odum and Heald (1972). Submerged vegetation in the estuary consists of five species of seagrasses and 216 species of algae. Taylor (1971) estimated 8,500 ha of bay bottom was vegetated by seagrasses and conspicuous benthic algae.

Sykes and Finucane (1966) report twenty-three species of major importance in Gulf of Mexico commercial fisheries occur in Tampa Bay during immaturity. Old Tampa Bay harbored greater numbers of these species than any other area. Hillsborough Bay, similar in salinity regime, harbored fewer important species than any other area.

The reader is referred to Olson and Morrill (1955), Taylor (1973), and Simon (1974) for complete literature reviews and detailed discussions on the present status of the estuary.

During the last 100 years four major types of dredging have impacted the bay: channel deepening, maintenance dredging, shell dredging, and dredging for landfill.

Channel Deepening

Tampa Bay has provided protected anchorage for ships since the 16th century, including vessels carrying Ponce de Leon and Hernando de Soto (Lohse et al., 1969). The shallow depths were sufficient until the drafts of vessels had increased and deeper channels than naturally existed were necessary. Since dredging first began in Tampa Bay in 1880, 107 km of channels have been created (Taylor, 1973). The material dredged from these channels has been placed adjacent to the channels as submerged or emergent spoil areas (Fig. 3), or used as landfill for shoreline development (Fig. 4, 5, 6, 7). As can be seen in these photographs this type of dredging has produced large turbidity plumes from uncontrolled overflow in spoil areas and cutterhead disturbance of the sediments. Illegal filling of submerged land (under the jurisdiction of the State of Florida) occurred routinely in the 1960s and penalties were minimal. Often the illegally filled land was sold to the dredging company after filling and resold at a good profit far in excess of the fine or cost of dredging. The filling of Redfish Creek in Lower Tampa Bay in 1969 (Fig. 4) is an example where the land was filled

Figure 3. Dredging at Port Manatee, Lower Tampa Bay, September, 1968. The dredge and the channel it is cutting can be seen at the arrow. The diked port area and the undisturbed Redfish Creek mangrove forest (upper right corner) are at the top of the picture.

without permits and the fill left in place instead of being ordered removed. The area is still severely damaged in 1976 and it is unlikely it will ever recover. This blatant disregard for dredge and fill permit procedures has finally led to more recent illegal fills being ordered removed at the expense of the dredger. This kind of enforcement has significantly reduced the incidence of illegal filling in Tampa Bay.

Sherk (1971) has discussed in detail the effects of suspended and deposited sediments on estuarine organisms. These include loss of habitat, decrease in euphotic zone depth, (increased) oxygen demand, nutrient sorption and release, (decreased) primary productivity, benthic community disruption, direct mortality and other gross effects. The reader is referred to this source for more detailed information. Unfortunately, little research has been done on the effects of channel dredging and spoil disposal in Tampa Bay. Complete and permanent destruction of benthic communities and intertidal marshes and mangrove forests is an obvious result (Fig. 3, 4, and 5). Most of the effects discussed by Sherk (1971) are less obvious and little studied. Taylor (1973) describes five sediment groups for Tampa Bay: deep ship channel, soft spoil, firm spoil, soft undredged, and firm undredged. The firm bottoms supported the largest number of individuals and species while the ship channel supported the least. Results from shell dredging

Figure 4. Dredging at Port Manatee, Lower Tampa Bay, June 1970. The channel creation and filling for the port is complete. Excess fill has been placed in the Redfish Creek mangrove forest, totally destroying it, and additional fill can be seen smothering the offshore seagrass meadows. No permits were issued for this work.

research (discussed later) indicate rapid recovery of benthic communities disturbed by small, target specific dredging projects. Some recovery in some older submerged spoil disposal sites is evident from the data of Taylor (1973). How long this took is not known. Recovery of disturbed seagrass meadows is extremely slow after dredging (Godcharles, 1971) or even motor boat prop damage (Zieman, 1976). No complete survey of the area occupied by seagrass meadows in Tampa Bay has ever been made, thus it is impossible to determine at the present time what damage has been done to this valuable habitat. The work of Taylor and Saloman (1968) in Boca Ciega Bay assumed a standing crop of 798 kg/ha (dry weight) of seagrasses over the total fill area of 1, 400 ha, even though some of the filled areas were bare. This was felt to be a reasonable compromise since actual measurements of the area of seagrass meadows lost was probably not feasible.

An additional problem of open water spoil disposal from channel deepening is the possible impedance of normal circulation in Tampa Bay. In a report prepared by the Federal Water Pollution Control Administration on water quality problems in Hillsborough Bay (F.W.P.C.A., 1969) the following recommendation was made:

Figure 5. Port Manatee, Lower Tampa Bay, November 1972. Arrows indicate the extent of smothered seagrass meadows offshore of the filled area that was previously Redfish Creek.

> A master plan for dredging and filling in Hillsborough Bay should be developed by the pertinent federal, state, and local operating and regulatory agencies. Certain spoil islands, resulting from channel dredging, which impair circulation, flushing and exchange in the Bay, should be removed and maintenance spoil dredging material should not be deposited in the Bay.

This recommendation resulted from dye tracer studies in conjunction with studies on the impact of sewage pollution in Hillsborough Bay, where most of the impeded circulation problems were believed to exist. This recommendation was endorsed by the U.S. Army Corps of Engineers (1970) in planning for the Tampa Harbor Deepening Project and a study was undertaken by the U.S. Geological Survey jointly funded by the Tampa Port Authority and the Corps of Engineers. The study included water quality sampling, gathering and analysis of current and tidal data, and use of a hydrodynamic digital computer model of the bay. Goodwin (1976) reports the results of five model runs (historical, existing, and three proposed modifications as part of the Harbor Deepening Project) as follows:

> Analysis of model results for simulation of channel improvement plans tested indicate that significant modification to the existing circulation pattern in Hillsborough Bay is

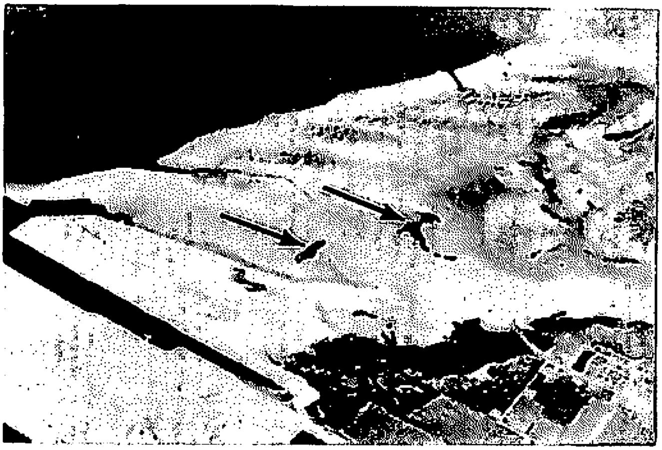

Figure 6. Channel dredging and filling to create Port Redwing in Hillsborough Bay, 1968. The fill site is incompletely diked and silt has spilled out and surrounded two Audubon Society Sanctuary Islands (arrows) and smothered submerged vegetation.

> possible. These analyses indicate that each improvement plan has desirable circulation features, but none provides a significantly improved flushing link between Hillsborough and Tampa Bays. Since little interchange existed between the two bays under natural conditions, the potential for significant circulation improvement is probably small for any spoil-island configuration.

Thus the conclusion that historical patterns of spoil deposition have impeded natural circulation is <u>not supported</u> by the U.S. Geological Survey, and while some improvement in circulation <u>within</u> Hillsborough Bay is possible, improved flushing from this highly industrialized portion of the bay is not felt possible. It should be noted that these conclusions are questioned by some scientists including those involved with a second computer model of the bay in operation at the University of South Florida. Further data gathering during the postdredging phase of the Harbor Deepening Project will hopefully resolve this question. Present plans for the project, which has been started, include dredging of "circulation cuts" through submerged spoil banks to improve internal circulation in Hillsborough Bay (Fig. 8). The entire project is scheduled to be completed in 1982 at a cost of $120 million. A total of 55,000,000 m^3 of material will be dredged to widen and deepen the main

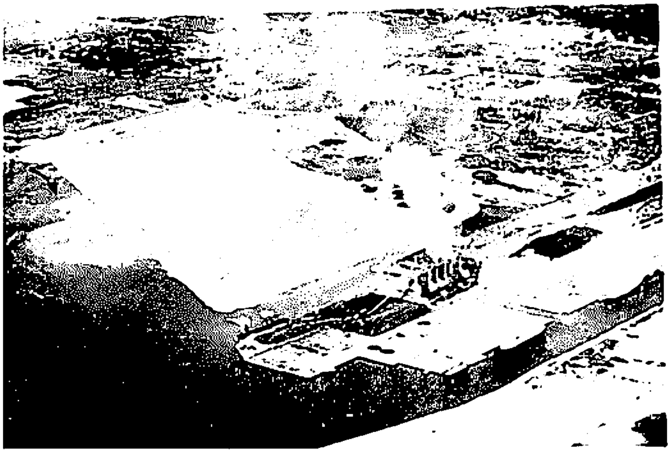

Figure 7. Deepening of East Bay (Upper Hillsborough Bay), September 1967. Material dredged was used to fill in submerged land and mangroves for a phosphate loading port facility.

ship channel from 10 to 13 m (existing depth 34 ft, finished depth 44 ft). There have been a number of revisions to the planned spoil disposal plan due to concern raised by scientists and lay citizens. All the spoil material is planned for open water disposal in the bay and an extensive monitoring program is planned in order to avoid the siltation problems previously seen in this kind of dredging (e.g., Fig. 3). In addition diked disposal areas will be created in Hillsborough Bay in order to contain much of the Harbor Deepening spoil and future maintenance spoil (see following section).

One of the unique features of the spoil disposal plan for Hillsbotough Bay (Fig. 8) is the creation of emergent recreation and wildlife islands. Their design is based on the work of Lewis and Dunstan (1975) on use of spoil islands by colonial seabirds in the Tampa area for nesting. Two islands located at the mouth of the Alafia River in Hillsborough Bay (Fig. 9) support large nesting colonies of seabirds including Brown Pelicans and White Ibis (Fig. 10a). In addition two species previously only occasionally observed in the Tampa Bay area have recently nested on these islands. Paul, Meyerriecks, and Dunstan (1975) report the Reddish Egret, rare in Florida since 1900, nesting on Bird Island in May 1974. The Roseate Spoonbill, last seen nesting in Tampa Bay in 1912, was reported nesting on Bird Island in April 1975 (Dunstan, 1976) (Fig. 10b). Part of the reason for the recent intensive use of these islands lies in the massive alteration to the submerged bottoms and feeding areas surrounding the traditional nesting sites by

TAMPA HARBOR, FLORIDA
MAIN CHANNEL
SECTIONS 4 and 5
PLAN

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

TO ACCOMPANY GENERAL DESIGN MEMORANDUM- PHASE II

FEBRUARY 1975 File No: 45-31,940

EMERGENT MAINTENANCE DISPOSAL AREA

RECREATION AND WILDLIFE ISLANDS

CIRCULATION CUT(-15'MLW DEPTH x 1500' WIDE)

10,000 0 10,000
SCALE IN FEET

Legend for Figure 8.

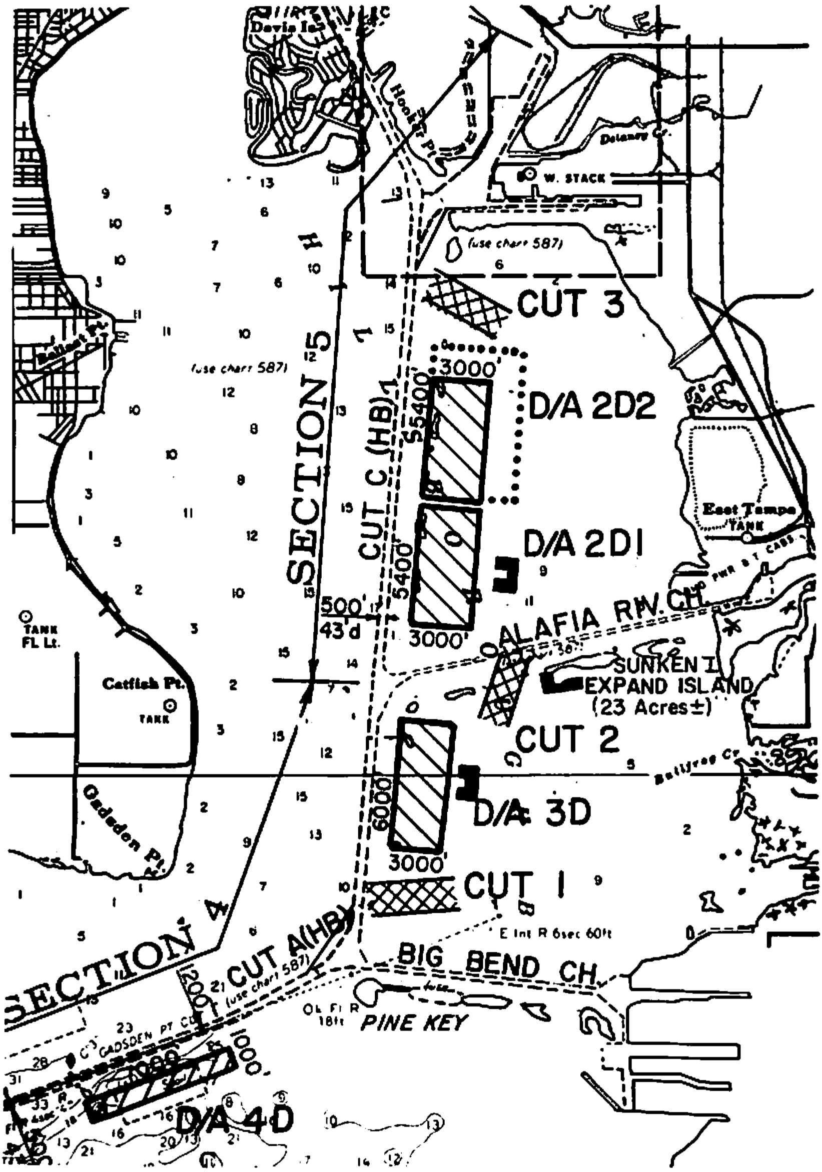

Figure 8. Proposed spoil disposal plan, Hillsborough Bay.

Figure 9. Two spoil islands at the mouth of the Alafia River, Hillsborough Bay. The upper island (Sunken Island) was created in 1961 and the lower island (Bird Island) was created in 1931. Sixteen thousand pairs of birds nest here annually.

dredging in 1966-67 (Fig. 7) and the loss of shoreline habitat to dredging and filling. It is hoped that the creation of islands from dredged material and properly planting them with native vegetation will provide additional habitat for colonial seabirds in Tampa Bay.

Finally it should be noted that the economic impact of channel deepening on the surrounding communities has been enormous. Cargo now being handled at the port is in excess of 42 million tons per year. This is an increase from 3,945,000 tons in 1940 and 25,898,000 tons in 1967. The port is the eighth largest in the nation with principal exports of phosphate and phosphatic products and imports of petroleum products, sulphur, and meats (Corps of Engineers, 1974). It has been estimated that the port provides jobs for some 36,000 wage earners with an annual salary of $210 million. The port is obviously an important part of the local economy and it is hoped that additional channel deepening to maintain the port can be accomplished with much more care and concern for the natural environment.

Maintenance Dredging

Once channels are deepened they must be maintained through dredging. Natural sediment inputs as well as man induced sediment input (e.g., sewage,

Figure 10a. White Ibis (Endocimus albus) photographed in their nesting colony on Sunken Island, April 1975.

Figure 10b. Roseate Spoonbill (Ajaia ajaja) nesting in a black mangrove tree (Avicennia germinans) on Bird Island, April 29, 1975. (From a slide taken by Helen Cruickshank for the National Audubon Society.)

runoff) gradually fill in these channels. Boyd et al. (1972) estimate the annual quantity of maintenance dredged material in the United States is 229 million m^3 as opposed to 61 million m^3 in new dredging. Historically large channel maintenance projects in Tampa Bay have been done with hydraulic dredges and open water disposal in spoil areas in the bay. Smaller berth maintenance projects were done with clamshell dredges mounted on a barge, again with open water disposal (Fig. 11). Recent concerns about water quality degradation from open water spoil disposal, particularly of contaminated spoil, led to the complete halt of open water spoiling in Tampa Bay at the end of 1973. Since then all maintenance dredging projects have been required to provide diked upland disposal areas (Fig. 12). The effectiveness of this requirement in reducing "pollution" from the maintenance material is widely argued (see U.S. Army Corps of Engineers, 1976, for update and list of available Dredged Material Research Program reports). The use of these upland disposal sites has increased the cost of maintenance dredging from \$1-2/m^3 to \$3-5/m^3 (Guy N. Verger, personal communication). In addition upland sites are scarce and valuable upland habitat or farmland may be permanently destroyed. Salt water intrusion into fresh water aquifers has also been a problem in the Tampa area. One problem solved by this procedure is the reduction in erosion of spoil back into the same channel from which it was dredged. The Corps of Engineers has decided that the long term solution to the problem is the creation of large (1.6 km x 0.8 km) emergent diked disposal areas within Hillsborough Bay as part of the Tampa Harbor Deepening Project (Fig. 8).

Figure 11. Open water disposal of maintenance spoil from berths in Hillsborough Bay into submerged spoil area behind an existing spoil island, December 1973.

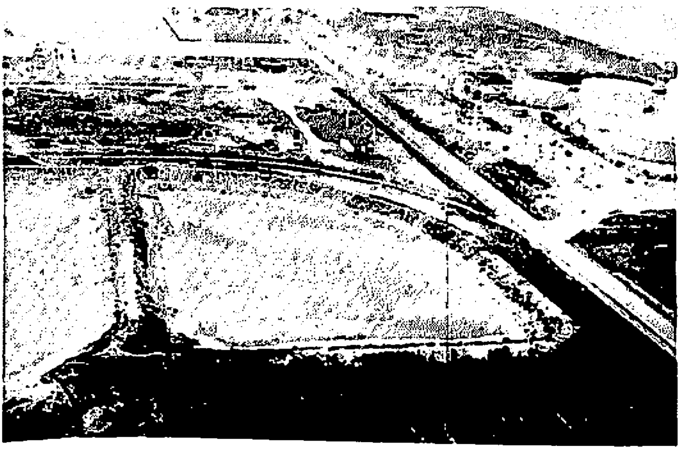

Figure 12. Diked upland disposal site for maintenance dredged material at Port Manatee, October 1976.

Maintenance dredged material will be hydraulically pumped into these diked areas and they are planned to hold the amounts of material to be generated over the next 30 years. The long term containment of much of the contaminated spoil in the upper harbor (due to sewage discharged from the City of Tampa sewer plant - 40 MGD - presently only primary treatment) is expected to improve the long term water quality picture for Hillsborough Bay. Whether this will offset the loss of benthic habitat due to the creation of the disposal sites is impossible to determine at this time.

Shell Dredging

The dredge mining of dead oyster shell from Tampa Bay has taken place since 1946. Nearly 18 million tons of shell has been removed since operations first began (Taylor, 1972). The process involves removal of the shell and associated sediment by hydraulic cutterhead dredge, sorting over screens, and return of water and fines to the bay (Fig. 13). The silt plume associated with this unused material has been of major concern to regulatory agencies and the boating public. In addition concern has been raised about the destruction of benthic organisms and the long term modification of the biological communities in the dredged areas.

A recently completed long term effects study (Simon, Doyle, and Connors, 1976) has reached the following conclusions:

Figure 13. Shell dredging in Hillsborough Bay, October 1972.

1. Total suspended load within the plume raised by shell dredging ranged from about 20 mg/l to over 50 mg/l, close to background to about one and one half times ambient.

2. Light penetration within the dredge plume varied from 100% transmission to a low of about 10% transmission over a 1 meter light path. Most measurements within the plume were over 80% transmission. Both suspended load and percent transmission indicated that the highest suspended loads usually occurred near the bottom.

3. Biologically, the area disturbed by shell dredging returned to the same species assemblage, had the same number of species, the same density patterns, and the same or slightly lower biomass than undisturbed bay bottom within less than 12 months.

As noted by the authors their results are very similar to those of previous workers in Tampa Bay on shorter term studies and to those of researchers in San Antonio Bay and Mobile Bay. In relation to other dredging in the bay, however, the report cautions:

> ...it must not be assumed that the massive Corps of Engineers project to deepen the Tampa Harbor shipping channels can in any way be compared to the effects of a small, tightly controlled, target specific shell dredging operation. Large amounts of fine material which may be thrown up by several large dredges operating simultaneously could have a serious sedimentation impact on portions of Tampa Bay.

The remaining estimated 15 million tons of shell is presently being mined under strict supervision by state and federal agencies.

Dredging for Landfill

McNulty, Lindall and Sykes (1972) calculated that in 1967 filled areas (including spoil islands, causeways, housing and industrial fill) in the Tampa Bay Estuary totaled 4,266 ha. Nearly all of this was created through dredging submerged or intertidal bay bottom and pumping the spoil into emergent land sites, creating land where there were once mangroves, tidal marshes, or seagrasses. Taylor and Saloman (1968) report the expected impact of the filling of 1,400 ha of bay bottom in Boca Ciega Bay that has occured since 1950 and reduced the total area of the bay by 20%. Their minimum estimates of annual loss of biological resources are 25,841 metric tons of infauna. This represents an annual loss of about $1.4 million. Passavant and Jefferson (1976) have recently rechecked the estimates of filled areas in Boca Ciega Bay and revised the total figure upward to 2,200 ha including some fill on emergent land that was covered and enlarged by dredge materials.

The characteristic "finger fill" type development of Boca Ciega Bay (Fig. 14) and elsewhere in Tampa Bay (Fig. 15) permanently destroys the benthic community and associated vegetation in the fill site and creates a dead end canal system that supports much fewer marine organisms (Sykes and Hall, 1970).

Hillsborough Bay has been greatly modified by dredging, primarily for industrial sites and port facilities, as can be seen in comparing Figures 16 and 17. Figure 16 is redrawn from Coast Chart 177 dated 1879, and shows the existing marine wetlands at that time, 2,378 ha. Figure 17 is redrawn from National Ocean Survey Chart 11412 (1975) and shows 400 ha of wetlands remaining. This represents a total loss of 83.2%. For Tampa Bay as a whole our research indicates a total loss of 44%, from 10,050 ha in 1876 to 5,630 ha in 1976.

What effect has this massive alteration to Hillsborough Bay had? Taylor, Hall, and Saloman (1970) report on the results of sampling for mollusks in Hillsborough Bay in 1963. Their analysis of benthic mollusks and sediments at 45 stations revealed no mollusks at 19 stations, one or more of the four predominant species at 18 stations, and numerous

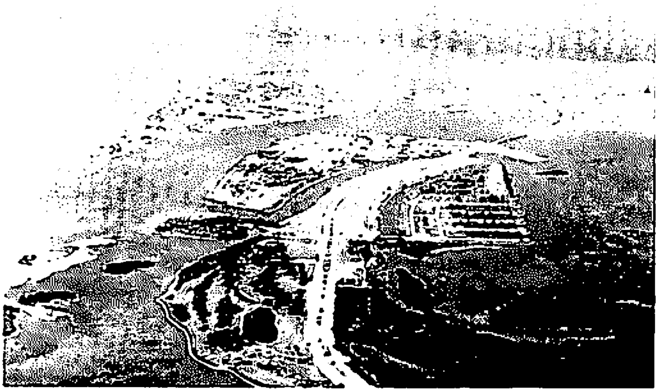

Figure 14. Boca Ciega Bay, September 1976.

Figure 15. The Apollo Beach dredge and fill project in Upper Tampa Bay, August 1969.

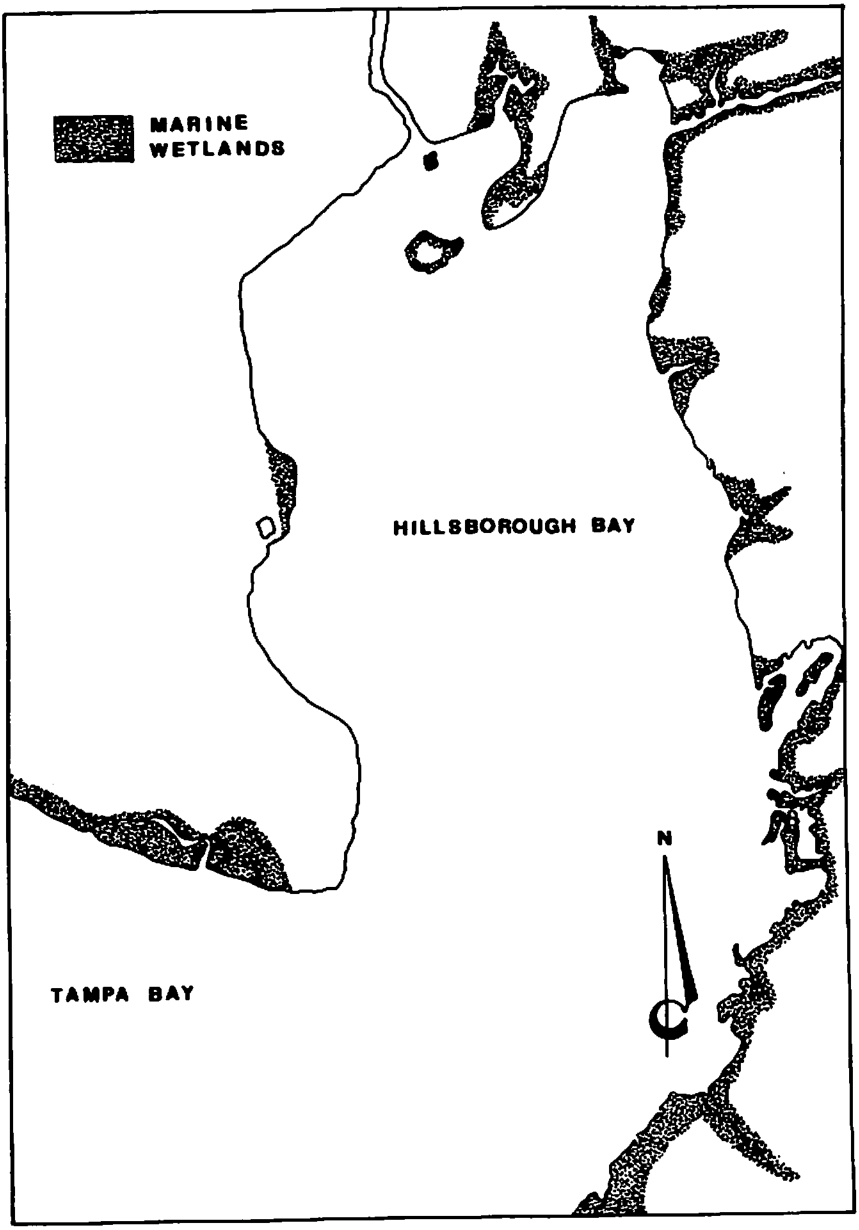

Figure 16. Hillsborough Bay and associated wetlands (2,378 ha) 1876.

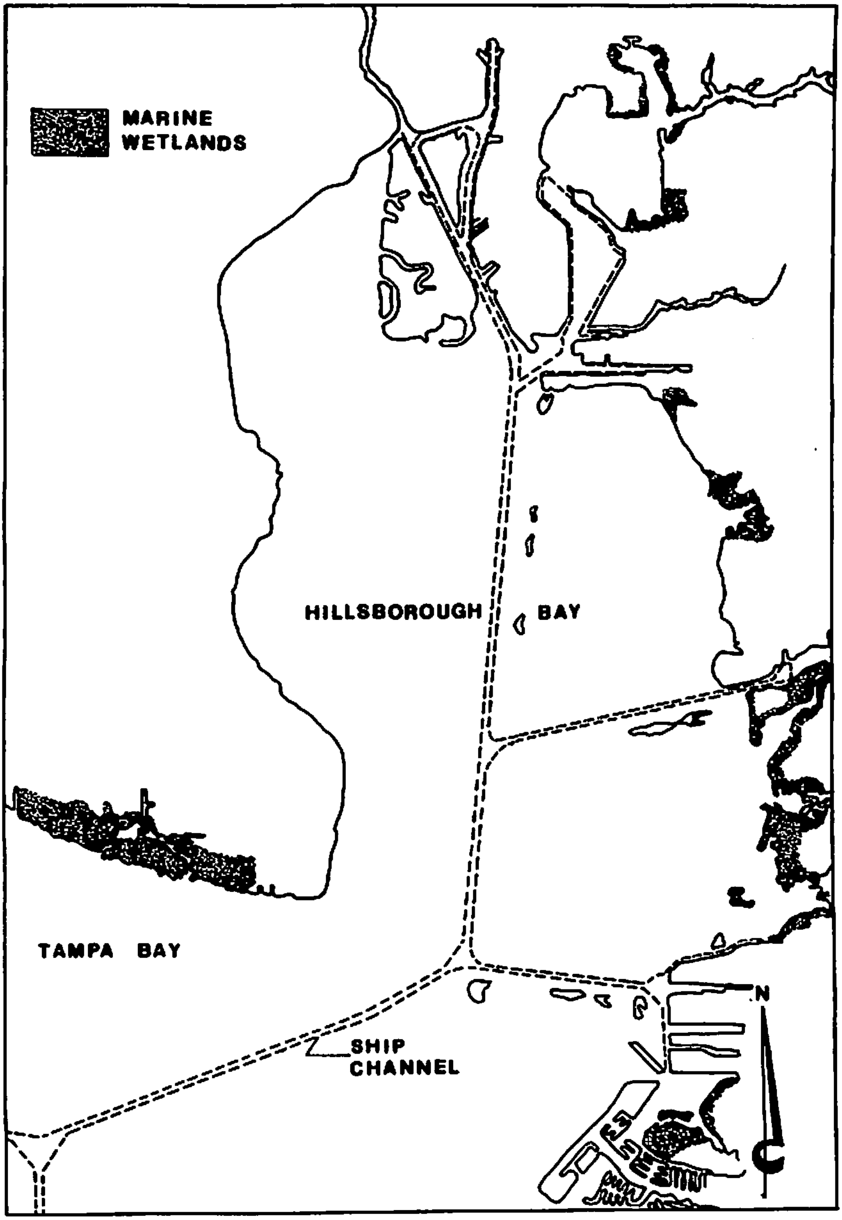

Figure 17. Hillsborough Bay and associated wetlands (400 ha) 1976.

species and large numbers of individuals at only 8 stations. From this information they concluded that 42% of the bay bottom was unhealthy, 36% marginal, and 22% healthy. Since 1963 six of the eight healthy stations have experienced large scale dredging impacts including channel deepening, spoil deposition, and filling of adjacent wetlands. As noted before the work of Sykes and Finucane (1966) has shown that Hillsborough Bay supports much fewer of the commercially important species than any other area of Tampa Bay. It should be pointed out that in addition to dredging sewage pollution has had a significant impact on Hillsborough Bay. Of the estimated 101 MGD of sewage entering Tampa Bay, 47% flows into Hillsborough Bay, most of it poorly treated. A new advanced waste treatment facility is scheduled for completion at Hookers Point (in Hillsborough Bay) in 1977 and will hopefully assist the recovery of this portion of the bay. It is during this same year that the major impact of the Hillsborough Bay portion of the Tampa Harbor Deepening Project (Fig. 8) will begin, and many scientists justifiably wonder how much more Hillsborough Bay can take.

As a result of the loss of wetland habitat and continued pollution in Tampa Bay commercial harvests of marine finfish and shellfish have declined. The figures in Table 1 show the commercial landings and value of Florida Gulf Coast fisheries (Taylor, Feigenbaum, and Stursa, 1973; Florida Department of Natural Resources, 1971; 1972). Although definite conclusions cannot be drawn from these figures there are certain trends that are disturbing. With increasing population and demand for seafood products the available fisheries appear to be declining. Their value at dockside to the fisherman will continue to increase, and so the price to the consumer. The general increase in environmental awareness and the obvious increase in the cost of marine products and their declining numbers convinced commercial fishermen, sports fishermen, and consumer that something had to be done. The result has been increased opposition to the issuance of dredge and fill permits, particularly for projects where water access was not absolutely essential. The recent denial of the Marco Island dredge and fill permit for most of the remainder of the controversial project saved over 80 km of mangrove shoreline from destruction, and represented a turning point for this kind of project. It is unlikely that any further massive dredge and fill such as has occurred in Boca Ciega Bay and Hillsborough Bay will ever be permitted again. With increased attempts to clean up other sources of pollution in estuaries like Tampa Bay it is certainly possible that the decline in catches shown in Table 1 will reverse, although the losses may be so great that catches of 135 million pounds (1960, 1965) may never occur again.

Table 1. Florida Gulf Coast Commercial Marine Landings and Value

YEAR	CATCH (1,000's of lbs)	VALUE ($1,000's)
1950	62,013	9,995
1951	88,271	15,414
1952	101,135	19,254
1953	108,027	25,372
1954	97,521	19,815
1955	105,756	21,190
1956	107,594	24,582
1957	109,275	24,205
1958	126,585	24,258
1959	131,887	18,191
1960	135,535	21,048
1961	125,379	20,303
1962	119,607	24,921
1963	124,683	22,477
1964	129,659	24,165
1965	135,866	26,866
1966	125,975	24,984
1967	114,408	23,118
1968	119,293	27,809
1969	116,500	29,500
1970	116,470	31,222
1971	107,485	31,187
1972	108,201	38,622

lb x 0.453 = kg

LITERATURE CITED

Boyd, M. B., R. T. Saucier, J. W. Keeley, R. L. Montgomery, R. D. Brown, D. B. Mathis, and C. J. Guice. 1972. Disposal of dredge spoil - problem identification and assessment and research program development. Tech. Rep. H-72-8. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 121 pp.

Division of State Planning, State of Florida. 1976. About the state comprehensive plan. DSP-BCP-39-16, 11 pp.

Dunstan, F. M. 1976. Roseate Spoonbill nesting in Tampa Bay, Florida. Fla. Field Nat., 4(2):25-27.

Federal Water Pollution Control Administration. 1969. Problems and management of water quality in Hillsborough Bay, Florida. 88 pp.

Florida Department of Natural Resources. 1971. Summary of Florida commercial marine landings 1971. 64 pp.

Florida Department of Natural Resources. 1972. Summary of Florida commercial marine landings 1972. 62 pp.

Godcharles, M. F. 1971. A study of the effects of a commercial hydraulic clam dredge on benthic communities in estuarine areas. Fla. Dept. Nat. Resources Mar. Res. Lab Tech. Ser. 65, 51 pp.

Goodwin, C. R. 1976. Circulation patterns for historical, existing, and proposed channel configurations in Hillsborough Bay, Florida. Pages 1-42 in Appendix A, U.S. Army Corps of Engineers. Supplement to final environmental impact statement Tampa Harbor project, Florida.

Heald, E. J. 1971. The production of organic detritus in a south Florida estuary. Sea Grant Tech. Bull. No. 6, 110 pp.

Lewis, R. R. and F. M. Dunstan. 1975. Use of spoil islands in re-establishing mangrove communities in Tampa Bay, Florida. Pages 766-775 _in_ G. Walsh et al., eds. Proceedings of the international symposium on biology and management of mangroves. Vol. II. Inst. of Food and Agricultural Sci. University of Florida, Gainesville, Florida.

Lohse, F. A., A. J. Scott, and C. Grant. 1969. Tampa Bay estuarine system - case study. _In_ Gulf Universities Research Consortium. Case studies of estuarine sedimentation and its relation to pollution of the estuarine environment - a report to the FWPCA.

McNulty, J. K., W. N. Lindall, and J. E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study, Florida: Phase I, area description. NOAA Tech. Rep. NMFS Circ. 368, 126 pp.

Odum, W. E. 1971. Pathways of energy flow in a south Florida estuary. Sea Grant Tech. Bull. No. 7, Univ. of Miami, 162 pp.

Odum, W. E. and E. J. Heald. 1972. Trophic analyses of an estuarine mangrove community. Bull. Mar. Sci. 22(3):671-738.

Olson, F. C. W. and J. B. Morrill, Jr. 1955. Literature survey of the Tampa Bay area. U.S. Navy Hydrographic Office, 66 pp.

Passavant, N. and C. A. Jefferson. 1976. Natural reclamation of filled land - Boca Ciega Bay. Pages 75-103 in R. R. Lewis and D. P. Cole, eds. Proceedings of the third annual conference on restoration of coastal vegetation in Florida. Hillsborough Community College, Tampa, Florida.

Paul, R. T., A. J. Meyerriecks, and F. M. Dunstan. 1975. Return of Reddish Egrets as breeding birds in Tampa Bay, Florida. Fla. Field Nat. 3(1):9-10.

Simon, J. L. 1974. Tampa Bay estuarine system - a synopsis. Fla. Sci. 37(4):217-244.

Simon, J. L., L. J. Doyle, and W. G. Connors. 1976. Environmental impact of oyster shell dredging in Tampa Bay. Report number 4: Final report on the long term effects of oyster shell dredging in Tampa Bay for the State of Florida, Department of Environmental Regulation. University of South Florida, Dept. of Biology and Dept. of Marine Science, 104 pp.

Sykes, J. E. and J. H. Finucane. 1966. Occurrence in Tampa Bay, Florida of immature species dominant in Gulf of Mexico commercial fisheries. U.S. Fish Wildlife Service, Fish. Bull. 65(2):369-379.

Sykes, J.E. and J. R. Hall. 1971. Comparative distribution of mollusks in dredged and undredged portions of an estuary, with a systematic list of species. U.S. Fish Wildlife Service, Fish. Bull. 68:299-306.

Taylor, J. L. 1971. Polychaetous annelids and benthic environments in Tampa Bay, Florida. Ph.D. Thesis, Univ. Fla., Gainesville, Fla., 1335 pp.

Taylor, J. L. 1973. Biological studies and inventory for the Tampa Harbor, Florida project. U.S. Army Corps of Engineers, Jacksonville District, 101 pp. + app.

Taylor, J. L. and C. H. Saloman. 1968. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida. U.S. Fish Wildlife Service, Fish. Bull. 67(2):213-241.

Taylor, J. L., J. R. Hall, and C. H. Saloman. 1970. Mollusks and benthic environments in Hillsborough Bay, Florida. U.S. Fish Wildlife Service, Fish. Bull. 68(2):191-202.

Taylor, J. L., D. L. Feigenbaum, and M. L. Stursa. 1973. Utilization of marine and coastal resources. Pages IV-1 - IV-63 in J. I. Jones et al., eds. A summary of the knowledge of the eastern Gulf of Mexico 1973. State University System of Florida Institute of Oceanography, St. Petersburg, Florida.

U.S. Army Corps of Engineers. 1970. Survey-review report on Tampa Harbor, Florida. Various paging.

U.S. Army Corps of Engineers. 1974. Final environmental impact statement Tampa Harbor project. 297 pp.

U.S. Army Corps of Engineers. 1976. Third annual report - dredged material research program. Environmental Effects Laboratory, Waterways Experiment Station, Vicksburg, Mississippi. 78 pp.

Zieman, J. C. 1976. The ecological effects of physical damage from motor boats on turtle grass beds in Southern Florida. Aq. Bot. 2(2):127-140.

CONTAINMENT SPOILING IN CENTRAL LONG ISLAND SOUND: AN EXAMPLE OF SHORT-TERM BIOLOGICAL ENHANCEMENT

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Abstract

Nineteen active spoiling sites located in Long Island Sound regularly receive dredge spoils from harbor maintenance projects principally from the Connecticut coast. Over 1 1/2 million cubic yards of spoil is dumped at these 19 sites each year. Most spoiling is confined to water depths greater than 60 feet, 2 1/2 to 5 nautical miles from the Connecticut coast.

The New Haven spoiling ground is the best studied in Long Island Sound. Yale University and University of Connecticut researchers have studied the biological effects of a 1 million cubic yard dump at a containment site south of New Haven, Connecticut. This study, initiated in 1972, continues to the present time.

Since April 1974 (cessation of dumping at the New Haven site) the number of bottom-dwelling species and their population densities are 2-3 times higher on the dump site relative to the ambient seafloor. Few species are common to both the dump ground and the ambient seafloor. The observed biological enhancement was predicted on the basis of earlier field experiments and ecologic theory.

A short-term increase in bottom productivity on a spoiling ground (or any physically disturbed bottom) is expected where the spoils are relatively clean. Dredging procedures can be designed, in many cases, to insure a clean dump surface for larval settlement and colonization.

A preliminary dredging policy has been drafted by the State of Connecticut on the basis of the New Haven dump-site research and from data available from other well-studied dump operations.

Introduction

The recovery of plant and animal populations following a major disturbance* has been documented for several terrestrial and a few

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*For this discussion I define a disturbance as an event, or events, that produces major reorganization of a community. While disturbances marine communities. Many aspects of recolonization are remarkably similar considering differences in habitat and participating species suggesting evolutionary convergence in survival strategies. Although disturbance may result in large changes in species composition, organism abundance, and levels of production, it is incorrect to assume that disturbance invariably results in reorganizations that are less productive or diverse than the predisturbed state. This assumption is often made, however, resulting in polarized debate on issues of environmental management.

Evaluating man's effect on the coastal zone requires an understanding of the resiliency of bottom communities to disturbance. We know little about rates of recolonization and sequence of species appearance following a disturbance; the relationship between stage of colonization and consumer productivity is, at best, a guess. Until these questions are addressed, results from myriad pollution studies now being carried out in coastal waters will, at best, permit only limited statements about short-term effects of specific stress factors and contribute little to prediction of long-term changes or recovery of community structure.

In order to approach these problems I present a brief summary of results of an on-going study of colonization following a seafloor disturbance in the form of a sedimentary spoil. More detailed data is available in Rhoads, Aller, and Goldhaber (1977).

Maintenance of harbor channel depths and shoreline construction generates over 1 1/2 million cubic yards of dredged material each year in L.I. Sound. Most of this sedimentary material is barged to spoiling sites in water depths greater than 60 feet, 2 1/2 to 5 nautical miles from the Connecticut coast (Fig. 1). This study is limited to the New Haven spoiling ground. Historically this site has been an active repository for maintenance spoils.

Study Area

Between October 6, 1973, and April 23, 1974, over $10^6 m^3$ of organic-rich silt and sand were dredged from the New Haven Harbor ship channel and dumped at a buoy in 18 meters of water about 10 km south of the harbor mouth (Fig. 2). Dredging was scheduled so that the most heavily polluted inner harbor sediment was buried below

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have diverse origins, effects, and occur on a wide range of time-space scales, I limit my discussion to local and intense physical disruption of the estuarine seafloor within the frequency range of ≥ 1 to ≤ 10 years. I will concentrate on demographic effects on bottom-living invertebrates.

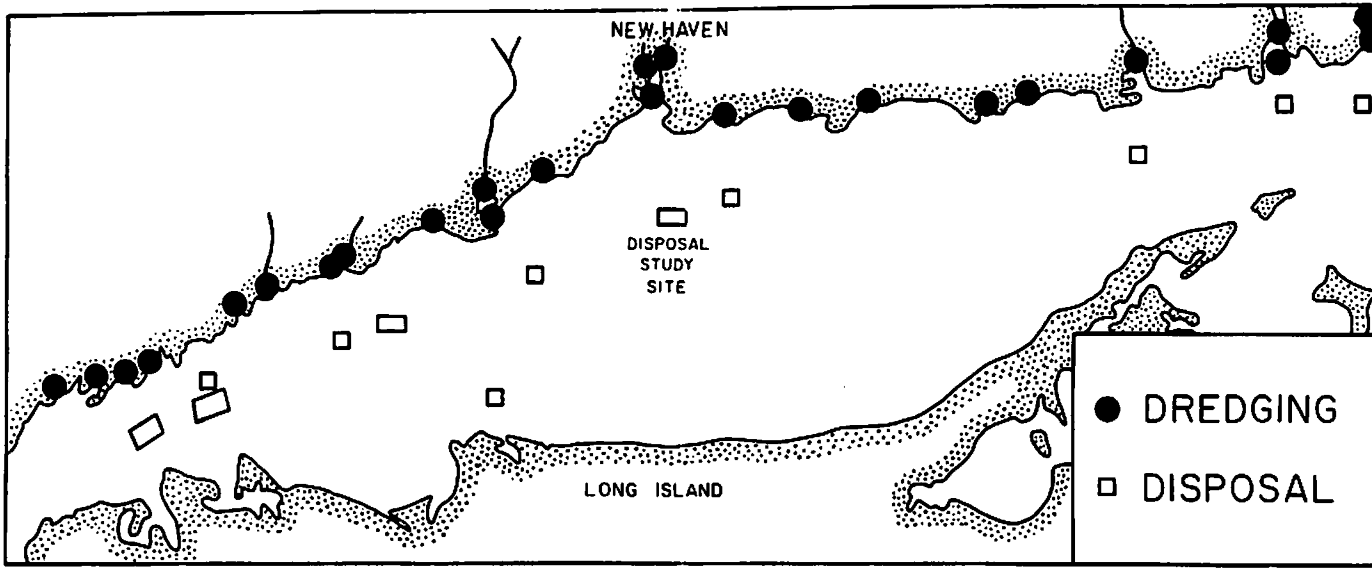

Figure 1. Location of dredging and disposal sites in Long Island Sound. The study site is located southeast of New Haven Harbor, Connecticut.

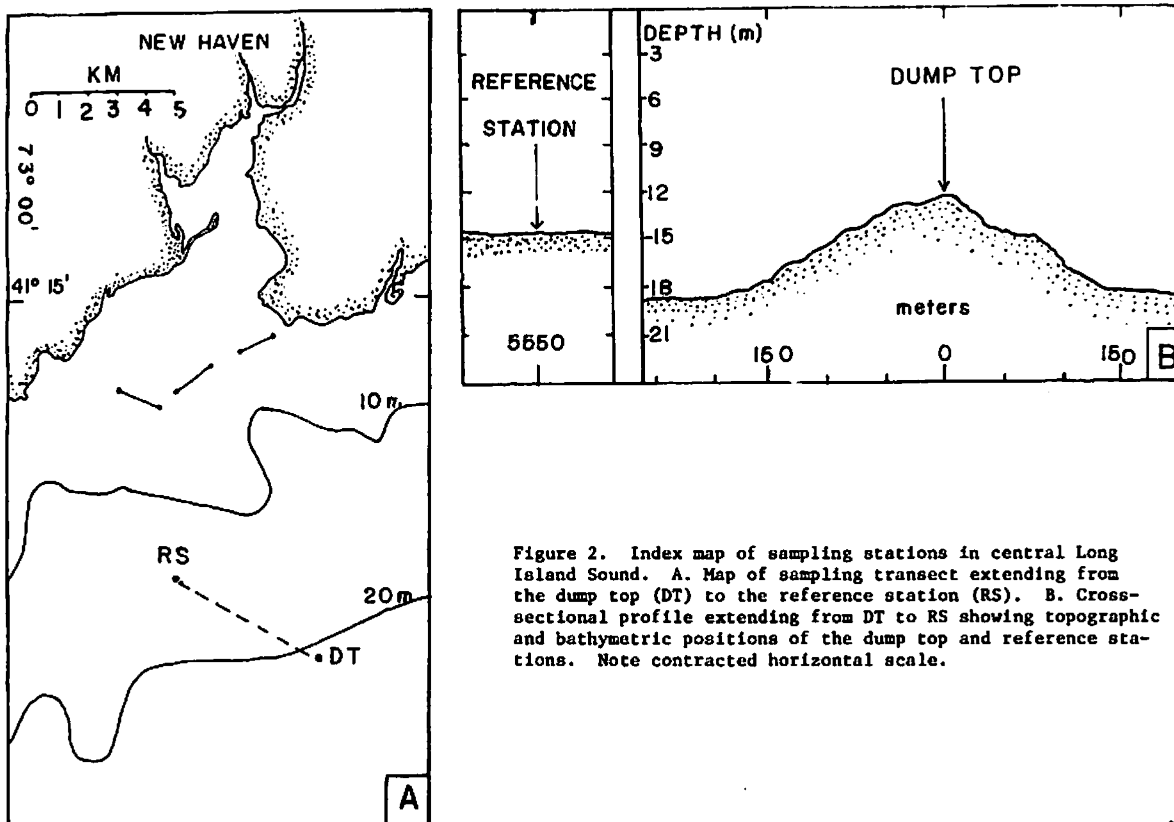

Figure 2. Index map of sampling stations in central Long Island Sound. A. Map of sampling transect extending from the dump top (DT) to the reference station (RS). B. Cross-sectional profile extending from DT to RS showing topographic and bathymetric positions of the dump top and reference stations. Note contracted horizontal scale.

clean sand from the outer harbor. The last few barge loads produced a more or less continuous sand cap up to several centimeters thick over the dump surface. Within a few weeks this sand cap was, in turn, covered with a layer of silty mud a few millimeters thick resuspended from the ambient seafloor by tidal-current scour.

After April 23, 1974, no further dumping took place. Observations on colonization began on July 18, 1974, and extended through August 1976, a period of 792 days.

A reference station (RS) was located on the natural silty-clay bottom 5.5 km northwest of the dump on a topographically flat bottom that historically has not experienced dumping. This area is characterized by a relatively predictable assemblage numerically dominated by the polychaete worm Nephtys incisa and the protobranch clams Nucula annulata and Yoldia limatula.

Methods

Sampling was done by SCUBA divers taking box cores with an area of 0.045 m^2 or from shipboard using a Van Veen Grab with an area of 0.25 m^2. Recovered samples were washed through a 1 mm mesh sieve and retained organisms identified and counted.

Results

Because the resolution of colonization events has been set by sieve size, sampling area, and sampling frequency, I can only roughly estimate when faunal densities reach an acme on the dump. This appears to be in November 1974, approximately 200 days after dumping (Fig. 3). During late fall of 1974 and winter 1975, the dump maintains mean abundances of 1000 to 2000 individuals ($\geq$1 mm)/m^2; about 2 to 10 times higher than the reference station. After the November peak, mean dump abundances steadily decline while those at the reference station generally increase. We estimate that the dump population drops below densities at the reference station in late 1975. At last sampling, mean dump densities are about 4 times lower than those at the reference station.

Mean species richness on the dump appears to peak between November 1974 and April 1975 (Fig. 4). The wide range in values for replicate samples during this period suggests a patchy distribution. From November 1974 to January 1975, the dump assemblage contains more species than the reference station. Although species richness appears to converge with the reference station in late 1975 and 1976, the Sorenson Affinity Index shows a similarity value in this time interval of about 0.10 (Fig. 5). The dump and reference station assemblages remain faunally distinct throughout the 26-month period of observation.

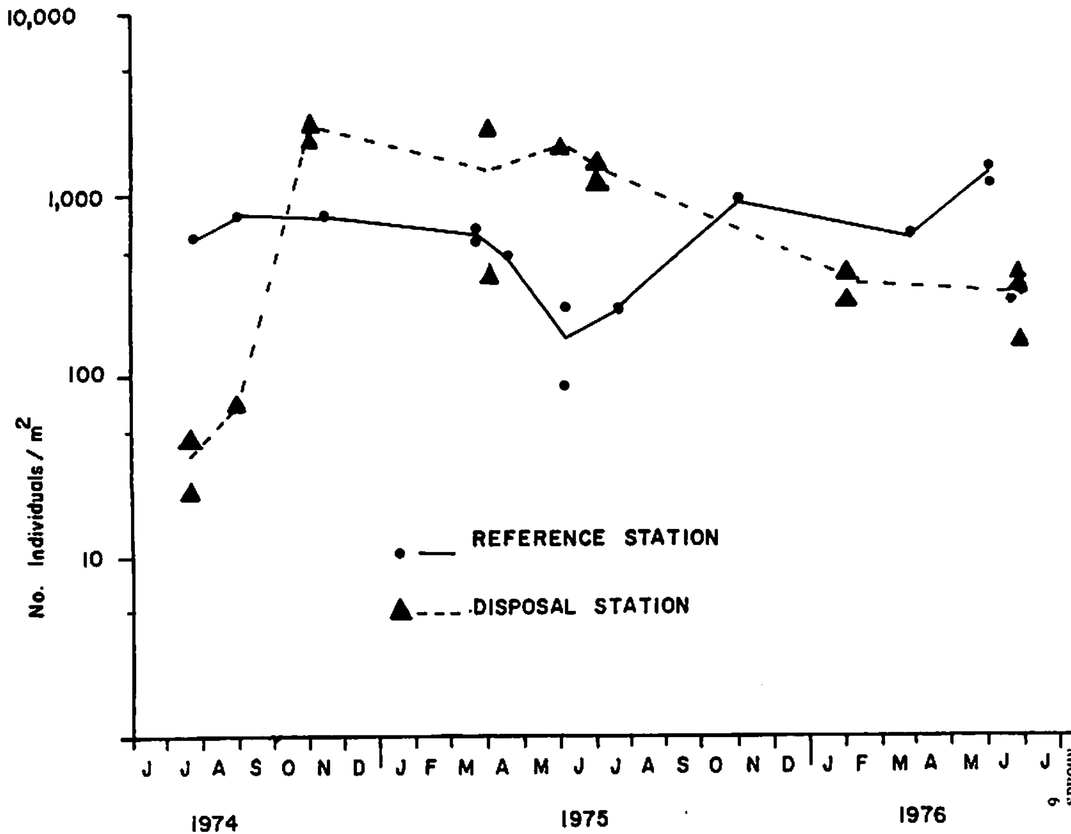

Figure 3. Faunal abundance of benthic organisms ≥1 mm in size at the disposal site and reference station, 1974-1976. Curves are fitted to mean values.

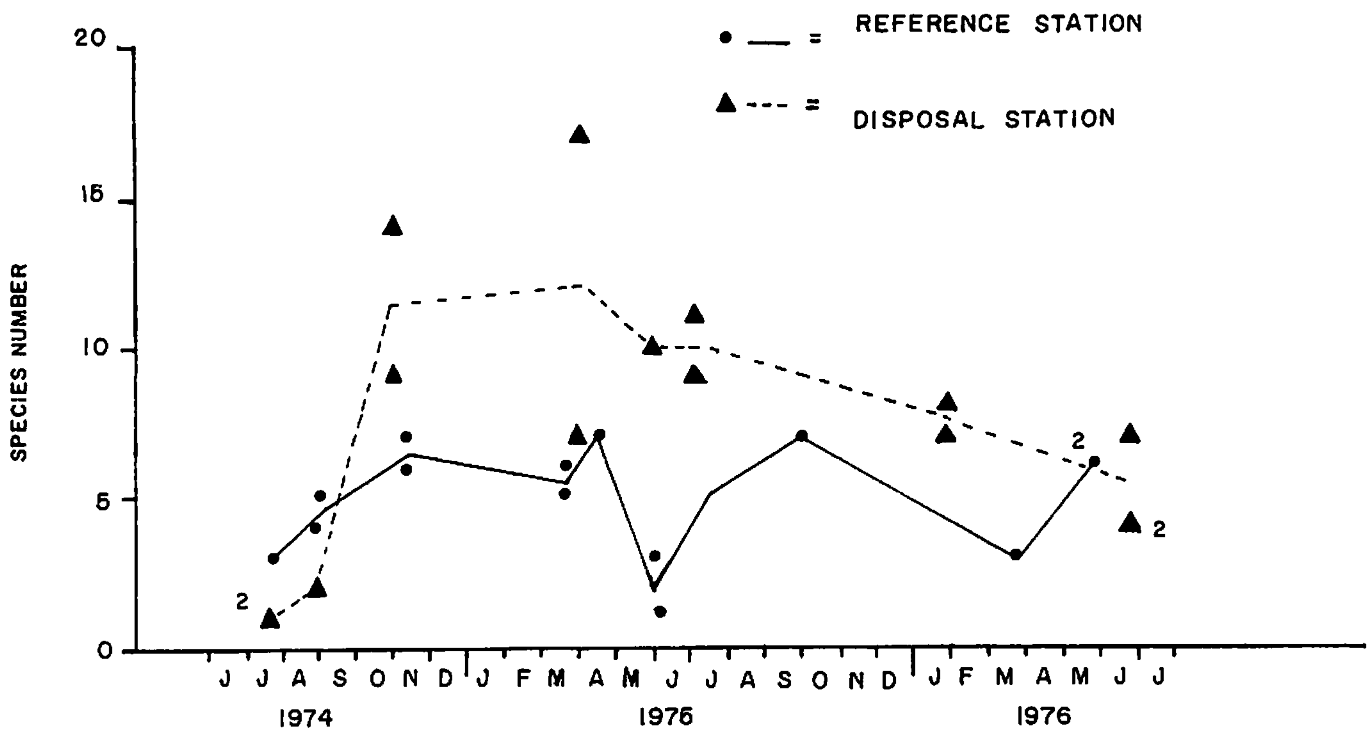

Figure 4. Species richness of benthic organisms ≥1 mm in size at the disposal site and reference station, 1974-1976. Curves are fitted to mean values.

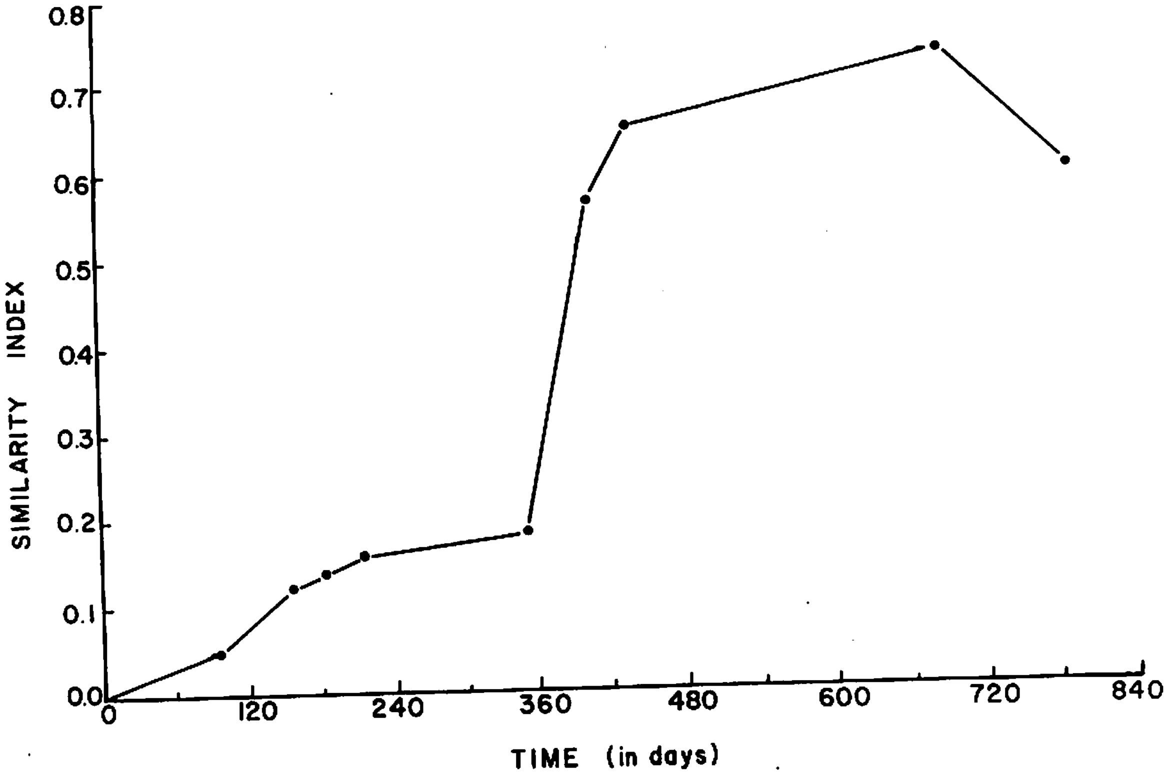

Figure 5. Sorenson affinity index comparing faunal similarity between the dump assemblage and reference station assemblage, 1974-1976. An index of 1 equals total similarity.

Discussion

Because heavily polluted spoil was covered with a cap of relatively clean sediment, colonization of the dump by invertebrates was rapid. Most of the pioneering organisms live near the surface of the bottom and feed from the water column or sediment-water interface. This is in contrast to the subsurface (infaunal) living habit and sediment-feeding of the reference station assemblage (Fig. 6).

The abundance of individuals and species richness at the dump exceeded that of the ambient seafloor for over one year after the initial recruitment period. Similar colonization patterns are described by McCall (1977). McCall conducted a colonization experiment by placing trays of defaunated silty mud on a muddy bottom in 14 meters of water near the study sites described in this paper. Trays were removed and replaced periodically to document rates and stages of colonization. Many species participating in McCall's colonization are in common with this study.

McCall (1977) arranged colonizers into three groupings (I, II, and III), based on time to first arrival, rate of population increase, absolute abundance at acme, and temporal persistence of populations (Fig. 7). That many species may be readily grouped into one of the three patterns indicates that adaptive strategies are shared by organisms with very different evolutionary histories. Adaptive strategies of end-member groupings (I and III) are given in Table 1. One may cautiously predict colonization potential (grouping) of a species by knowing details of its life history (Table 2). Conversely, general aspects of an organism's life history may be deduced from observing its population growth response in a secondary succession.

Following a major disturbance, the new habitat is invaded by a myriad of species having group I attributes (Tables 1 and 2). Although individual biomass values are low compared with later colonizers, growth rates and recruitment rates are high characterizing an assemblage of high secondary productivity. This explains initially high abundance and species richness at the dump. As group II and III species appear later in colonization, the mean growth rate of both individuals and populations decreases. Species richness also decreases as several group I species disappear. The specific factors which eliminate or exclude group I species is unknown. Explanations commonly invoke competitive exclusion or over-exploitation of resources.

With the exception of seasonal variance, the reference station assemblage remains relatively constant. This part of the seafloor experiences disturbance only during major storms. The three species dominating this station (Fig. 6) have group II and III features. High survivorship combined with conservative recruitment results in a predictable population structure.

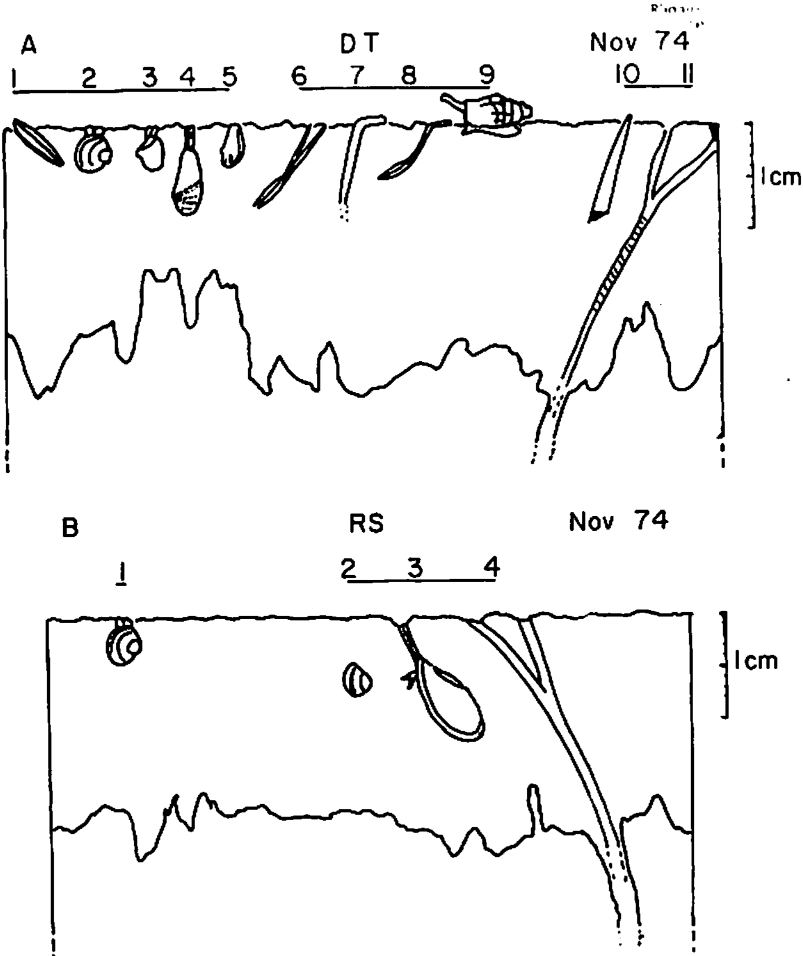

Figure 6. Reconstruction of the dump top and northwest control stations in November 1974. A. Dump assemblage: I. Suspension feeders - 1, *Pandora gouldiana*, 2, *Pitar morrhuana*, 3, *Mulinia lateralis*, 4, *Petricola pholadiformis*, 5, *Lyonsia hyalina*; II. Surface deposit feeders - 6, *Tellina agilis*, 7, *Owenia fusiformis*, 8, *Macoma tenta*, 9, *Nassarius trivittatus*; III. Deep deposit feeders - 10, *Pectinaria* sp., 11, *Nephtys incisa*; B. Reference station assemblage: I. Suspension feeder - 1, *Pitar morrhuana*; II. Deep deposit feeders - 2, *Nucula annulata*, 3, *Yoldia limatula*, 4, *Nephtys incisa*. Data from Rhoads, Aller, and Goldhaber (1977).

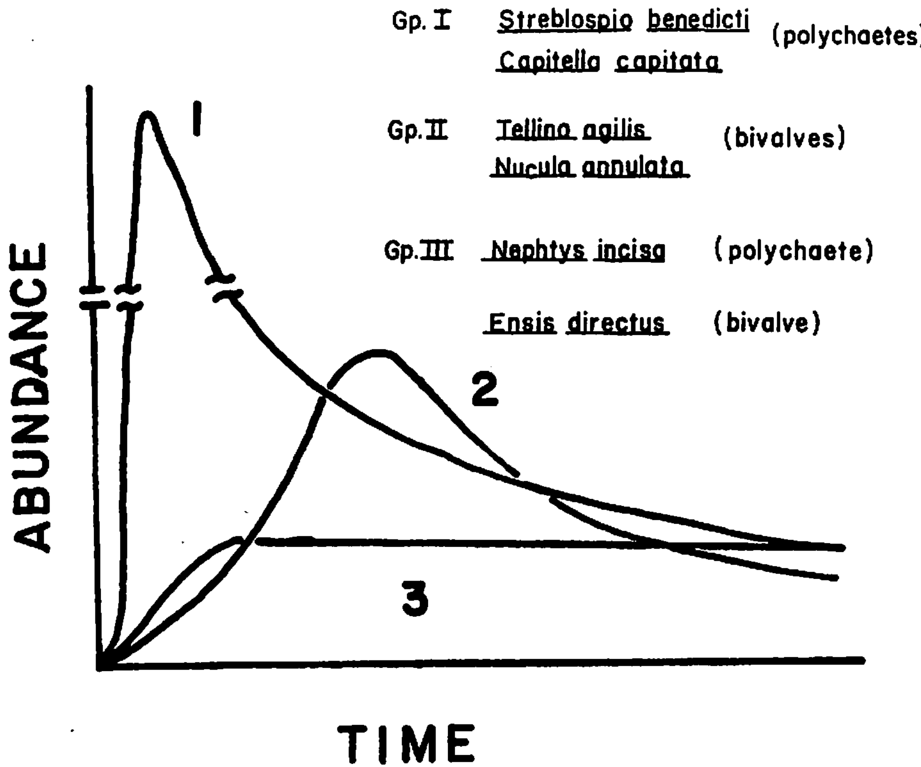

Figure 7. Population growth curves (idealized) for group I, II, and III colonizers. The group I and II curves are exponential. Group III follows a logistic growth law. Examples of organisms falling into these groupings are given. (From McCall, 1977).

Table 1. Summary of Group I and Group III Adaptive Types

Group I	Group III
1. OPPORTUNISTIC SPECIES a. Many reproductions per year b. High recruitment c. Rapid development d. Early colonizers e. High death rate	1. EQUILIBRIUM SPECIES a. Few reproductions per year b. Low recruitment c. Slow development d. Late colonizers e. Low death rate
2. SMALL	2. LARGE
3. SEDENTARY	3. MOBILE
4. DEPOSIT FEEDERS (mostly surface feeders)	4. DEPOSIT AND SUSPENSION FEEDERS
5. BROOD PROTECTION; LECITHOTROPHIC LARVAE	5. NO BROOD PROTECTION; PLANKTOTROPHIC LARVAE

SOURCE: McCall (1977)

In summary, the short-term effects of containment spoiling appears to favor a pioneering assemblage of near surface living invertebrates which feed at, or above, the bottom. Their life history features result in exponential rates of recruitment, culminating in a dense albeit transient assemblage of high species richness. Secondary productivity is high relative to the ambient (undisturbed) seafloor assemblage.

In the absence of further disturbance, this biological enhancement is short lived. Because the survivorship of group I colonizers is short and group I species tend to over-exploit resources, the pioneering sere is unpredictable in both space and time. On the time scale of several years the density of organisms at the dump, as well as species number, is expected to have high variance relative to the ambient community.

It would be interesting to know if, had dumping been resumed in early spring 1975 and again in 1976 (prior to spring reproduction), the dump assemblage could have been maintained in a more or less continuous state of exponential recruitment. The relationship between disturbance and high consumer productivity may account for the observation that many dump sites are favored feeding areas for demersal fish and lobsters. The productivity enhancing role of disturbance is well known in land communities (e.g., Gadgil and Solbrig, 1972; Margalef, 1969; Pianka, 1970; Wright, 1974) but has received little attention at the level of consumers, especially in marine systems.

From our work in Long Island Sound, I recommend that containment spoiling be used in those cases where polluted sediments can be covered

Table 2. Summary of Life Habits of Common Colonizing Species

	Maximum linear size	Biomass dry Wt.	Relative mobility	Feeding type	Larval feeding type	Development type	Egg Protection	# Eggs per female	Time to maturity (days)	Relative death rate
Group I										
Streblospio benedicti	20X1mm	.15-.5mg	sedentary	SDF	P	Short pelagic	brood chamber	30-400	30	high
Capitella capitata	20X1mm	.15-.5mg	sedentary	NSDF	L,P	S. pelagic, L. pelagic & direct	egg cases in tube	6-600	30-40	high
Ampelisca abdita	5-7mm	.5-1mg	sedentary	SDF,SF	L	direct	brood chamber	20-40	40-80	high
Owenia fusiformis	20X3mm	.5-1mg	sedentary	SDF,SF	P'	short pelagic	gelatinous string	U	U	high
Group II										
Nucula proxima	5-7mm	5mg	sporadic	DF	L	short pelagic	none	4100	U	medium
Tellina agilis	10mm	5mg	mobile	SDF	P	long pelagic?	none	U	U	medium
Group III										
Nepthys incisa	50X5mm	10mg	very mobile	NSDF	P	long pelagic?	none	U	U	low
Ensis directus	50X10mm	10mg	very mobile	SF	P'	long pelagic	none	$12\text{-}20\times10^6$	U	low

NOTE: Modified from McCall (1977).

Key: SDF = selective deposit feeder; NSDF = non-selective deposit-feeder; SF = suspension feeder; DF = deposit feeder; P = planktotrophic; L = lecithotrophic.

with a mantle of clean sediment, especially sand. Environmental managers may wish to test the disturbance-secondary productivity hypothesis by frequently using a single spoiling site rather than using multiple sites at a lower frequency.

The reader will understand that these recommendations are based on observations on the effect of disturbance on demographic phenomena and do not address problems of pollutant uptake by colonizing organisms. Also, these recommendations may not be validly applied to deep-sea disposal or to tropical marine environments.

Acknowledgments

Several colleagues have participated in this research: R. Aller, P. McCall, R. Wells, and J. Yingst. This does not mean that they necessarily endorse all of my conclusions or recommendations.

References Cited

Gadgil, M., and O. T. Solbrig, 1972, The concept of r- and k- selection: evidence from wild flowers and some theoretical considerations: The Am. Naturalist, V. 106, no. 947, pp. 14-31.

McCall, P. L., 1977, Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound: Jour. Mar. Res., May issue (in press).

Margalef, R., 1969, Diversity and stability: a practical proposal and a model of interdependence: IN: Diversity and Stability in Ecological Systems, pp. 25-37 (G. M. Woodwell and H. H. Smith, eds.), Brookhaven National Laboratory, Upton, N.Y., 264 pp.

Pianka, E., 1970, On r and K selection: Am. Naturalist, V. 104, pp. 592-597.

Rhoads, D. C., R. C. Aller, and M. B. Goldhaber, 1977, The influence of colonizing benthos on physical properties and chemical diagenesis of the estuarine seafloor: IN: Ecology of Marine Benthos (B. Coell, ed.) Belle Baruch Institute, Univ. S. Carolina, Georgetown, S.C. (in press).

Wright, H. E., 1974, Landscape development, forest fires, and wilderness management: Science, V. 186, no. 4163, pp. 487-495.

DREDGING AND ITS IMPACTS ON UPPER CHESAPEAKE BAY: SOME OBSERVATIONS

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Abstract

Baltimore Harbor is located at the head of the Patapsco estuary, a small tributary arm of the upper Chesapeake Bay. The upper Chesapeake Bay is a region of naturally high sedimentation rates, and shipping channels must be maintained by relatively frequent dredging. Historically, the bulk of the material dredged from Baltimore Harbor has been disposed of on wetlands or fastlands adjacent to the Harbor, or overboard within the Harbor. The bulk of the material dredged from the connecting channels and from the approach channel to the Chesapeake and Delaware Canal has been disposed of overboard within the upper Bay, and the bulk of the material dredged from the Canal itself has been deposited on lands bordering the Canal.

The Port of Baltimore is Maryland's most important economic component, but the upper Chesapeake Bay and the Chesapeake and Delaware Canal are not only major shipping avenues, they are also important spawning and nursery areas for a variety of commercially and recreationally important finfish. And, the main body of the Bay adjacent to Baltimore Harbor has important shellfish beds. The perceived conflict between fisheries and dredging and disposal, coupled with more stringent criteria that have been promulgated in recent years for disposal of dredged materials in open waters has resulted in prolonged delays in carrying out dredging projects, sometimes with significant economic perturbations.

Studies of the acute effects of dredging and spoil disposal in the upper Chesapeake Bay have failed to show any significant or persistent deleterious effects on the environment or the biota. Studies of any chronic effects that might ensue are virtually non-existent and are badly needed.

Dredging has been a persistent activity in the upper Chesapeake Bay and must continue to be if Baltimore is to remain a major port, if indeed it is to remain a major city. A comprehensive regional dredging and spoil disposal plan should be developed for the upper Chesapeake Bay to ensure effective operation of the Port of Baltimore. A conceptual plan is outlined.

Introduction

The Chesapeake Bay, one of the world's largest estuaries, has been an important waterway for shipping and transportation since colonial times. Today it supports two of the nation's major seaports--Baltimore near its head, and Norfolk, near its mouth. In 1974 these ports ranked fifth and seventh, respectively, in the United States in terms of tons of cargo processed. Over 34,000 commercial ships entered the Port of Baltimore in 1974, transporting nearly 60 million tons of freight.

The historical growth of the Port of Baltimore and its current status as the third largest importing port in the country, have resulted in the extensive deepening of its harbor and the creation of shipping channels by dredging throughout the upper Bay, including the approach channel through the Elk River to the Chesapeake and Delaware (C & D) Canal. At present, there are over 50 NM of dredged channels in the upper Chesapeake Bay.

Naturally high sedimentation rates of the upper Bay have been primarily responsible for the large amounts of dredging required to maintain adequate depths in these channels. Since 1946, for example, over 26 x 10^6yds^3 of material have been dredged for maintenance from the Baltimore federal navigation project areas and from the C & D Canal approach channel. Approximately 22 x 10^6yds^3, or about 80% of this spoil, have been placed in various open water sites in the upper Bay, Figure 1.

The increasing use of Chesapeake Bay for shipping and transportation and the concomitant requirements for dredging, have in recent years been perceived by many

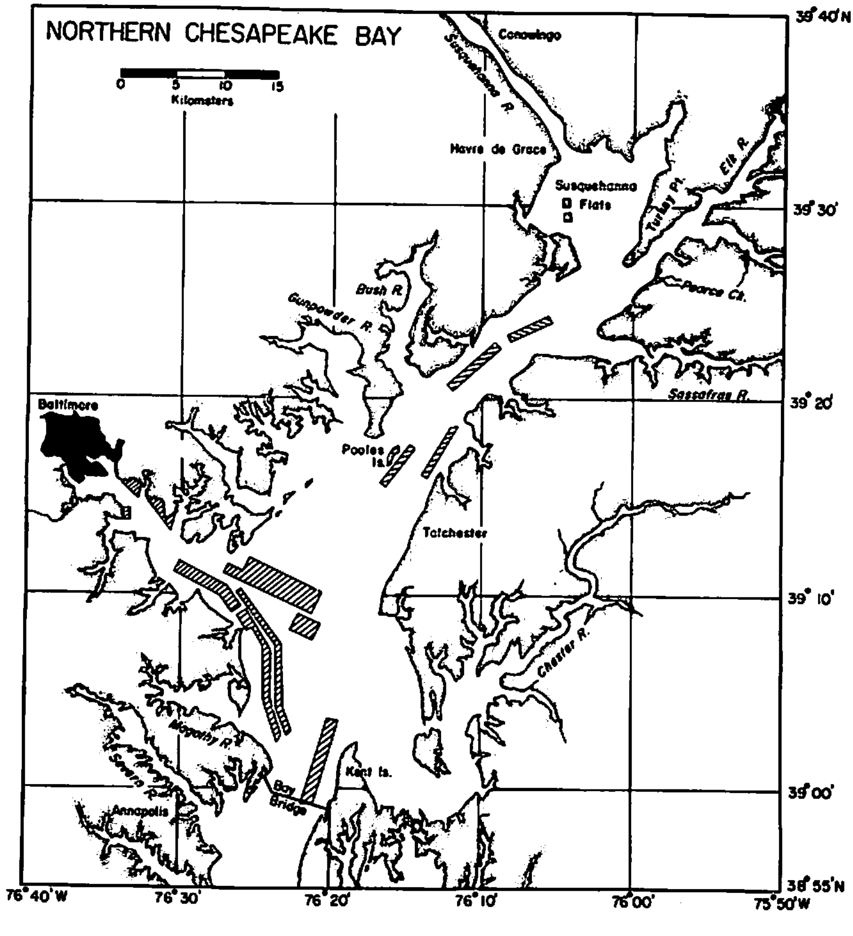

Figure 1. Map of upper Chesapeake Bay showing spoil disposal sites that are now open, or have recently been open.

environmentalists and baymen to be in conflict with other uses of the Bay, particularly with recreational and commercial fishing and with other recreational and aesthetic uses. In 1973 over 600 x 10^6 pounds of finfish and shellfish were harvested from the Chesapeake Bay estuarine system with an estimated landed value of $49 million. Dredging per se has not been the focus of this controversy; rather the disposal of the dredged material in the open waters of the upper Bay and its anticipated adverse effects on environmental quality and on the living resources. These concerns have led, since the late 1960s, to frequent and prolonged delays in maintenance and improvement dredging projects by federal, local and private interests. These delays in turn have occasioned significant economic hardships to private and public interests due to underutilization of facilities and to loss of potential tax revenues. It appears obvious that if the Harbor and its associated approach and connecting channels are to be maintained even at their present project depths, a significant fraction of the dredged material will be disposed of in the open waters of the upper Bay. It is unlikely that suitable sites are available to make land disposal an acceptable alternative.

The growth of Baltimore as a port has played a major role in the development of Baltimore as a city and Maryland as a state, and it continues to do so. Reasons for locating the town and port of Baltimore on the upper Patapsco, a tributary estuary to the upper Chesapeake Bay were varied and valid in colonial days. The Patapsco offered a protected harbor with relatively deep water--deep relative to the draft of most of the ocean-going vessels of that period--except near its head, and the waterfalls on the lower reaches of the Jones Falls River provided a ready source of power to run the mills. Being at the Fall Line, Baltimore is at the head of navigation.

Given the choice today, one might well not select this as a site for a major port. The prevailing depths in the Harbor and in the approach areas are considerably less than the channel depths required to accommodate even medium sized ocean-going vessels, and the high sedimentation rates make frequent maintenance dredging a necessity. Furthermore, since Baltimore Harbor is located in the upper reaches of the Chesapeake Bay, to enter the Harbor, ships must travel relatively long distances within the Bay through important shellfish, finfish and recreational areas. Despite these drawbacks the Port of Baltimore is near the head of the Patapsco estuary in the upper reaches of the Chesapeake Bay, and it could not be relocated without serious social and economic perturbations.

Clearly, if the Port of Baltimore is to be "preserved," a decision which has been in effect operationally for about 200 years, frequent maintenance dredging and probably some improvement dredging, will be necessary.

It is the purpose of this paper to assess whether or not shipping is an important and legitimate activity for the upper Chesapeake Bay; one that can be accommodated with acceptable risk to the environment and its biota through proper planning and management. We shall focus our attention on the dredging and disposal activities required to support this activity. In making this assessment we will describe the sedimentation processes that characterize the upper Bay, review the magnitude and nature of the dredging and disposal operations, assess the impact these activities have had on the environment and its resources, and evaluate the economic importance of the Port of Baltimore to the City of Baltimore and to the State of Maryland.

Units are reported in British engineering units to conform with standard dredging terminology. Table 1 gives the factors for converting British engineering units to metric units.

TABLE 1

Conversions from British Engineering to Metric Units

To Convert From	To	Divide By
inches (in)	centimeter (cm)	0.3937
feet (ft)	meters (m)	3.2808
nautical miles (NM)	kilometers (km)	0.5396
sq. statute miles (mi^2)	sq. kilometers (km^2)	0.3861
acres	sq. kilometers (km^2)	247.1054
cubic feet (ft^3)	cubic meters (m^3)	35.3147
cubic yards (yd^3)	cubic meters (m^3)	1.3080
feet/sec (ft/s)	centimeters/sec (cm/s)	0.0328
knot	meters/sec (m/s)	1.9425
short ton	metric ton	1.1023

Sedimentation in Upper Chesapeake Bay

A Geological Perspective. The Chesapeake Bay is an estuary--a semi-enclosed coastal body of water freely connected to the ocean and within which sea water is measurably diluted by fresh water from land drainage (Pritchard, 1967). Fresh water from numerous rivers and streams is mixed within the semi-enclosed Chesapeake Bay basin with sea water that enters through the Virginia Capes. The mixing, primarily by tides, produces density gradients that drive the characteristic two-layered circulation pattern that eventually leads to the discharge of the fresh water to the Atlantic Ocean.

The Chesapeake Bay estuarine system lies entirely within the Atlantic Coastal Plain, a broad, gently sloping plain bounded on the west by the crystalline rocks of the Piedmont and on the east by the edge of the continental shelf. A classic example of a submerged river valley estuary, the Chesapeake Bay estuary was formed by drowning its ancestral river valley system by the most recent rise in sea level which began 15,000 to 18,000 years ago. At that time sea level was approximately 400 feet below its present level and the ocean shoreline lay near the outer edge of the continental shelf. As the glaciers began to melt and retreat, the meltwater was returned to the sea by rivers and streams and the sea began to rise and advance across the continental shelf. The transgressing sea probably reached the present mouth of the Bay about 10,000 years ago. As the sea continued to rise it penetrated progressively deeper into the Bay basin, drowning the ancestral Susquehanna river valley system, converting it from a riverine to an estuarine system.

The age of the modern Chesapeake Bay estuary decreases from its mouth to its head; the upper Chesapeake Bay estuary is no more than 3,000 to 4,000 years old. The Chesapeake Bay estuary then, is very young geologically. Its highly dendritic form is inherited and is indicative of its youthfulness. As the Bay matures, there is a progressive rectification, or straightening of its coastline; headlands are attacked by waves and currents and reentrants in the coastline are filled with littorally drifted material. Like other estuaries, the Chesapeake Bay is an ephemeral feature on a geologic time scale. It is being rapidly filled with sediments; sediments from rivers, from shore erosion, from primary production, and from the sea. Typically estuaries fill from their heads and their margins. The Chesapeake Bay is no exception.

An "estuarine delta" is forming in the upper reaches of the estuary--near the new river mouth. The delta will grow progressively seaward extending the realm of the Susquehanna and displacing the intruding sea farther seaward. Lateral accretion by marshes also plays a significant role in some areas of the Bay. These same sedimentation patterns characterize the tributary estuaries as well as the Bay proper; they fill from their heads and from their margins. As the Bay contracts in volume, depth, and area, the intruding sea is progressively displaced seaward, transforming the estuarine system back into a river valley system. Eventually, the Susquehanna will reach the sea through a broad depositional plain and the transformation will be complete. If relative sea level remains nearly constant, this evolutionary process will take at most a few tens of thousands of years to complete. If relative sea level falls, the estuary's lifetime will be shortened. If relative sea level rises, the life of the estuary will be increased.

Man's activities throughout the drainage basin can, and indeed have, accelerated the rate of infilling, thus shortening the Bay's geological lifetime. But, more important, the by-products of his activities such as improperly treated sewage, pesticides, herbicides, petroleum products, chlorinated hydrocarbons, a variety of other chemicals, and also sediment, may alter the Bay, or segments of it, to the extent that its useful biological and recreational lifetimes could be cut drastically shorter than its geological lifetime--perhaps several orders of magnitude shorter. Some people include dredging and spoil disposal in this category of major threats to the vitality of the Chesapeake Bay estuarine system.

Riverflow. The upper Chesapeake Bay is the estuary of the Susquehanna River. The Susquehanna, which enters at the head of the Bay, supplies approximately 50% of the total fresh water input to the Chesapeake Bay estuarine system and more than 90% of the total input above (north of) the mouth of the Patapsco. With a long-term mean flow of about 35,000 ft^3/s, the Susquehanna is the largest river discharging to the Atlantic Ocean through the eastern seaboard of the United States. The characteristic annual flow pattern of the Susquehanna--high runoff in spring resulting from snowmelt and rainfall followed by low to moderate flow throughout most of the remainder of the year--is typical of mid-latitude rivers. At the present time there is no significant regulation of the flow of the Susquehanna which is highly variable. The yearly average flows, over approximately the past half century, have a standard deviation of greater than 20% of the long-term mean. Seasonal fluctuations in average flow are even greater; the minimum monthly discharge averages 7,000 ft^3/sec, and the maximum monthly flow averages approximately 117,000 ft^3/s (Schubel, 1972a). Relatively large short-term fluctuations also occur.

During the spring freshet and other occasional short periods of very high riverflow, the Susquehanna dominates the circulation in the upper reaches of the Bay; the characteristic net nontidal circulation is overpowered in the upper 10 - 20 NM of the Bay, and the net flow is seaward at all depths. River domination is expected considering the discharge and the geometry of this segment of the basin. A riverflow of 100,000 - 140,000 ft^3/s produces a mean seaward velocity of about 0.3 knots through an average cross-section upstream from 39°17'N, Pooles Island. Discharge during the typical spring freshet is frequently so great that the tidal reaches of the Susquehanna are extended as far seaward as 39°13'N--almost 28 NM from the mouth of the River at Havre de Grace, Maryland (Schubel, 1972b).

During periods of high flow, the transition from river to estuary is marked by a sharp front separating the fresh river water from the salty estuary water. Longitudinal salinity gradients greater than 6‰ in 3 NM are common during the spring freshet. The front moves upstream and downstream in response to changing river discharge, but until June, 1972, had not been reported farther seaward than about 39°13'N (Tolchester). During Tropical Storm Agnes in June, 1972, the rampaging river displaced the front all the way down to the Chesapeake Bay Bridge off Annapolis, approximately 39°00'N.

The marked variations of the fresh water inflow produce large temporal variations of salinity. The variations are most marked, of course, in the upper reaches of the Bay. Near Pooles Island in the upper Chesapeake Bay the salinity during 1960, a year of relatively high riverflow, ranged from 0.4‰ in April to 8.3‰ in December--more than a 20-fold range. During 1964, a year of relatively low riverflow, the range in salinity near Pooles Island was from 0.8‰ in March to 13.3‰ in December--nearly a 17-fold range.

The temporal variations in salinity in the upper Bay provide the basic mechanism for the flushing of tributary estuaries such as the Gunpowder, Bush, Back, Mogothy, and Severn. The small fresh water inputs to these tributaries are insufficient to maintain a steady circulation pattern, and the water that fills them is derived largely from the adjacent Bay. It is only in the upper reaches of these tributaries that the salinity distribution is significantly affected by their fresh water inflows. The primary factor controlling the exchange of water between these tributaries and the Bay is the temporal variation in the salinity of the upper layer in the adjacent Bay. The salinity of the surface layers of the upper Bay varies seasonally with maximum values in the fall and minimum values in the spring. The salinity changes in the tributaries lag behind those in the adjacent Bay. During winter and early spring when the salinity in the Bay is decreasing with time, the salinity in the tributaries is, at any given time, higher than in the Bay. As a result water flows into the tributaries at the surface from the Bay, and out of the tributaries in the deeper layers into the Bay. In late spring, summer, and early fall when the salinity of the Bay is increasing, the salinity in the tributaries is less than in the adjacent Bay, and hence the waters of the tributaries flow out at the surface, while Bay waters flow into the tributaries along the bottom. Since these estuaries are shallow, channel depths generally less than 20 feet, only the upper layer of the Bay participates in the exchange with the tributaries.

The circulation pattern in these tributaries is thus reversed at least twice each year. Some of the smaller estuaries tributary to the head of the Bay, such as the Gunpowder and the Bush, are renewed more often. These estuaries are subject to rapid renewal rates because of large, short-period fluctuations in the salinity of the adjacent Bay; fluctuations produced by sudden, large changes in the discharge of the Susquehanna.

While Baltimore Harbor is referred to as the estuary of the Patapsco its circulation is driven primarily by the adjacent Bay. The average daily inflow of fresh water to the Harbor from the Patapsco and its other tributary streams is only about 1/315 of the volume of the Harbor. Tidal currents are relatively sluggish within the Harbor and it has been estimated that renewal of Harbor water by tidal flushing would require approximately 150 days. Tracer studies show however that the mean residence time for water in the Harbor is only about 10 days. Clearly another mechanism must exist to provide for a renewal rate of about 10% of the Harbor volume per day.

Pritchard (1968) has shown that this mechanism is a three-layered circulation pattern driven by differences in the vertical variations in salinity in the Harbor and the adjacent Bay. There is an inflow into the Harbor both at the surface and along the bottom, and a return flow at mid-depth. The volume rate of inflow and discharge from the Harbor as a result of this circulation pattern has been shown to be remarkably steady throughout the year and to amount to about 17,000 ft^3/s, or approximately 10% of the Harbor volume per day. The dredged navigation channel that is maintained at essentially the same depth as the adjacent Bay plays an important role in this circulation pattern. If there were no dredged channel, the circulation would be expected to be similar to that described for the Gunpowder, Bush, and other tributaries. The three-layered circulation pattern also plays an important role in sedimentation processes in the Harbor. The net upstream flow near the bottom carries sedimentary particles from the Bay into the Harbor and accelerates the sedimentation in the navigation channels.

The longitudinal variation in surface salinity over the length of the Bay ranges from 25 - 30‰ at its mouth to the salinity of the Susquehanna River water, about 0.05‰, near its head. The flows of the other rivers tributary to the upper Bay are small and have little effect on the salinity distribution or sedimentation pattern of the main body of the upper Bay (Schubel, 1972a).

Sediment Inputs. Sediments are introduced into the upper Chesapeake Bay by rivers, shore erosion, primary productivity, and transport from more seaward segments of the estuary. The sources are thus external, internal and marginal. The Susquehanna is the dominant sediment source to the main body of the Bay from its head, at least as far seaward as the mouth of the Patapsco, and perhaps farther. During years of "typical" riverflow, when the average flow of the Susquehanna is between about 30,000 ft^3/s and 40,000 ft^3/s, the Susquehanna discharges between 0.5 - 1.0 x 10^6 short tons of suspended sediment. The bulk of it, more than three-fourths, is usually discharged during the spring freshet when both the riverflow and the concentration of suspended sediment are high.

During extreme floods the Susquehanna may discharge many times more sediment in a week than during an entire "average" year. In a one week period in June, 1972, following the passage of Tropical Storm Agnes, the Susquehanna discharged more than 34 x 10^6 short tons of suspended sediment (Schubel, 1974). Following Tropical Storm Eloise (September, 1975), the Susquehanna discharged more than 11 x 10^6 short tons in one week (M. G. Gross, personal communication, October, 1976).

The sediment discharged by the Susquehanna is predominantly fine-grained silt and clay. Most of the sand carried by the River is deposited in the reservoirs along the lower reaches of the River and does not reach the Bay. The bulk, more than three-fourths, of the silt and clay that is discharged into the Bay is trapped in the upper reaches of the Bay from Tolchester to Turkey Point by the net non-tidal circulation which creates an effective sediment trap in the transition zone where the net upstream flow of the lower layer dissipates until the net flow is downstream at all depths (Schubel, 1968a, 1971, 1972b). Fine particles that settle into the lower layer are carried back upstream by its net upstream flow leading to an accumulation of sediment both on the bottom and suspended within the waters of the upper reaches of the Bay. Such accumulations of suspended sediment, called "turbidity maxima," are characterized by turbidities and suspended sediment concentrations that are higher than those either farther upstream in the source river or farther seaward in the estuary. The turbidity maximum in the upper reaches of the Bay has been described in some detail by Schubel (1968a, 1968b, 1971, 1972b).

Since the Susquehanna is the only river discharging directly into the main body of the Bay, it is the only important source of fluvial sediment to the Bay proper (Schubel, 1968a,b; 1971, 1972b). Most of the sediment discharged by the other rivers is deposited in the upper reaches of their estuaries and does not reach the Bay proper. In the middle and lower reaches of the Bay, shore erosion is not only a major source of sediment, but probably the most important source (Schubel, 1968a,b; 1971, Biggs, 1970a; Schubel and Carter, in press). The margins of the Bay are being digested at an alarming rate (Singewald and Slaughter, 1949; Schubel, 1968a; Palmer, 1973). Schubel (1968a) estimated that shore erosion of the segment of the Bay from the mouth of the Susquehanna to Tolchester contributes an average of about 0.3 x 10^6 short tons of sediment to the Bay each year. Approximately one-third of this is silt and clay-sized material. The contribution of silt and clay from shore erosion to this segment of the Bay, 0.1 x 10^6 short tons/yr, is approximately 10 - 20% of the input from the Susquehanna during years of average riverflow. Biggs (1970a) made a similar estimate for the Bay from a few miles north of the northern end of Kent Island south to the mouth of the Potomac. He reported an annual average input of about 1.4 x 10^6 short tons of which about 25% is silt and clay. According to Biggs (1970a), this contribution of silt and clay accounted for about 52% of the total input of suspended sediment to that segment of the Bay.

The relative importance of the contribution of sediment from shore erosion clearly increases in a seaward direction and it becomes the dominant source in the middle reaches of the Bay.

Sediments are also introduced into the Bay by internal sources. Biggs (1970a) estimated that primary productivity accounted for about 4% of the total suspended sediment in the upper reaches of the Bay from the mouth of the Susquehanna to below Tolchester, and for about 40% of the total for the segment of the Bay below Tolchester to the mouth of the Patuxent. Approximately half of these totals were attributed to skeletal material. The contribution of benthic populations to the sediments of the Bay has not been documented.

It is clear that there is a net upstream flow of sediment in the lower layers of the Bay proper and its major tributaries, but the net flux through any cross-section of the Bay is not known. Recently Schubel and Carter (in press) constructed a simple model that indicated that the Bay is a source of sediment to its tributary estuaries, rather than a sink.

Sedimentation Rates. Sedimentation rates in the Chesapeake Bay are poorly known. All published estimates of contemporary and recent sedimentation rates are based on simple sediment budget models in which the sedimentation rate was the calculated term required to balance the budget. Using such a model Schubel (1968a) estimated that during years of average riverflow the sedimentation rate in the upper reaches of the Bay from Tolchester to Turkey Point averaged about 0.08 - 0.12 in/yr. Using a similar model for approximately this same segment of the Bay, Biggs (1970a) estimated a mean sedimentation rate of 0.15 in/yr. Schubel (1971, 1976) has at various times estimated mean sedimentation rates of 0.04 - 0.08 in/yr for the middle reaches of the Bay, and Biggs (1970a) estimated it at about 0.04 in/yr. Recently, Schubel and Hirschberg (in press) reported the first radiometrically determined contemporary sedimentation rate for the Chesapeake Bay. For a core from a station off Tilghman Island (38°41'30"N, 76°24'00"W) using the Pb^{210} dating method, they estimated a mean sedimentation rate of between 0.04 - 0.06 in/yr for the past century or so. Goldberg and co-workers (E. D. Goldberg, personal communication, September, 1976) have also made some Pb^{210} measurements for the Chesapeake Bay, but none have been published.

Average sedimentation rates estimated from sediment budgets from "typical" years are relatively meaningless in the upper reaches of the Bay--above Tolchester. The geological record of this part of the estuarine system is dominated by floods. During Tropical Storm Agnes (June, 1972), Schubel and Zabawa (in press) and Zabawa and Schubel (1974) estimated that the sediment discharged would, if spread uniformly over the area between Tolchester and Turkey Point, form a layer about 7.5 in thick. Cores taken throughout this area showed accumulations of from 4 - 12 in outside of the channel, and long stretches of the channel shoaled by more than 3 ft.

Even in pre-colonial days sedimentation rates in the upper Chesapeake Bay were relatively high--relative to other parts of the Bay--because of the estuarine circulation regime which entraps much of the sediment within this segment of the Bay. With settling of the region, sediment yields were dramatically increased as lands were deforested for agriculture. Sediment yields were typically increased from an average of less than 100 short tons/mi^2/yr to more than 600 short tons/mi^2/yr. Hundreds of thousands of acres in the Chesapeake region were cleared with axe and fire for tobacco farming. After two or three crops, the nutrients were depleted and new lands were needed for growing tobacco. The old fields were frequently abandoned and left bare to be eroded by the wind and rain. Much of the released sediment was carried by rivers and streams into the Chesapeake Bay estuarine system.

Even before 1800, siltation was a serious problem in harbors such as Upper Marlboro on the Patuxent River, Port Tobacco on the Port Tobacco River (a tributary to the Potomac), and Joppatown at the mouth of the Little Gunpowder. In the early 1700s Joppatown was the county seat of Baltimore County and Maryland's most prosperous and important seaport. By 1750 the port had declined in importance, primarily because of sedimentation problems, and in 1768 the county seat was moved to Baltimore. Stone mooring posts that once held the hawsers of seagoing vessels are now two or more miles from navigable water

(Gottschalk, 1945). Sediment yields from agricultural areas are generally lower today than in the mid-1700s to late 1800s because of better soil conservation practices but are still considerably higher than in pre-colonial days when the land was heavily vegetated.

Urbanization is the most recent of man's activities to contribute large amounts of sediment to streams. Sediment loads derived from land being cleared or filled for the building of houses, roads, and other facilities are best documented in the area between Washington, D.C. and Baltimore, Maryland. During periods when housing developments, shopping centers, and highways are being built, the soil is disturbed and left exposed to wind and rain. Sediment yields may reach 60,000 to 80, 000 short tons/ mi^2/yr. Even though the soil is left exposed to erosion of this intensity for only a short time--a few years at most--the amount of land cleared for new housing and ancillary uses in the Washington-Baltimore area has been so great in recent years that the contribution of sediment is significantly large. Harold Guy of the U.S. Geological Survey has estimated that the Potomac River receives about a million tons of sediment per year from streams that drain the metropolitan Washington area. This is about the same amount of sediment that the Potomac River brings into the Washington area from all its other upland sources.

Another of man's activities that increases the sedimentation rates of estuaries is the disposal of dissolved phosphorus, nitrogen and other plant nutrients into rivers and estuaries. Municipal sewage effluents, including effluents that have received secondary treatment--the highest degree of conventional treatment--contain high concentrations of nutrients. In some areas, agricultural runoff from fertilized croplands and animal feedlots also contributes nutrients to river waters and estuaries. These nutrients promote the growth of diatoms and other microscopic plants (phytoplankton) both in the rivers and in the estuaries that the rivers flow into. The mineral structures formed by many of these organisms persist after the organisms die and become part of the sediment loads of the rivers and the sedimentary deposits of the estuaries. The Army Corps of Engineers estimates, for example, that the diatom frustules produced in the Delaware River and Delaware Bay contribute about the same amount of sediment (a million-and-a-half tons per year) to the Delaware estuary as all other upland river sources. The effects of nutrient loading from municipal wastes on primary productivity are readily observable in the Potomac estuary, in

Baltimore Harbor and the Back River estuary. Stimulation of plant growth by nutrient-enriched runoff from agricultural areas is apparent in the upper Chesapeake Bay.

Man's activities can also decrease sediment inputs. Construction of reservoirs on the lower reaches of the Susquehanna and on other tributary rivers decreased the inputs of sediment to the Bay and virtually eliminated any discharge of sand.

The net effect of man's activities has certainly been to increase the sediment inputs to the upper Chesapeake Bay over those characteristic of pre-colonial days, but we can not say by how much.

While it is clear that more effort should be directed at reducing sediment at the source through proper soil conservation practices, sedimentation rates will remain relatively high throughout the upper Chesapeake Bay and particularly in the dredged navigation channels. Maintenance dredging will continue to be required so long as the upper Bay is a major shipping artery and Baltimore Harbor is a major port.

Bottom Sediments. The bottom sediments of the upper Bay are predominantly silt and clay except in the nearshore zone where sand locally derived from erosion of the coast predominates (Ryan, 1953; Schubel, 1968a; Palmer et al., 1976). Sand is also abundant on the Susquehanna flats--an estuarine delta formed near the head of the estuary by deposition of sand discharged by the Susquehanna during periods of high flow. Since construction of the dams along the lower reaches of the Susquehanna, very little sand, and all of that fine-grained, is discharged into the Bay. Conowingo, the last of the dams to be constructed and the one closest to the mouth of the River, was completed in 1928. The only active sources of sand to the main body of the Bay are its margins.

Quartz is by far the most abundant mineral in the silt and sand size fractions and generally accounts for more than 90% by mass of the total sand-silt fraction. Muscovite, glauconite, and biogenic particles are also ubiquitous in the silt size fraction. The most common clay minerals are illite, kaolinite, and montmorillonite which occur roughly in the ratios 2:1:1 (Owens et al., 1974).

A map showing the percent by mass of clay in the bottom sediments of the main body of the upper Chesapeake Bay, in the Patapsco estuary and in the lower Chester River estuary is presented in Figure 2. A map depicting the distribution pattern of the ratio of the mass of the silt fraction to the sand fraction in the same area is shown in Figure 3. These figures clearly show that the upper Bay is largely blanketed by mud (silt and clay), and that the mean grain size of the bottom sediments in the Bay proper tends to decrease downstream. Relatively little has been published about the character of the sediments in the tributary estuaries to the upper Bay, other than the Patapsco and the lower Chester. The sedimentological and geochemical investigations being conducted by the Maryland Geological Survey in the major tributaries will provide much needed information.

It is well known that many contaminants--metals, hydrocarbons, chlorinated hydrocarbons (CHC), including pesticides and polychlorinated biphenyls (PCB), microorganisms, and oils and greases--are adsorbed to particulate matter and are concentrated in the finer size fractions. Since these contaminants are scavenged relatively rapidly from the water by fine-grained particulate matter, their dispersal and accumulation are controlled largely by suspended sediment dispersal systems.

Turekian and Scott (1967) and Carpenter et al. (1975) reported on the introduction of metals to the upper Bay by the Susquehanna. There have been few published studies documenting the levels of metals or other contaminants in the bottom sediments of the upper Chesapeake Bay and its tributary estuaries, except in Baltimore Harbor, and fewer still of the processes that control the occurrence and the distribution of these contaminants in time and space, and their availability for uptake by organisms.

Sediments within Baltimore Harbor are enriched in most metals with concentrations 3 - 50 times those found in texturally similar sediments along the axis of the main body of the Bay (Villa and Johnson, 1974). The average chromium, copper and lead values in the Harbor were 20, 50 and 13 times the corresponding values in the Bay proper. Cadmium was approximately six times higher in the Harbor than in the Bay. Of all metals analyzed, only manganese had approximately equal concentrations in the two areas. The distribution of metals within the Harbor, as shown by Villa and Johnson's (1974) analyses of samples from 176 stations, generally reflected the industrial inputs. Their report points out "all Harbor metals investigated but manganese were 3 to 50 times greater than their Bay

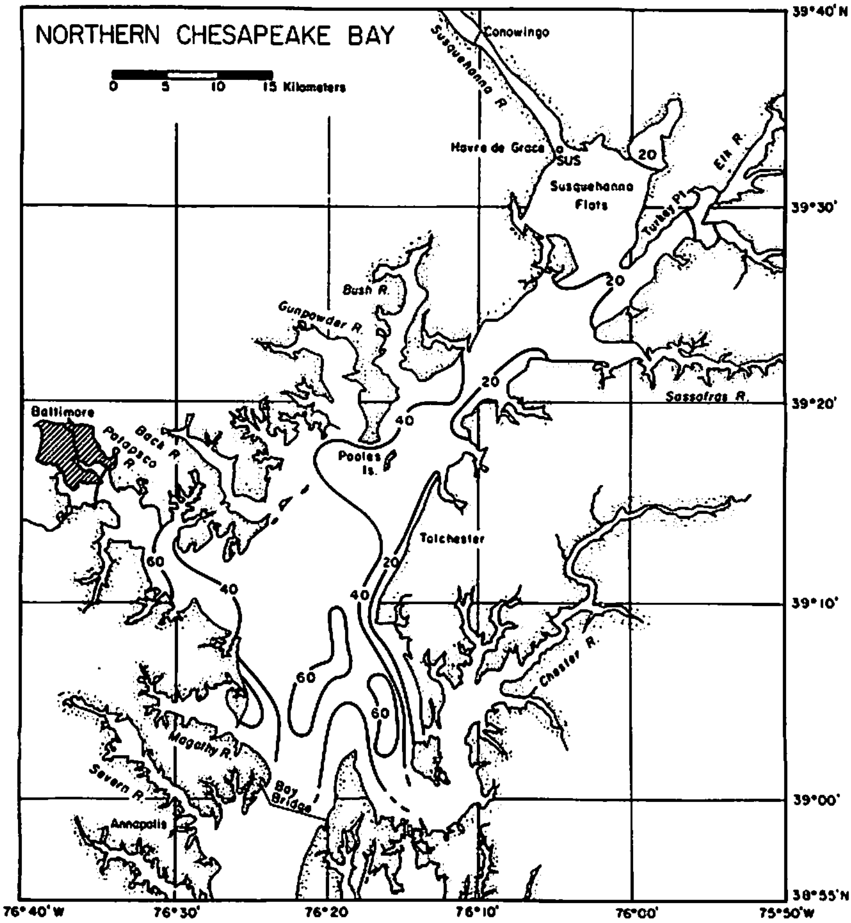

Figure 2. Map showing the percent by mass clay in the surface sediments of the upper Bay (After Palmer et al. 1975).

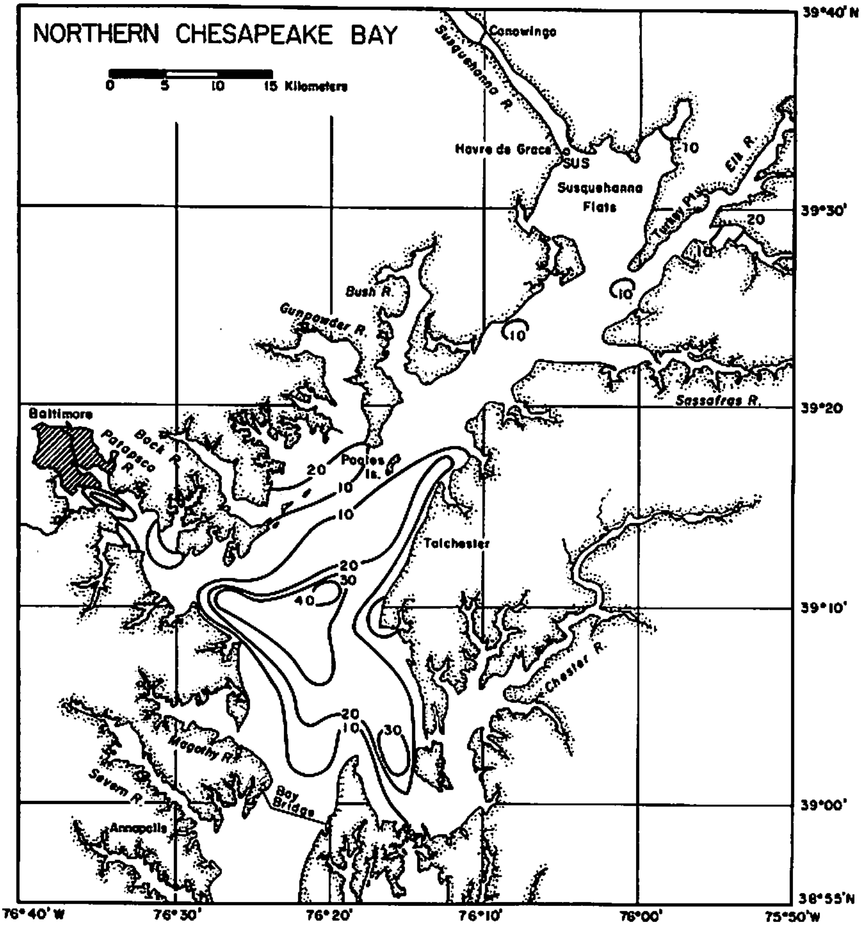

Figure 3. Map of the ratio of silt to sand in the surface sediments of the upper Bay (After Palmer et al. 1975).

counterparts. These factors should be carefully weighed when considering the disposal of dredged spoil in any open Bay areas."

High metal concentrations in sediment are not in themselves diagnostic indicators of "pollution" unless the metals are available for biological uptake. The methods of extraction of metals from the sediments for chemical analyses used in Villa and Johnson's (1974) study do not give a reliable indication of the available fraction; that fraction available for biological uptake, or that might be mobilized during dredging and disposal.

Munson (1975) documented the distributions of total PCBs and DDTR (the total residual of the pesticide DDT) in the surficial sediments of the main body of the upper Chesapeake Bay and the Patapsco estuary. His analyses showed "that the sediments of Baltimore Harbor are quite high in PCB compared with the rest of the bay, except the station at the mouth of the Gunpowder River." The highest values of DDTR were also found in Baltimore Harbor and the mouth of the Gunpowder although the range in values was much more restricted.

While there are relatively few observations of contaminant levels in the surficial sediments of the upper Bay, analyses of the longer-term sedimentary record are even more scarce. Schubel (1972a) reported on the distribution of extractable iron and zinc in a 53 inch long core taken in the upper Chesapeake Bay off Howell Point. The core was sampled at the surface and at eight inch increments to the bottom of the core. One might have anticipated that the concentrations of iron and zinc would decrease with depth, since man's impact has presumably increased in recent decades. The results showed, however, that below the surficial layer the concentrations were nearly uniform with depth. The concentration of zinc was about 70 ppm (dry weight) and the concentration of iron about 20 ppt (dry weight).

The Susquehanna River is probably the major source of sediment to the main body of the Chesapeake Bay at least as far seaward as the mouth of the Patapsco, and to the lower reaches of the estuaries that are tributary to this segment of the Bay. Near the head of the Bay--from Tolchester to Turkey Point--the sedimentation is completely dominated by the Susquehanna River (Schubel, 1968a,b; 1971; 1972a,b).

Scientists of the Chesapeake Bay Institute recently completed a geochemical study comparing the sediments in the channel of the upper Chesapeake Bay from Pooles Island to Turkey Point with those in the overboard spoil disposal area to the west of the channel (M. G. Gross, personal communication, November, 1976). These data are not available for our examination, but we find it difficult to conceive how the sediments in the two areas could be significantly different in most properties. One might anticipate that sediments in the channels would be slightly finer-grained and perhaps be enriched in oils and greases.

Dredging and Development of the Port of Baltimore

Baltimore Harbor. Colonization of what is now the State of Maryland began early in the 17th century with the explorations of Captain John Smith. The area was quickly settled and by mid-century what is now Anne Arundel County was relatively well populated along its navigable waterways (Owens, 1941). The first attempts at founding a "Baltimore Town," first on the Bush River in 1683 and ten years later on the eastern shore, failed. These settlements were little more than shipment points for tobacco, the colony's only commercial produce of any importance. In 1729, another area was laid out for a Baltimore Town, on the Northwest Branch of the Patapsco River at Cole's Harbor, the site of present day Baltimore, Figure 4.

The colonial harbor of Baltimore Town was surrounded by marshes and swamps. The prevailing depth in Cole's Harbor (now the inner Harbor) was generally too shallow for trans-Atlantic sailing vessels, and most such vessels were forced to lay off Fell's Point. The first wharves from Cole's Harbor to deep water extended up to 1,000 ft over marshland. In 1730 only Calvert Street reached navigable water. According to Scharf (1881), the sediment carried by the Jones Falls had rendered most of the northern side of Cole's Harbor a "mud shoal," and a huge marsh (now Harrison Street) extended along the eastern shoreline of the Town. Mining of iron ore and tobacco farming near Elk Ridge dramatically increased sediment yields leading the Maryland Assembly to pass an environmental act, probably the first in the colonies, in 1753, an "Act to prevent injuring the navigation to Baltimore-town, and to the inspecting house at Elk Ridge Landing, on Patapsco River" (Original Recorded Laws of Maryland HS #1, p. 117).

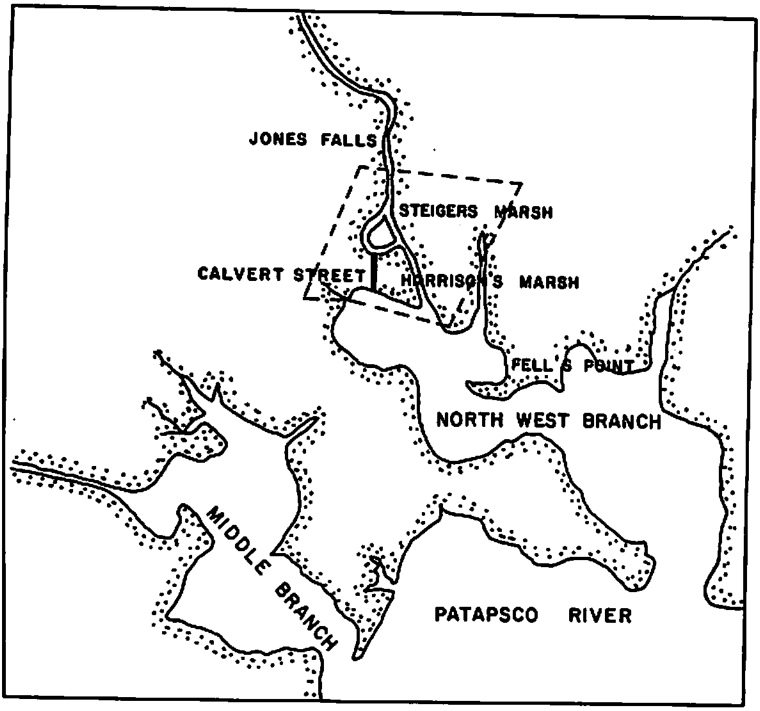

Figure 4. Map of Baltimore Harbor during the Colonial period.

While not accessible to seagoing vessels even in colonial days, the tributary streams of the area were navigable for shallow-draft boats far above present day limits. The Patapsco was open to Elk Ridge Landing, six to seven miles above the present head of navigation (Scharf, 1881; USACE, Annual Report, 1931). The navigable part of the Middle Branch was about four miles long, and Curtis Bay and Creek were open for about six miles. The natural water depths of the North and Middle Branches were about 17 ft at mean low water, and the original controlling depth in Curtis Bay was 20 ft (USACE, Annual Report, 1914). Today the prevailing depths in these areas are less than about 15, 10, and 15 ft, respectively.

By the mid-18th century, silting of the Harbor was a recognized problem. One early ordinance forbade the deposition of soil on marshes to extend private property without construction of a retaining wall of logs or stone (Owens, 1941). The first dredging of the Harbor dates to about 1780; mud was dug up with a makeshift arrangement of scoops and pulleys and deposited on adjacent wetlands. This served the land needs of the growing town as well, and buildings spread over the newly created fastlands (Owens, 1941).

Baltimore became a Port of Entry in the 1780s. To further development of the Port a tax was levied against entering cargo, and the money given to the "Wardens of the Port," a committee responsible for improving and maintaining the waterways. Gradually the shorelines were altered significantly; a shallow bay near Fell's Point was filled and built upon, as were the "hook" at Fell's Point and the marshes at Jones Falls. Bends in the river were filled, cutoff channels were dug, and stone retaining walls constructed to help control flooding (Owens, 1941). Steiger's Marsh and Harrison Marsh had virtually disappeared by the end of the century. A writer in 1818 noted:

> ". . . it will be found that not one-third of the surface of the basin, covered with navigable water in 1752, remains open; and that the extent of basin which is left is now more shallow by five to ten feet than it was twenty-five years ago. . . the water has shoaled to the exclusion of ship navigation above Fell's Point" (cited in Scharf, 1881).

The history of federal participation in navigation improvements in Baltimore Harbor dates back to 14 December 1826 when the U.S. House of Representatives passed a resolution directing the Secretary of the Navy to report on the survey of the Harbor that had been carried out under the direction of Master Commandant Clayton on 4 November 1826. The first federal appropriation for navigation improvements in the Harbor came a decade later in 1836 when Congress appropriated $20,000 to "deepen the Harbor of Baltimore" (USACE, Annual Report, 1916). No project dimensions were specified with the initial appropriation, but in 1852, the law was revised and dimensions were fixed to provide a channel 22 ft deep and 150 ft wide to deep water in Chesapeake Bay. The upper channel, from Fort McHenry to below Fort Carroll, was 6 NM long, and was naturally 19 to 21 ft deep at mean low water. The lower section of the channel, from 1.5 mi below Fort Carroll to approximately 4 mi past North Point, was 9 NM in length and 16 to 18 ft deep naturally (Scharf, 1881).

Little of the authorized work was actually done prior to the Civil War, and only the lower reaches of the channel had been completed by 1860 (U.S. Engineer Office, Baltimore, 1886). In 1872 the project was again revised and divided into three sections (from north to south): the Fort McHenry, Brewerton and Craighill channels. Dimensions were increased for a complete channel 400 ft wide at the lower end tapering to 250 ft wide at the upper end, with a uniform depth of 24 ft (USACE, Annual Report, 1916). This dredging was completed in 1874 (U.S. Engineer Office, Baltimore, 1886). In 1881 it was realized that the Brewerton section was subject to continuous shoaling by sediments carried into Chesapeake Bay by the Susquehanna River (USACE, Annual Report, 1916). This led to relocation of this section to a shorter route. The project dimensions were increased that year to provide an entire channel 27 ft deep and 600 ft wide. It was believed by the Corps of Engineers (Craighill, 1874; cited in USACE, Annual Report, 1916) that "constant and careful use . . . by screw-steamers" would maintain and improve the channel depth.

Further improvements to the project were authorized by Congress in 1896. These specified a channel 30 ft deep, 600 ft wide at the bottom, and 1,200 ft wide at the angles between sections. In 1892 and 1896 Curtis Bay and Middle Branch, respectively, were also adopted as federal navigation projects. Dimensions for the Curtis Bay section, as modified in 1902, specified a channel 30 ft deep and 250 ft wide, from the main ship channel (Fort McHenry section) to the wharves in South Baltimore Harbor. This work was completed in 1904. Specifications for the Middle Branch included a channel 27 ft deep and 100 ft wide from the main ship channel to Eutaw Street, with a turning basin 400 ft square (USACE, Annual Report, 1921). This channel had previously been dredged by the City to a depth of 15 ft (USACE, Annual Report, 1931). The federal improvements were completed in 1905.

Commercial shipping interests in Baltimore constantly urged improvements to the channels over the last half of the 19th century. The City provided much of the money for the dredging and was responsible for the first improvement of the inner Harbor (Northwest Branch), and its connection to the main ship channel (USACE, Annual Report, 1915). In 1867 the Wardens of the Port were replaced by a Harbor Board, and it was largely through the efforts of this committee that the project was so often improved by the federal government.

Since 1896, further improvements to the three projects (later incorporated into one) have been authorized by Congress twelve times. Depths of 35, 37, 39, 42, and 50 ft in all or parts of the main ship channel were specified in 1905, 1930, 1945, 1958, and 1970, although Congress has not appropriated any money for the last authorization and no improvement dredging has been done under it. This calls for a main ship channel from Chesapeake Bay to Fort McHenry 50 ft deep and 800 ft wide, a 50 ft deep and 600 ft wide Curtis Bay channel, a Northwest Branch (east) channel 49 ft deep and 600 ft wide and a Northwest Branch (west) channel 40 ft deep and 600 ft wide. Included in the project are three turning basins (and other anchorages) the shallowest depth of which being 40 ft and the narrowest width 950 ft (USACE, Annual Report, 1974).

The initial improvement dredging of the inner Harbor was done by local interests and the Town and City of Baltimore. As mentioned above, this work dates to the 18th century. The last improvement of the inner Harbor by the City occurred after World War I. This produced 2.7 x 10^6yds^3 of spoil which were placed behind bulkheads. In 1931 the City of Baltimore constructed an airport for which about 10 x 10^6yds^3 of spoil from federal dredging were used as fill. Local interests have been responsible for the creation and maintenance of docks and waterfront channels. Although figures for the total amount of dredging done by City and local interests are not available, it is probable that most spoil created by this dredging, for maintenance and improvement, was placed on land within City limits well into the 20th century. In recent years most spoil produced by private dredging--which frequently reaches several hundred thousands of cubic yards per instance--has almost certainly been dumped in the upper Bay.

<u>Channels in Main Body of Upper Bay</u>

The Approach Channel to the C & D Canal. Rapid economic growth of the Port of Baltimore was not only responsible for constant improvement of its Harbor and channels, but also was the ultimate cause of federal takeover of the Chesapeake and Delaware (C & D) Canal in 1919, its subsequent transformation to a sea level ship canal, and its enlargement. Massive improvements to this route, authorized by Congress in 1935, included creation of an approach channel in the Elk River in the upper Bay 27 ft deep and 250 ft wide (USACE, Annual Report, 1974). This work was performed by the Philadelphia District of the Army Corps of Engineers, whose jurisdiction into Chesapeake Bay extends only as far as the seaward end of this channel.

Improvement dredging to create the approach channel occurred in federal fiscal years FY 1937-38. This work resulted in a channel approximately 11 NM long, and produced over 24 x 10^6yds^3 of spoil, all of which were disposed of on land near Pearce Creek, at the mouth of the Elk River.

Maintenance dredging from FY 1938-63 generated at least 8 x 10^6yds^3 of spoil, or an average of about 300,000 yds^3 yearly. The disposal areas for this spoil are not identified in the annual reports.

Improvement dredging of the approach channel was again authorized in 1954, and fixed dimensions of the channel at 35 ft deep and 450 ft wide, and also included an anchorage in the Elk River 1,200 ft wide and about 3,700 ft long. This new-work dredging was in progress from FY 1964-68, and resulted in over 19 x 10^6yds^3 of dredged spoil, of which probably half were dumped overboard in the upper Bay in sites which run parallel to the approach channel. No further improvement work to the approach channel has been authorized by Congress since 1954.

Maintenance dredging of this channel since FY 1964 has produced over 2 x 10^6yds^3 of spoil, or about 170,000 yds^3/yr on average. It is probable that about one-half of this was also disposed of overboard in the sites mentioned above.

Creation and improvement of this channel has produced over 43 x 10^6yds^3 of dredged spoil; maintenance dredging over its lifetime approaches about 10 x 10^6yds^3. Although exact figures on overboard disposal of spoil from this channel are not available, it is likely that a minimum of 10 x 10^6yds^3, and perhaps as much as 20 x 10^6yds^3, have been dumped in the upper Bay since FY 1937. It is estimated that future maintenance dredging requirements for this channel will be at the rate of 150,000 - 200,000 yds^3/yr.

The Connecting Channel from Baltimore to the C & D Approach Channel. In 1945 Congressional authorization for improvement dredging for Baltimore Harbor and its channels included for the first time the construction of a connecting channel, 27 ft deep and 400 ft wide, from the Cutoff-Brewerton Angle of the main ship channel to deep water in Chesapeake Bay, Figure 5. The purpose of this connecting channel was to improve access to the Canal through the upper Bay. This dredging was done in 1947 and produced about 5 x 10^6yds^3 of spoil, all of which were dumped overboard in deep water outside of the channel.

In 1958 further improvement authorization for the entire Baltimore project specified enlargement of the connecting channel to 35 ft deep and 600 ft wide. The connecting channel was extended to include three disconnected sections leading through the upper Bay to the C & D Canal approach channel, Figure 5. Hopper dredging for this purpose did not begin until 1968, and only 2 x 10^6yds^3 of spoil were removed from the channel, leaving most of the improvement work undone (R. Cucina, USACE, personal communication, October, 1976). This spoil was also dumped overboard in deep water in the upper Bay. The present depths of the entire connecting channel are from about 25 to 30 ft. Further enlargement to this channel was not included in the last Congressional improvement authorization in 1970, and the Baltimore District of the Corps of Engineers has tentatively scheduled improvement dredging to the 1958 standard for the early 1980s (R. Cucina, personal communication, October, 1976).

The exact amount of material removed from the connecting channel since its creation for maintenance is unknown. No maintenance dredging has been done in the sections of the channel created in 1968. About 1 x 10^6yds^3 were removed by hopper dredge from the original section of this channel from FY 1962-67. Almost all of this spoil was deposited in the Kent Island dump site. Some maintenance dredging of the same section occurred in the 1950s, but the

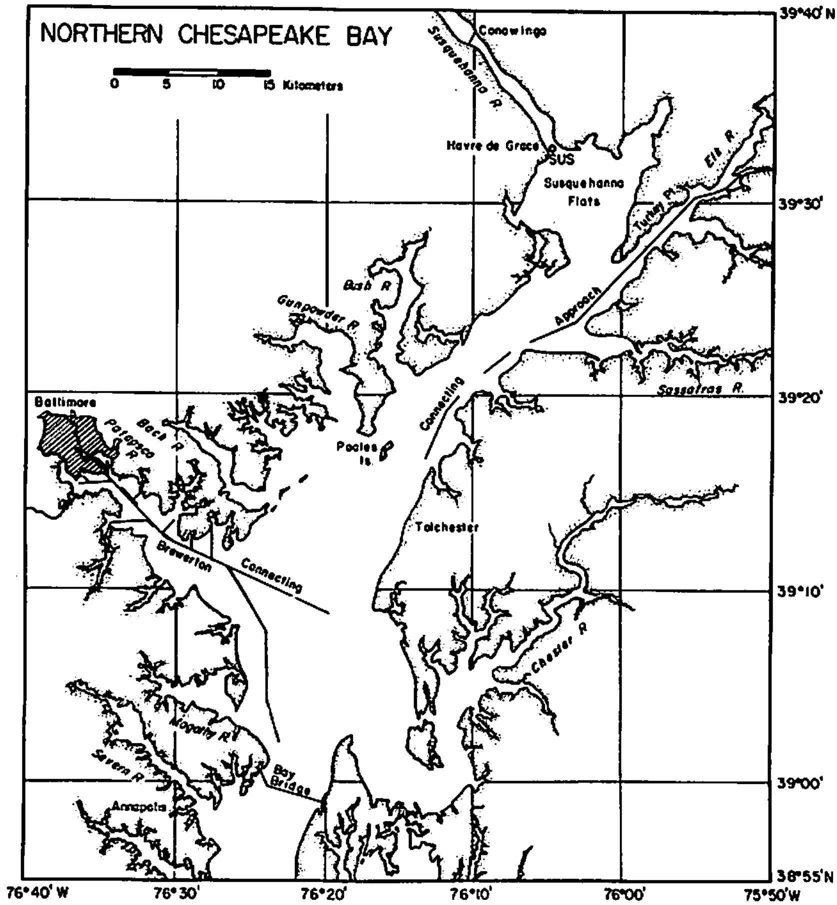

Figure 5. Map of upper Chesapeake Bay showing the major shipping channels maintained by dredging. The channel to Port Deposit is not shown.

amounts removed and the disposal areas used in the upper Bay are unknown.

Some Summary Statistics on Dredging in Upper Chesapeake Bay

Dredging in the Baltimore District of the U.S. Army Corps of Engineers. A graphical summary of the volumes of material dredged by the Army Corps of Engineers from Baltimore Harbor, its main ship channels and the connecting channel, in successive five year periods from 1870-1975 is presented in Figure 6. The figure clearly shows that most of the material dredged from these areas has been for new work. A plot of the cumulative volume of material dredged from these areas over the period 1869-1976 is presented in Figure 7. These data show that over 180 x $10^6 yds^3$ of material have been dredged from the entire Baltimore project area since 1869, and that approximately 130 x $10^6 yds^3$, or more than 70% of it, have been for new work. In the last 30 years, about 70 x $10^6 yds^3$ of material have been dredged from these areas, of which 51 x $10^6 yds^3$ or about 70%, have been for new work. Examination of U.S. Army Corps of Engineers records indicates that almost all of the total volume dredged by the Corps since 1869 has been disposed of in a variety of open water sites in the upper Chesapeake Bay. Historically, the material dredged from the inner Harbor has either been disposed of overboard within the Harbor, or much more frequently it has been placed on adjacent wetlands and fastlands. Sediments dredged from the outer Harbor, from the approach channels to the Harbor, and from the connecting channels off the mouth of the Harbor and in the upper Bay above Pooles Island have been disposed of overboard in areas paralleling the channels or on the Kent Island dumping grounds.

Since FY 1946 about 37 x $10^6 yds^3$ of spoil have been removed by the Corps of Engineers from Baltimore Harbor and its main ship channel for improvement. No improvement dredging has been done in this area of the Baltimore project to enlarge the channels to the 1970 authorized dimensions and the last new work dredging in this area was completed in FY 1966. Most of this dredging was done in the three sections of the main ship channel: Fort McHenry, Brewerton, and Craighill. Thirty million cubic yards of this spoil were disposed of overboard, usually in spoil areas which run parallel to the main ship channel. Over 6 x $10^6 yds^3$ were dumped in the Kent Island site in the upper Bay, and about 300,000 yds^3 from the Harbor area were placed on shore.

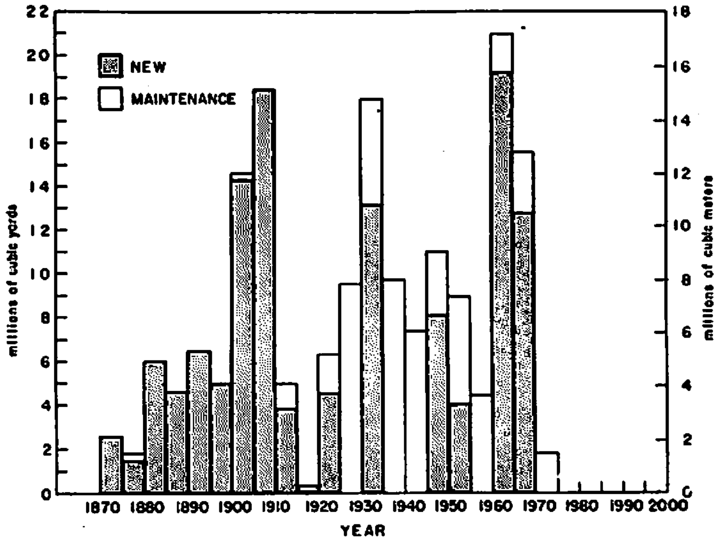

Figure 6. Volume of material dredged from Baltimore Harbor Project area during successive five-year periods, 1870-1975.

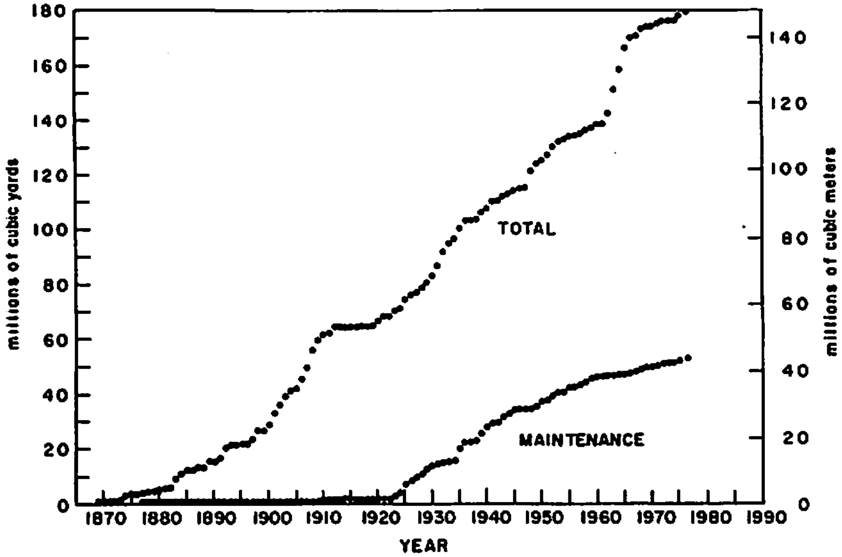

Figure 7. Cumulative volume of material dredged from Baltimore Harbor Project area, 1869-1976. The figure includes material dredged from the connecting channel in the upper Bay.

Dredging for maintenance of the Harbor and main ship channel by the Corps of Engineers since 1946 has produced at least 16 x 10^6yds^3 of spoil. About 6 x 10^6yds^3 of this were placed at the Kent Island dump site, the remainder being disposed of overboard in various sites in the upper Bay. At least most, and perhaps all, of this maintenance work was performed by hopper dredges.

The areas of this part of the Baltimore project which require the most frequent maintenance dredging are the angles between sections of the main ship channel. Shoaling in the Harbor itself is far less severe. The main ship channel, particularly the angles, requires yearly maintenance dredging. In FY 1975 and 1976, for instance, a total of about 1.5 x 10^6yds^3 of spoil were removed from these areas, and a conservative estimate of maintenance dredging requirements for Baltimore Harbor and the main ship channel is 500,000 yds^3/yr (R. Cucina, personal communication, October, 1976).

Dredging in the Philadelphia District of the U.S. Army Corps of Engineers--the Approach to the C & D Canal. Figure 8 shows the cumulative volume of material dredged from the approach to the C & D Canal between 1937, when the first dredging was conducted, and 1976. The data do not include material dredged from the Canal itself. The total volume of material dredged over this 40-year period is nearly 55 x 10^6yds^3, of which only about 10 x 10^6yds^3 were maintenance. Certainly more than 10 x 10^6yds^3, and perhaps as much as 20 x 10^6yds^3, were disposed of overboard. The remainder was placed on fastlands bordering the Bay.

Economic Importance of the Port of Baltimore

According to a 1973 economic impact study of the Port of Baltimore on Maryland, carried out by the University of Maryland (Hille et al., 1975), the Port of Baltimore is the most important economic component of the State of Maryland, having a total impact of about \$2.5 billion each year. The total direct impact is greater than \$740 million each year while the total indirect impact is approximately \$1.8 billion. Direct impacts are those that arise directly from the traffic handled by the Port and include: vessel disbursements, crew expenditures, surface transportation, insurance and banking, and port services. Indirect impacts are those which are dependent on the Port but not directly related to the traffic handled by it. These include such categories as port-

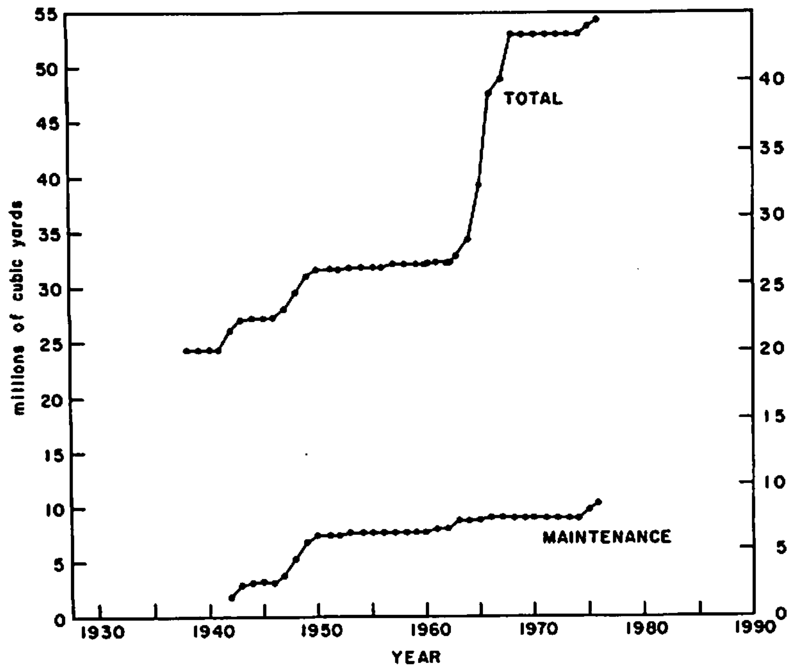

Figure 8. Cumulative volume of material dredged from the approach to Chesapeake and Delaware Canal, 1937-1975. The figure does not include material dredged from the Canal itself.

related primary metals processing, other port-dependent processing, shipbuilding, repair and dismantling, and government expenditures. The study showed that of the direct impacts, the most significant contribution came from the inland surface movement of cargoes which approached $370 million. Primary metals processing, whose total contribution exceeded $900 million, was the most significant of indirect impacts.

The report points out that in 1973 the Port directly employed 65,000 people and that port-related employment added another 104,000 jobs. This total indicates that about 10% of all jobs in Maryland are ultimately dependent on the Port.

In 1973, Maryland had a Gross State Product (GSP) of $25.1 billion. Of this total, the Port accounted for $2.5 billion, or nearly 10% of the overall GSP. In 1973 the Port was responsible for $317.3 million of tax contributions to the State, county, and local governments of Maryland. Baltimore City received $115.1 million (36%) of this total, Baltimore County $86.9 million (27%), the State $82.5 million (26%), and $32.9 million (10%) went to other local subdivision governments. According to the 1973 economic impact study, the Port of Baltimore is "the ultimate source of a significant proportion of the total goods and services produced in the State of Maryland. Its impact on the economy of the State is immense."

The importance of the Port of Baltimore to the City of Baltimore and to the State of Maryland is clear. But, fisheries and recreational uses of the upper Bay are also economically important, although their values are more difficult to assess. And if communion with nature is one of man's ultimate sources of happiness as Dubos (1968) suggests, then one can not adequately measure the recreational and aesthetic value of an estuary in dollars and cents. The justification for dredging and spoil disposal must be assessed not only in terms of the value of the shipping to the economy but also in terms of the extent of the impacts of these activities on the environment and the biota of the upper Bay--their conflicts with other uses.

Dredging-Related Research

Large amounts of money have been spent on dredging-related research in the Chesapeake Bay. Over the past ten years alone, the State of Maryland has contracted for about

$3 million of dredging-related research and has spent a large amount of money on in-house projects (F. Hamons, personal communication, October, 1976). There has also been a substantial amount of federally-supported research related to dredging problems in the Chesapeake Bay. These research projects have covered a variety of field studies including: physical behavior of dredged materials during and subsequent to disposal; effects of suspended sediment released during dredging and disposal on plankton (including ichthyoplankton), fish and water quality; effects of dredging and disposal on benthic communities; effects of enlarging the Chesapeake and Delaware Canal on the distribution of salinity in the upper Bay; and the sources and distribution of metals and halogenated hydrocarbons in the upper Bay. There have also been a number of laboratory studies to assess: effects of suspended solids on a variety of estuarine organisms; uptake by shellfish of contaminants adsorbed to fine particles; and the affinity of particles for contaminants.

As pointed out previously, since 1946 more than 70 x 10^6yds^3 of material dredged from the Harbor, its approach and connecting channels, and from the approach to the C & D Canal have been disposed of in open water sites in the upper Chesapeake Bay, most by overboard methods.

The most comprehensive field investigation of the acute (gross) effects of dredging and overboard spoil disposal on the environment and biota of the upper Chesapeake Bay was conducted by scientists of the University of Maryland's Chesapeake Biological Laboratory between November, 1965, and November, 1968. The last time there was any significant dredging in the connecting channel in the upper Bay and in the approach to the C & D Canal was between 1964 and 1967. Most of the material was disposed of overboard through a submerged pipe with a right angle elbow and deflected off a plate parallel to the sea surface and located at a depth of about 6 ft--3 ft below the point of discharge. The disposal area was to the west of the channel.

The studies were designed to determine "gross effects" which were defined by Cronin (1970) to:

> "include those relatively large-scale effects which can be detected by the methods used in each project. These were designed to test for any massive mortalities, population reductions at

> the sites tested, or indications of direct and lethal damage to individual organisms."

These investigations showed that the effects of the discharge plume on water quality--suspended sediment (turbidity), dissolved oxygen and nutrients--were local and did not persist after dredging was halted for any reason. According to Biggs (1970b), the maximum linear extent of the turbid plume detectable with transmissometers was about 17,000 ft, and it usually did not exceed 9,000 ft. An increase in turbidity over background levels was never measured more than one tidal excursion from the source, and the areal extent of the plume was confined to an area of less than 1.5 NM^2. The total surface area of the segment of the main body of the upper Bay from Tolchester to Turkey Point is approximately 120 NM^2. Shape and orientation of the plume were highly variable because of the vigorous tidal currents, 1 to 2 knots, and whenever dredging was stopped the excess turbidities dissipated to background levels within one to two hours.

Biggs (1970b) documented the distribution of dissolved oxygen within the turbid plume and in surrounding waters and reported

> "the data indicate that there was little or no oxygen sag except near the discharge site. Dissolved oxygen did decrease about 1 ppm (from 10 ppm to 9 ppm) within the first 600 m down current of the discharge site on 25 October 1967."

Flemer (1970) studied the acute effects of the turbid plumes on the phytoplankton of the upper Bay and observed that there were no gross effects. He regarded short-term effects of reduced light levels but noted that the effects were temporary. In the same report Goodwyn (1970) recorded the absence of any gross effects of the dredging and disposal operations on the zooplankton of the area.

Dovel (1970) concentrated his attention in the upper Bay dredging study on fish eggs and larvae. He pointed out that his field studies were far from the ideal experiment one could design to assess the gross effects of dredging and disposal on fish eggs and larvae and recommended that proper controlled laboratory experiments should be conducted. Such studies were subsequently done by Schubel and Wang (1973), Schubel et al. (1974), Auld and Schubel (1974), Morgan et al. (1973), and Sherk et al. (1975). Despite the limitations that Dovel points out concerning his field studies, they did fail to show any "gross effects as a result of dredging and spoil disposal activities."

In his studies of adult fish, Ritchie (1970) sampled the upper Bay from Tolchester to Turkey Point at monthly intervals from July, 1965, through June, 1968, with an otter trawl to document the distributions of fish in time and space in the upper Bay. He also placed fish of four different species--hogchocker, white perch, striped bass, and channel catfish--in cages in the disposal area to assess the effects of increased concentrations of suspended sediment on these fish. Gills of the exposed fish were examined microscopically to assess any damage to the epithelial cells of the gill filamental lamellae. From these and other associated investigations Ritchie conducted he concluded:

> "in summary, no gross effects, either beneficial or detrimental, of the shallow water overboard disposal in the upper Chesapeake Bay on the species of fish available for study were detected and/or related to the disposal."

As one would expect, the most significant and persistent effects of the dredging and disposal operation in the upper Bay were on the bottom dwelling organisms, the benthos. Pfitzenmeyer (1970) reported that shortly after disposal there was a 71% reduction in the density (number/area) of benthic organisms in the disposal area and that there was a "marked reduction" in the species diversity index. There was also a marked decrease in the species diversity index in the dredged area--the channel--after completion of the operation. The reported increase of 51% in the number of individuals in the dredged area may be due to the recruitment of the worm S. viridus, or as Pfitzenmeyer points out, it may not be meaningful because the density of organisms was very low and highly variable.

Recovery of benthic communities in the dredged and the disposal areas began soon after the project was completed and within one and one-half years the benthic communities of both areas were approximately at pre-dredging conditions.

In summary, the most comprehensive study of acute effects of overboard spoil disposal in the upper Chesapeake Bay failed to document any significant and persistent deleterious effects on water quality or on the biota. An assessment of these and other data and of the collective recommendation of each of the scientists that participated in this study indicates that major dredging and overboard disposal operations should probably be conducted during fall (October, November) or late winter and early spring (January through March) to ensure minimum impact on benthos, fish eggs and larval and adult fishes. According to Flemer et al. (1968), "October and November would be the time when dredging and spoil disposal would have the least effect on the biological components of upper Chesapeake Bay." It has not been established, however, that operations carried out during other seasons would have any significant or persistent adverse effects on the biota.

Cronin et al. (1976) investigated the physical effects of hopper dredge disposal on the Kent Island dumping grounds, and more recently Cronin et al. (in press) studied the effects of barge disposal in the outer Harbor. Both studies indicated that any demonstrable effects of disposal on water quality were local and did not persist. Investigators from the Chesapeake Biological Laboratory are documenting the effects of disposal on the benthic communities of the outer Harbor (W. B. Cronin, personal communication, November, 1976), but these data are not available for our review.

The only persistent effect of open water disposal that has been reported in the upper Chesapeake Bay is the interference of spoil deposits with drift nets used by many commercial fishermen in that area (F. Hamons, personal communication, November, 1976).

Laboratory experiments (Schubel and Wang, 1973; Schubel et al., 1974; Auld and Schubel, 1974; Sherk et al., 1975; Morgan, 1973) designed to assess the effect of different concentrations of suspended sediment on a variety of estuarine organisms indicate, in our opinion, that the excess concentrations of suspended sediment associated with dredging and disposal activities do not represent a demonstrable threat to the fauna of the upper Bay.

Studies have not been conducted that permit an unequivocal assessment of any chronic biological effects that might result either from exposure of organisms to spoil and associated contaminants for long periods, or from exposures to relatively subtle, but persistent, changes of the physico-chemico milieu resulting from dredging and spoil disposal. There is little justification--except perhaps to mollify the public--for repeating extensive studies of acute effects with future dredging projects. Some monitoring will be required for social-political reasons but it should be limited. Considerably more attention should be directed at the much more difficult questions of assessing chronic effects, and of developing an effective dredged spoil management plan.

While no significant or persistent deleterious environmental effects have been documented as a result of open water disposal of material dredged from the main shipping channel of the upper Chesapeake Bay overboard disposal is not the most effective method to minimize the frequency of dredging required to maintain the connecting channel in the upper Bay and the approach channel to the C & D Canal. Preliminary observations by Biggs (1970) indicated that a significant amount (more than 10%) of the dredged material placed in the overboard disposal area in 1966 could not be accounted for 150 days after completion of the project. This is not surprising. Schubel's research (1968a,b; 1969; 1971) on sedimentation processes in the upper Chesapeake Bay has clearly shown that sediments naturally or intentionally deposited on the flanks of the Bay, particularly to the west of the channel, are actively resuspended by wind waves and tidal currents and that there is a significant non-advective transport of fine suspended material toward the channel. The sedimentation rate in the channel, and therefore the frequency of dredging, could be reduced by confining the dredged material in nearshore areas or on fastlands, or by open water disposal in deeper areas of the Bay farther seaward in the estuary. The relative merits of the several methods of disposal, including the benefit/cost ratios, have not been adequately assessed.

Based upon a critical examination of all the pertinent published data and on our own experience, we conclude unequivocally that past dredging and spoil disposal operations have not had any demonstrable persistent deleterious effects on water quality or on the biota of the upper Bay. We also conclude that major dredging and disposal projects can, with proper planning and management, be carried out in the future with predictable and acceptable risk.

Recommendation: The Need for a Regional Dredged Material Management Plan

"The Port of Baltimore has long been recognized as Maryland's greatest economic asset" (Hille et al., 1975). If Baltimore is to remain a major port its channels must be maintained at least at their current project depths. Once the decision has been made to "preserve" the Port of Baltimore, a decision that has been implicit for about 200 years, it would seem reasonable to expect that a strategy would have been developed to ensure the maintenance of its channels. This has not been done. The recurrent maintenance dredging projects have frequently been delayed for one or more years since the 1960s. These delays have resulted in inconvenience, hazards to navigation, and a loss of revenue, all without the development of a workable dredged material management plan to avoid repetition of the problem.

Sedimentation processes and the resultant dredging problems in the upper Chesapeake Bay and its tributary estuaries are generic, and can therefore be effectively solved (managed) only through a decision that establishes a rule, a principle. To be effective, the decision must have built into it the action to carry it out, and a feedback mechanism to assess its effectiveness in a recurrent fashion. This "action" should be a regional dredged material management plan.

Scientists at the Marine Sciences Research Center of the State University of New York are developing a regional management plan for dredging and spoil disposal in the upper Chesapeake Bay with support from the State of Maryland, the U.S. Environmental Protection Agency, and the Rockefeller Foundation. The plan will include:

- designation and ranking of various areas for disposal of different "types"--quantities and qualities--of dredged material;
- recommendations as to time of year and methods of dredging and spoil disposal to minimize any deleterious environmental impacts;
- assessment of possible creative uses of dredged material in this region. These might include:

a. combining spoil disposal with shell mining,
b. construction of recreational islands,
c. use of dredged material to intentionally alter topography, and consequently circulation to improve productivity.

The plan, which will be based largely on existing data, will include a set of maps delimiting different "types" of sites--overboard, diked, etc.--for different "types" of spoil--different quantities and qualities. The areas will be ranked in terms of their assimilative capacities without suffering persistent and significant ecological or aesthetic damage. The map and plan will be based upon:

I. Ecological considerations
   A. Acute
   B. Chronic
II. Economic considerations
   A. Transport costs for different sites inside and outside Chesapeake Bay
   B. Capacity of various sites and of this segment of the Bay to receive dredged materials before experiencing persistent and significant aesthetic or ecological damage
   C. Proximity to possible shell mining sites
III. Social-political considerations
   A. Proximity to recreational areas used for water-contact sports and shellfish-finfish areas
   B. Proximity to "political" (governmental) boundaries
IV. An assessment of the methods and times of disposal and their relative impacts. Recommendations will be made as to the most desirable times of year, and methods of disposal to minimize impact.

While we are convinced that a dredged spoil management plan can be developed that will be scientifically defensible, we are less sure that it will be politically acceptable. Still, such a plan is long overdue.

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References

Auld, A. H. and J. R. Schubel. 1974. Effects of suspended sediment on fish eggs and larvae. Special Report 40 of the Chesapeake Bay Institute, the Johns Hopkins University, Baltimore, Maryland. 61 pp.

Biggs, R. B. 1970a. Sources and distribution of suspended sediment in northern Chesapeake Bay. Marine Geol. 9: 187-201.

Biggs, R. B. 1970b. Geology and hydrography, project A. Pages 7-15 in Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Special Report 3 of the University of Maryland's Natural Resources Institute (Chesapeake Biological Laboratory, Solomons, Maryland).

Carpenter, J. H., W. L. Bradford, and V. Grant. 1975. Processes affecting the composition of estuarine waters (HCO_3, Fe, Mn, Zn, Cu, Ni, Cr. Co, and Cd). Pages 188-214 in L. E. Cronin, ed. Estuarine Research, Vol. 1. Chemistry, Biology, and the Estuarine System. Academic Press, New York.

Cronin, L. I. 1970. Conclusions and recommendations. Pages 1-6 in Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Special Report 3 of the University of Maryland's Natural Resources Institute (Chesapeake Biological Laboratory, Solomons, Maryland).

Cronin, W. B. and M. G. Gross. (in press). Preliminary report on monitoring of dredging operation (Baltimore Harbor, Rock Point Dump Site) 10 April-26 May 1976. To be printed by Maryland Department of Natural Resources.

Cronin, W. B., M. G. Gross, J. A. Boggs, H. D. Palmer, J. L. Nolder, and D. G. Wilson. 1976. Monitoring of open water dredge material disposal operations at Kent Island disposal site and survey of associated environmental impacts. Sections One and Two published by the Chesapeake Bay Institute of the Johns Hopkins University, Baltimore, Maryland 21218; and the Westinghouse Ocean Research Laboratory, Annapolis, Maryland 21202.

Dovel, W. L. 1970. Fish eggs and larvae, Project E. Pages 42-49 in Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Special Report 3 of the University of Maryland's Natural Resources Institute (Chesapeake Biological Laboratory, Solomons, Maryland).

Dubos, R. 1968. So Human an Animal. Charles Scribner's Sons, New York. 267 pp.

Flemer, D. A., W. L. Dovel, H. T. Pfitzenmeyer, and D. E. Ritchie, Jr. 1968. Biological effects of spoil disposal in Chesapeake Bay. Jour. Sanitary Eng. Div., Proc. Amer. Soc. Civil Eng., Proc. Paper 6081, 94:683-706.

Flemer, D. A. 1970. Phytoplankton, Project B. Pages 16-25 in Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Special Report 3 of the University of Maryland's Natural Resources Institute (Chesapeake Biological Laboratory, Solomons, Maryland).

Goodwyn, F., Jr. 1970. Zooplankton, Project D. Pages 39-41 in Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Special Report 3 of the University of Maryland's Natural Resources Institute (Chesapeake Biological Laboratory, Solomons, Maryland).

Gottschalk, L. D. 1945. Effects of soil erosion on navigation in upper Chesapeake Bay. Geogr. Rev. 35:319-338.

Hille, S. J., C. A. Taff, A. J. Thieblot, Jr., and M. P. McGee. 1975. The economic impact of the Port of Baltimore on Maryland. Executive Summary Report prepared for the Maryland Department of Transportation. Division of Transportation, Business and Public Policy, College of

Business and Management, University of Maryland, College Park, Maryland 20742. 129 pp.

Morgan, R. P. II, V. J. Rasin, Jr., and L. A. Noe. 1973. Hydrographic and ecological effects of enlargement of the Chesapeake and Delaware Canal, Appendix XI: Effects of suspended sediments on the development of eggs and larvae of striped bass and white perch. University of Maryland, Natural Resources Institute, Ref. 73-110, 15 pp. + 6 figs.

Munson, T. O. 1975. Biochemistry, Chpt 6. Pages 6-1 through 6-30 in Upper Bay Survey, Vol. II, Technical Report. T. O. Munson (Project Chief Scientist), D. K. Ela (Project Manager), and C. Rutledge, Jr. (Project Engineer and Coordinating Editor). Westinghouse Electric Corporation, Oceanic Division, Annapolis, Maryland 21404.

Owens, H. 1941. Baltimore on the Chesapeake. Doubleday, Doran & Co., Inc., Garden City, New York. 342 pp.

Owens, J. P., L. A. Sirkin, and K. Stefansson. 1974. Chemical, mineralogic, and palynologic character of the upper Wisconsinan-Lower Holocene fill in parts of Hudson, Delaware, and Chesapeake estuaries. Jour. Sed. Petrology 44:390-408.

Palmer, H. D. 1973. Shoreline erosion in upper Chesapeake Bay: the role of ground water. Shore and Beach 41:18-22.

Palmer, H. D., J. R. Schubel, and W. B. Cronin. 1975. Estuarine sedimentology, Chpt. 4. Pages 4-11 through 4-63 in Upper Bay Survey, Vol. II, Technical Report. T. O. Munson (Project Chief Scientist), D. K. Ela (Project Manager), and C. Rutledge, Jr. (Project Engineer and Coordinating Editor). Westinghouse Electric Corporation, Oceanic Division, Annapolis, Maryland 21404.

Pfitzenmeyer, H. T. 1970. Benthos, Project C. Pages 26-38 in Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Special Report 3 of the University of Maryland's Natural Resources Institute (Chesapeake Biological Laboratory, Solomons, Maryland).

Pritchard, D. W. 1967. What is an estuary: physical viewpoint. Pages 3-5 in G. H. Lauff, ed. Estuaries. Amer. Assoc. Adv. Sci. Pub. No. 83.

Pritchard, D. W. 1968. Chemical and physical oceanography of the Bay. Pages II-49 to II-74 in Proceedings of the Governor's Conference on Chesapeake Bay. Summary proceedings of the Governor's Conference held at Wye Institute in Maryland on 12-13 September 1968. 213 pp. + appendices.

Ritchie, D. E., Jr. 1970. Fish, Project F. Pages 50-63 in Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Special Report 3 of the University of Maryland's Natural Resources Institute (Chesapeake Biological Laboratory, Solomons, Maryland).

Ryan, J. D. 1953. The sediments of Chesapeake Bay. Maryland Department of Geology, Mines and Water Resources Bull. 12. 120 pp.

Scharf, J. 1881. History of Baltimore City and County. Louis H. Everts, Philadelphia. 947 pp.

Schubel, J. R. 1968a. Suspended sediment of the northern Chesapeake Bay. Tech. Rep. 35, Chesapeake Bay Institute of the Johns Hopkins University. 264 pp.

Schubel, J. R. 1968b. Turbidity maximum of northern Chesapeake Bay. Science 161:1013-1015.

Schubel, J. R., ed. 1971. The Estuarine Environment, Estuaries and Estuarine Sedimentation. Amer. Geol. Inst., Washington, D.C. Short course lecture notes. 324 pp. (not numbered consecutively).

Schubel, J. R. 1972a. The physical and chemical conditions of the Chesapeake Bay. Jour. Wash. Acad. Sci. 62:56-87.

Schubel, J. R. 1972b. Distribution and transportation of suspended sediment in upper Chesapeake Bay. Pages 151-167 in B. W. Nelson, ed. Environmental Framework of Coastal Plain Estuaries. Geol. Soc. Amer. Memoir 133.

Schubel, J. R. 1974. Effects of Tropical Storm Agnes on the suspended solids of the northern Chesapeake Bay. Pages 113-132 in R. J. Gibbs, ed. Suspended Solids in Water. Plenum Press, New York.

Schubel, J. R. 1976. Suspended sediment in Chesapeake Bay. Pages 245-264 in Proceedings, Civil Engineering in the Oceans III, Vol. 1. American Society of Civil Engineers, 345 East 47th Street, New York 10017.

Schubel, J. R., A. H. Auld, and G. M. Schmidt. 1974. Effects of suspended sediment on the development and hatching success of yellow perch and striped bass eggs. Special Report 35 of the Chesapeake Bay Institute, the Johns Hopkins University, Baltimore, Maryland 21218. 12 pp.

Schubel, J. R. and H. H. Carter. (in press) Suspended sediment budget for Chesapeake Bay. Pages 48-61 in Martin Wiley, ed. Estuarine Processes, Vol. II: Circulation, Sediments, and Transfer of Material in the Estuary. Academic Press, New York.

Schubel, J. R. and D. J. Hirschberg. (in press) Pb^{210}-determined sedimentation rate, and accumulation of metals in sediments at a station in Chesapeake Bay. Chesapeake Science 18 (4).

Schubel, J. R. and J. C. S. Wang. 1973. The effects of suspended sediment on the hatching success of Perca flavescens (Yellow Perch), Morone Americana (White Perch), Morone saxatilis (Striped Bass), and Alosa pseudoharengus (Alewife) eggs. Special Report 30 of the Chesapeake Bay Institute, the Johns Hopkins University, Baltimore, Maryland 21218. 77 pp.

Schubel, J. R. and C. F. Zabawa. (in press) Agnes in the geological record of upper Chesapeake Bay. In The Effects of Tropical Storm Agnes on the Chesapeake Bay. Johns Hopkins University Press, Baltimore, Maryland.

Sherk, J. A., J. M. O'Connor, and D. A. Neumann. 1975. Effects of suspended and deposited sediments on estuarine environments. Pages 541-558 in L. E. Cronin, ed. Estuarine Research, Vol. II. Academic Press, New York.

Singewald, J. T. and T. H. Slaughter. 1949. Shore erosion in tidewater Maryland. Maryland Department of Geology, Mines and Water Resources Bull. 6. 140 pp.

Turekian, K. K. and M. R. Scott. 1967. Concentrations of Cr, Ag, Mo, Ni, Co and Mn in suspended material in streams. Environ. Sci. Techn. 1:940-942.

U.S. Army Corps of Engineers. Annual Reports of the Chief of Engineers, 1869-1974. Washington, D.C.

Villa, O., Jr. and P. G. Johnson. 1974. Distribution of metals in Baltimore Harbor sediments. Technical Report 59, Annapolis Field Office, Region III, Environmental Protection Agency. 64 pp., not numbered consecutively.

Zabawa, C. F. and J. R. Schubel. 1974. Geological effects of Tropical Storm Agnes on upper Chesapeake Bay. Maritime Sediments 10:79-84.

IMPACTS OF COASTAL DREDGING IN SAN PEDRO BAY, CALIFORNIA

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Port of Los Angeles

My remarks today are concerned with the impacts of recent California conservation and environmental planning and coastal zone management legislation affecting California ports in general and the San Pedro Bay ports of Los Angeles and Long Beach in particular. My remarks are intended to emphasize the fact that environmentalists must consider developed ports as a unique element in a coastal zone and must develop standards for such prime national economic bases which are different from standards for pristine, undeveloped coastal areas.

The attached enclosures to my remarks illustrate the historical development of the ports of Los Angeles and Long Beach in San Pedro Bay, California.

Enclosure 1 — The general Southern California area served by the ports—an area of 150 cities and about 7 million people.
Enclosure 2 — San Pedro Bay in 1872 when it was a lighterage area.
Enclosure 3 — San Pedro Bay in 1976.
Enclosure 4 — The 1990 proposed development plan for San Pedro Bay.
Enclosure 5 — The 1976 configuration superimposed on the 1872 configuration.

Coastal zone conservation legislation has been passed in many states and is under preparation in many others. The California Coastal Act of 1976 will become effective on January 1st, and is the end result of an initiative act that went into effect in 1972 entitled, "The California Coastal Zone Conservation Act of 1972". The 1972 Act set up a state commission and six regional coastal commissions granting the commissions development permit power in the coastal zone and charged them with preparing a coastal plan to be codified by the legislature to protect and manage the Coast. The 1972 Act, in its general provisions, stated that:

> " — the permanent protection of the remaining natural and scenic resources of the coastal zone is a paramount concern to present and future residents of the state and nation; that in order to promote the public safety, health, and welfare and to protect public and private property, wildlife, marine fisheries, and other ocean resources, and the natural environment, it is necessary to preserve the ecological balance of the coastal zone and prevent its further deterioration and destruction; that it is the policy of the state to preserve, protect and, where possible, to restore the resources of the coastal zone for the enjoyment of the current and succeeding generations; —"

Based on this and similar language, the commissions and their staffs, in drawing up their coastal plan, concluded and publicly stated that they were not mandated to consider the economic consequences of their recommendations for legislation to protect and manage the coastal zone. Needless to say, this conclusion came under fire with the first drafts of the plan and remained under increasingly heavy fire right down to the final passage of the coastal act. Environmentalists dominated in the commissions and prevailed in all of the plan proposals to the point that polarization of opposing forces from business, labor, and other state and local government agencies became so strong that the original coastal plan bill was amended over 300 times and then was voted down in committee. With even further amendments, the plan was shifted to a skeleton bill as an amendment and was finally passed by the Legislature, conditioned on the passage of two other amending bills. The final bill barely passed, and there was little resemblance between the provisions of the coastal plan and the bill first introduced and the one finally passed. An example of this lengthy process was in the treatment of dredging and filling in the coastal zone in general and in the major ports in particular.

The drafters of the Coastal Plan began with the premise that dredging and filling coastal waters was an intolerable devastation of the coast, and any continuance of this type of development would have an adverse and irreversible effect on the natural environment of the coast. Their approach to dredging and filling can best be characterized as almost a nameless horror that was destroying the natural coastal environment for all time. While there were some conceding comments that in some situations dredging and filling might be required, the final provisions of the plan would have made such activities virtually impossible. It was like being in favor of motherhood, but making pregnancy illegal. In treating dredging and filling, absolutely no distinction was made between long-established ports, developed by dredging and filling, and the pristine areas of the coast. The California coast is 1100 miles long—major ports occupy less than 2% of this area and San Pedro Bay ports less than ½ of 1%—yet the proposed standards and prohibitions were to apply without regard to where they were undertaken. It was as logical as saying that if a restricted speed of 25 mph in a school zone was proper and needed, then that should be the speed limit everywhere.

It is interesting to note that in the actual findings of fact and statements contained in the final plan, no conclusive evidence was produced to support the fear of dredging and filling which led to the prohibitive legislative provisions recommended in the plan.

Dredging was found to have the following adverse impacts:

- It disrupts and adversely affects the marine environment.
- It changes water circulation patterns introducing new conditions that some species cannot tolerate.
- It causes turbidity and places toxicants in solution.
- It destroys bottom life.
- It destroys tidal mudflats, salt marshes, wetlands and estuarine areas.

Filling was found to have the following adverse impacts:

- It destroys bottom life and the biological productivity of coastal water areas.
- It changes water circulation patterns.
- There are adverse impacts on marine organisms in fill sites.

The plan was silent on qualifying these adverse impacts (many of them transtitory and many others unquantifiable) against the positive economic impacts on man's environment resulting from dredging and filling to accommodate deep-draft ships and changes in cargo volume and form.

In order to avoid or at least completely minimize the need for dredging and filling, the plan and recommended legislation went to great lengths to describe what they termed "less environmentally damaging alternatives". Briefly, these alternatives and their supporting logic to prove that dredging and filling were not needed were as follows:

- Develop other energy sources such as solar and thermal sources. Legislate energy conservation and consumption levels in homes and businesses, and restructure energy utility rates. Through these measures, less crude oil would have to be imported; and therefore, channels would not have to be dredged for the large-size tankers.
- Require higher berth utilization at existing port facilities by mandating multiple-company use, thus eliminating the need for filling port waters for new berthing facilities.
- Use LASH vessels more in California ports because use of these vessels, who can anchor in existing deep water and send barges into existing port facilities, would effectively eliminate the need for any dredging.
- Distribute commodity flows and ship traffic between ports through a state agency to insure maximum utilization of existing facilities, thus precluding dredging and filling.
- Review existing port areas and increase the efficiency of ports by intensifying use, and preclude competition between ports because that results in overbuilding and unnecessary port developments, particularly dredging and filling.

There is not time to examine the naive and simplistic premises which the environmental staffs used to arrive at these conclusions. It is sufficient to say that they evidenced no understanding of how the maritime industry functions. The conclusion was that dredging and filling was not only damaging, but completely unnecessary in ports, and they then worked back with convoluted logic to prove it.

Recommendations for legislative codification concerning port dredging and filling were:

- No facilities (i.e. channels or terminals) to be built that would accommodate tankers larger than 150,000 DWT (later changed to tankers having a draft in excess of 60 feet).

- No dredging or filling to be permitted until all existing facilities were used efficiently and to maximum capacity. (It must be noted that no standards or guidelines were established to determine these conditions except that the state agency administering the plan would make this determination.) The logic here was like saying you can't build a modern auto parking area because you have underutilized livery stables.
- No dredging or filling to be allowed if any other port in the region had any surplus facility capacity.
- The state coastal agency to have jurisdiction over the need for any facility, including dredging and fill projects.
- Coastal waters could only be diked and filled for new or expanded facilities meaning that new land could not be created by fill and thereby create valuable waterfront land, unless the port had a user for such land under contract.
- Permitted dredging was to be planned, scheduled and carried out to avoid disruption to fish and bird breeding and migrations, marine habitats and water circulation.
- And finally, as if all of these constraints were not enough, there was a proposed regulation that would have completely prohibited filling coastal waters and would have inhibited dredging by forcing expensive deep-water offshore disposal of spoils. The regulation required that whenever coastal water was diked and filled, an equivalent compensation area of one to one, or an area of equal or greater biological productivity, was to be created to replace the filled area and that the replacement activity was to be commenced before the fill project could be started. If no such replacement area was available adjacent to or in the area of the fill, then the area would have to be purchased and excavated and turned over to another public agency.

In the Port of Los Angeles, we quantified what this would cost. We are just about to have our Main Channel dredged from 35 feet to 45 feet by the Corps of Engineers, and our plans call for a fill area in coastal water in the outer harbor of about 183 acres, representing an open-land area adjacent to deep water which is in demand and badly needed. There are now 183 acres of existing land within the Port's boundaries which could be excavated to provide 183 acres of new coastal waters. So, under this regulation, the Port would have been required to buy this much coastal land elsewhere, pay for the excavation and disposal of soil and turn it over to some other public agency. Assuming that we were lucky and an equivalent productive area was found to be on a one-to-one basis (although the regulation did not suggest how equivalency was to be arrived at), we determined that in order to buy 183 acres of coastal land outside of the Port, excavate all the soil and dispose of it someplace inland, prepare a couple of EIR's, and pay the legal fees and sell the necessary revenue bonds, the restoration would cost us about 53 million dollars. To avoid equivalent replacement, the offshore disposal costs to a permitted site about 28 miles from the port would add about 41 million dollars to a 13.6 million dollar project.

The replacement project over the 20 years of bond amortization would cost us about 115 million dollars for 183 acres that didn't even belong to us. Needless to say, no port could afford this even if it were legally possible to spend its revenues in this manner. That proposed regulation was strenuously objected to by California ports for almost a year and was not modified to exclude ports until the final weeks before passage of the legislation. The proponents of this regulation did not amend it on the merits of its elimination, but only because of the possibility of port opposition to the bill in the Senate which might easily have resulted in no coastal conservation legislation. This particular regulation can lead to the conclusion that its proponents considered coastal water to be more environmentally and productively valuable than coastal land—a philosophy not elsewhere expressed nor elaborated on. In the proposed legislation, the word "feasible" frequently appeared. However, the following definition was originally incorporated into the bill: " 'Feasible' means practicable, based on a case-by-case analysis, taking into account short-term economic, social and technological constraints as weighed against the long-term benefits of strict and immediate compliance with the provisions of this division." If you can figure that out, let me know how you would similarly define "infeasible". Fortunately, Webster's definition was substituted in the final legislation.

After a great deal of negotiating with the proponents of this extreme legislation, the ports were able to get more reasonable regulations for ports in the Act as finally passed. Reasonable amendments became possible because of the environmentalists desire to get coastal conservation legislation passed this year rather than because of the merits of modifying their original regulations.

The recently passed Act, as if affects dredging and filling, contains the following:

- The equivalent replacement area requirement for filled area in ports was deleted.
- Permitted dredging was to be planned to minimize, rather than avoid, disruption to fish and birds, etc.
- Restriction on facilities based on tanker size and draft were deleted.
- Filling was to be permitted to develop waterfront land independently of a stipulated use.
- No existing facility utilization factors to be used to restrict dredging and filling.
- Dredging and filling development not contingent on facility availability in another port in the region.
- Multi-company use of facilities not mandated.
- State agency to have no jurisdiction over facility need.

One outstanding conclusion that has to be carefully considered from now on by environmentalists, port authorities and other maritime interests is the relationship of the natural environment and the economic environment. The natural and economic environments in the coastal zone are not mutually exclusive but are, in actuality, inseparable. Man's environment, which contributes to his welfare and the quality of his life, is a blended combination of the economic and natural environments. Man's first demand on his environment is for his livelihood, and his second is for his pleasure.

In considering the resources of a coastal zone, there is a point where the quantified values of each of these environments affecting the public welfare must be weighed against each other in order to make the most optimum contribution to that welfare. When the cumulative economic value generated in the relatively small port areas in the total coastal zone are compared with the cumulative value of the natural environment's losses in those areas, these losses are relatively infinitesimal. Therefore, the policies, regulations and standards used to protect and preserve the economic environment of the relatively small port areas in the coastal zone must be entirely different from those which are to be applied to protect and preserve the natural environment of the remaining areas of the coastal zone.

The port areas lying within the coastal zone are dedicated by law in California to the economic environment of commerce, navigation and fisheries; and as such, they cannot be equated to the larger pristine areas of the coastal zone, nor should they be constrained by the policies and regulations primarily based on the needed protection, preservation and restoration of the natural environment in such other coastal areas. Within the port areas, the satisfaction of the economic needs and demands obviously far outweigh the impact on the relatively small port-occupied areas of the total state coastal marine environment.

The value of the ports as economic resources, compared to their value as natural environmental resources to the public welfare, can be easily measured by considering the following supposition. Suppose that of all the coastal zone areas lying within the boundaries of existing ports were to suddenly disappear, where would the greatest loss to the public welfare occur? Would it be in the loss of biological productivity on land and in coastal waters and wetlands, or would it be in the loss of the economic productivity of those areas? The answer is obvious: The relative loss of the natural environment would be infinitesimal compared to the catastrophic economic loss. This is an exaggerated example, but the relativity it illustrates is valid and critically important to the public welfare when ports, as coastal resources, are evaluated.

The greatest threat to the economic welfare of ports and to the economy and public welfare which they support is the threat of obsolescence of its facilities—ranging from channels to specific facilities. Obsolescence of a port's capital-intensive facilities is caused by changes in any of the various elements of the maritime industry which it serves. Thus, changes in vessel draft, size or carrying characteristics, cargo form, cargo handling and storage methods and cargo volumes are the major factors which create demands on ports to deepen channels; to expand, modify or convert existing facilities; to shift port users from old to new facilities; and to create new land areas compatible in configuration and location to ship and cargo service requirements. If ports are unable to plan and execute developments and changes to meet these demands expeditiously, their facilities will rapidly become obsolete and underutilized because of the lack of demand for outmoded facilities or the inability of new deep-draft vessels to use existing or expanded facilities located along shallow channels. The growth of new deeper-draft vessels, many of which are subsidized by the federal government replacing older, shallow-draft vessels in foreign and domestic waterborne commerce, is a well-established fact and represents the greatest threat to overall port obsolescence.

The history of port development is a history of changes to avoid obsolescence as the maritime industry has changed. An analysis of port facilities at any given time will generally always indicate that some facilities or areas are or are becoming underutilized. The analysis will also generally indicate that demand for these facilities has declined or stopped because ship and cargo types and forms have changed and made them inefficient or unusable, and therefore, obsolete. The analysis will also indicate that ports are always in the planning and development process to anticipate and avoid the obsolescence of their facilities.

The criteria for port development are simply established as the need for a port to expeditiously respond to port users' demands for facility changes to accommodate changes in ships and cargo forms, types, and flows in order for the port to make required accommodations, and in that manner, preclude the threat of obsolescence to their existing facilities. The protection against obsolescence is the protection of the port's continuing contributions to the public welfare.

The California coastal plan singled out dredging and filling for imposing unreasonable restraints on these two activities without recognizing their critical importance to port development; nor did it recognize that the present value and contribution of port resources to the public welfare has been due solely to the use of these two development tools since the inception of the California ports. No case has been made, nor has one even been suggested, that previous port dredging and filling has adversely affected the public welfare, or detracted from the value of ports as a primary coastal resource. The loss of the relatively small biologically productive area of the natural environment through this historical process of dredging and filling has resulted in the off-setting gains in the economic environment on a ratio of uncalculable thousands to one. No case has been made which concludes that this ratio has or will be reversed. No greater case exists supporting this than in reviewing the historical development of the completely man-made ports of Los Angeles and Long Beach in San Pedro Bay where waterborne commerce through the two ports in 1975 was over 62 million tons with a value of 16.5 billion dollars, representing 57% of all California waterborne commerce. The California plan policies on dredging and filling are considered proper for coastal areas outside of the boundaries of existing ports. Dredging and filling for ports has two sound values contributing to the public welfare which far outweigh the minimal and transitory adverse impacts on the small areas of the coast's natural environment found in ports: (1) Dredging — accommodates new deep-draft vessels in deeper channels, turning basins and berthing spaces; protects, preserves and adds economic value to existing port resources; and (2) Filling — the best method of controlled and contained disposal of dredging spoils creating, at the same time, new land which is a needed, usable, man-made resource and asset adding significant economic value to an existing coastal resource.

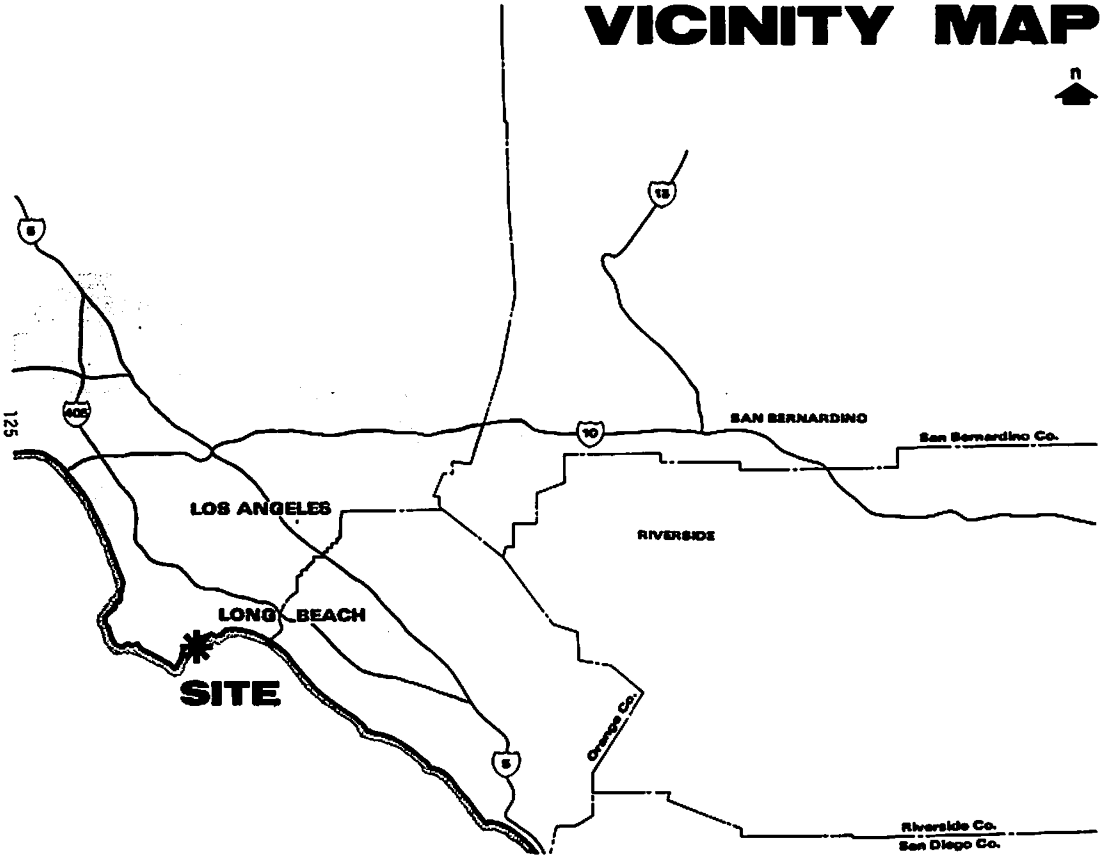
The problem of state versus federal jurisdiction and interest with particular reference to dredging in established ports poses some very basic and critical problems in drawing up state coastal zone conservation legislation. The question that will have to be ultimately answered in state legislation and control is this: Are deep-draft approaches, channels and turning basins in ports, which accommodate foreign and domestic shipping and waterborne commerce and national defense needs, unequivocally more in the national interest than in the interests of the various states? A recent ruling by a panel of federal judges invalidated a State of Washington law that prohibited the passage of tankers of more than 125,000 DWT through Rosario Strait in Puget Sound. The state passed the law as an environmental protection measure, but the federal judges ruled that the state's restrictions were preempted by federal regulation in the field, were violative of the commerce clause, and invaded the foreign affairs powers of the United States. In connection with this type of problem, there is still another question to be considered: Can a state law restrict the dredged depths in its established ports as a means of denying the use of the port to deep-draft U.S. and foreign shipping in the interests of its own presumed environmental protection?

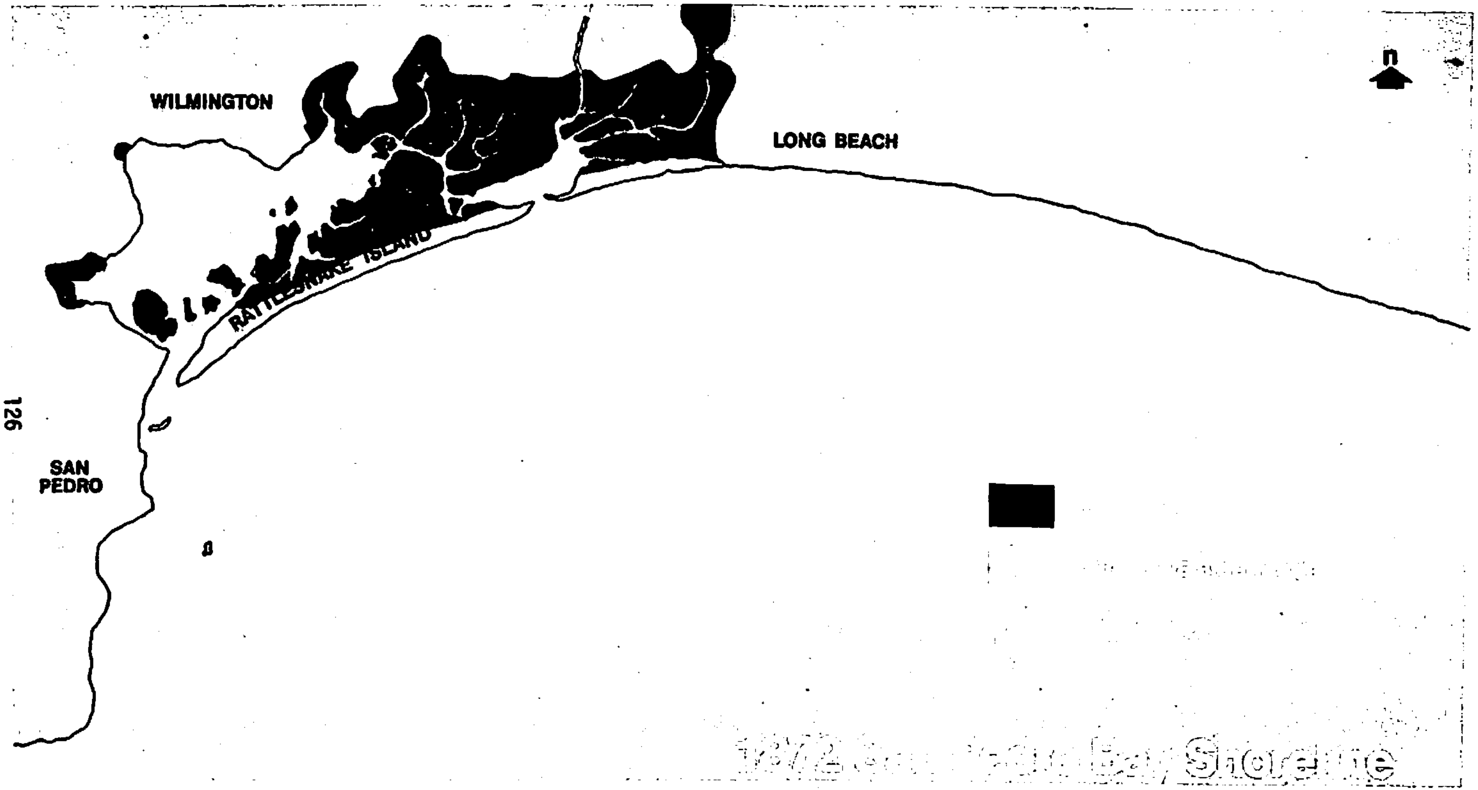
In our arguments with the proponents of the California plan, particularly with the 60-foot draft tanker restriction, we asked them if they would object to facilities such as channels and terminals to accommodate a large movement of a dry-bulk cargo in large vessels requiring 70-foot depths in a port. They said probably not. We then asked them if they would deny port entrance to a tanker drawing 65 feet in a port having 70-foot depths, and they said no, but stated that they would deny the construction of a wharf, terminal and berthing area to accommodate it. What becomes immediately obvious is that the proponents of the tanker restriction were proposing what would amount to a selective naval blockade of the California ports as a means of controlling large movements of energy supplies to inland areas beyond their jurisdiction and as a means of controlling large tankers operating on the high seas also beyond their jurisdiction. The 60-foot restriction was removed from the legislation, as it was obvious that the restriction was not based on protecting the coastal zone's ecology.

Over and above federal interest and jurisdiction over foreign and domestic commerce is the necessity of adequate ports for national defense. Many of the ships in both the U.S. merchant fleet, built under government subsidy, and the fleets of our potential allies, as well as new ships on order for both fleets, have deep drafts which preclude their using many U.S. ports. For example, 60% of the existing tankers in world fleets and 82% of new tankers on order are unable to use ports with maximum depths of 35 feet; 38% of new tankers on order worldwide and 27% on order in U.S. shipbuilding yards are unable to use ports with a maximum depth of 50 feet.

If U.S. ports cannot accommodate a significant part of deep-draft merchant fleets under the U.S. flag and under the flags of our potential allies, then our national defense strategy has been frustrated to that extent. For purposes of national defense, it is as important to insure that all major U.S. ports should have depths to accommodate deep-draft merchant vessels as it is to subsidize their construction and to count on being able to use such merchant vessels for national defense without having them restricted to a limited number of deep-draft ports in the future.

VICINITY MAP

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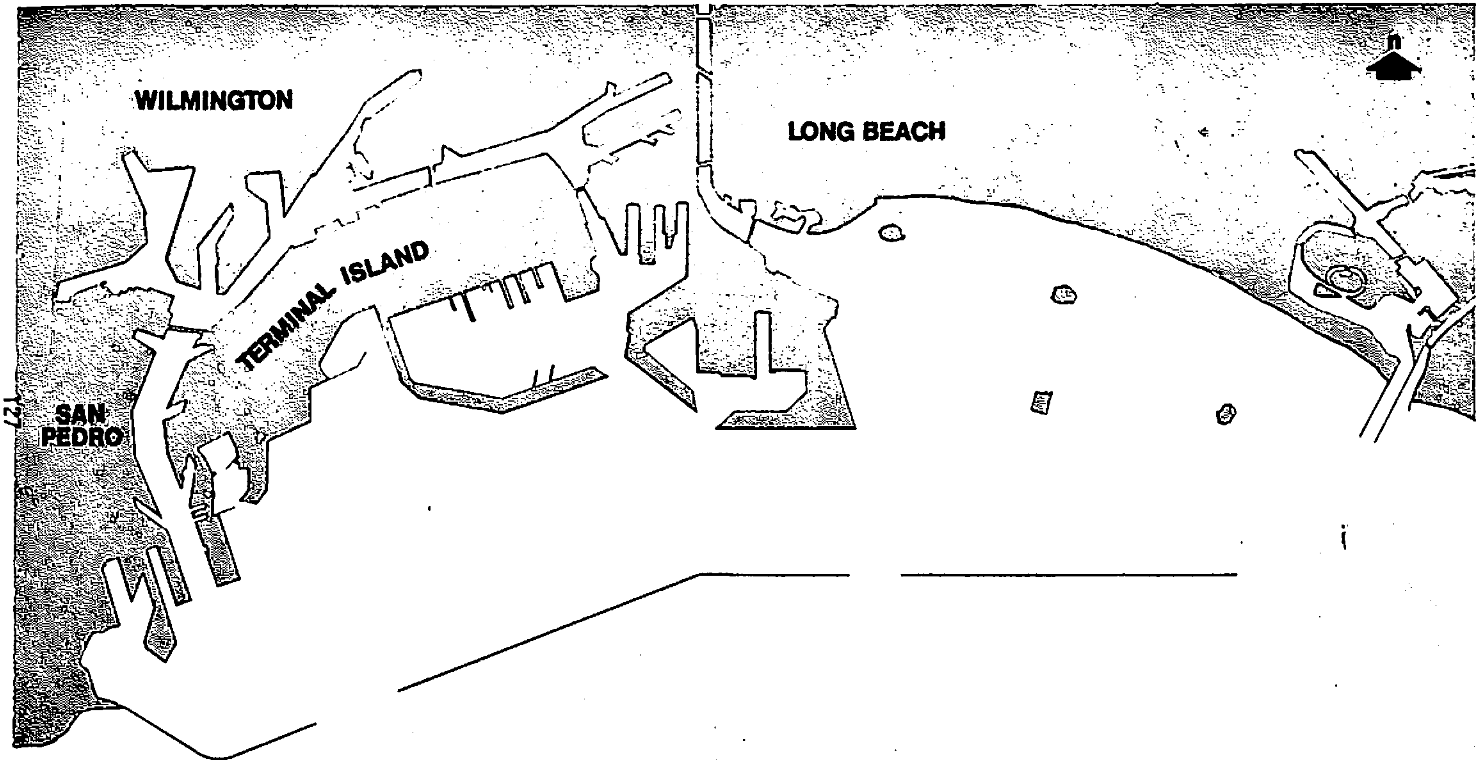
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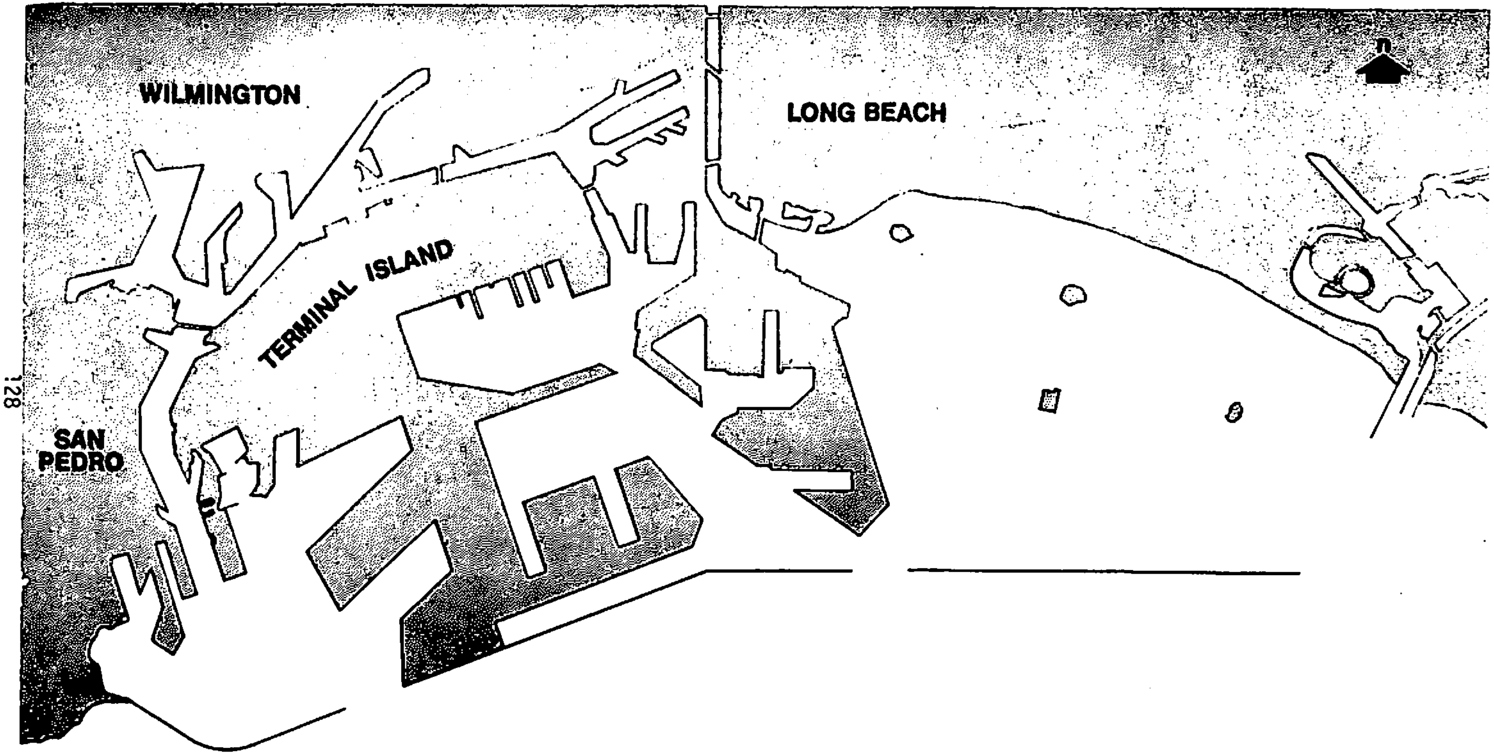
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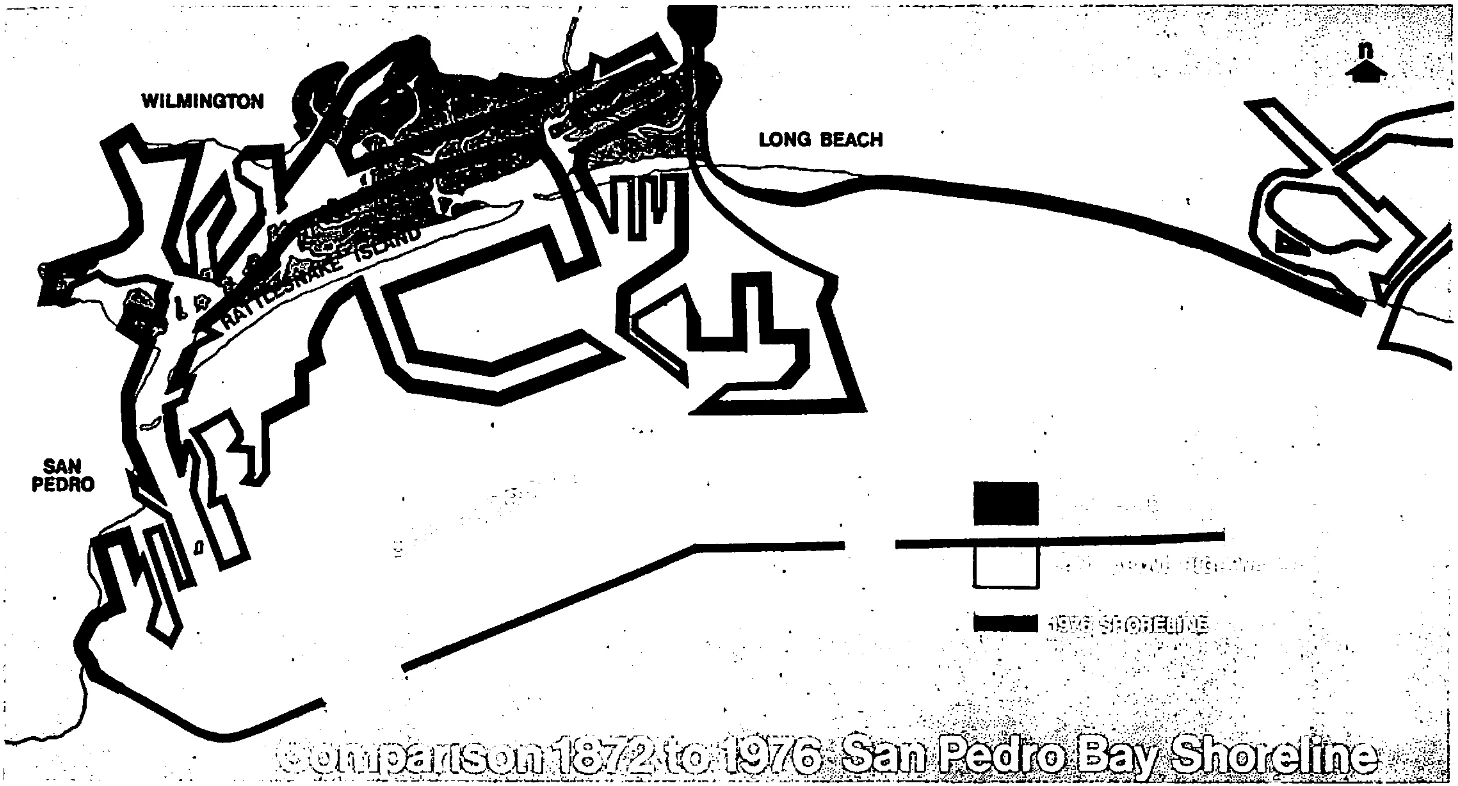

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WILMINGTON
LONG BEACH
RATTLESNAKE ISLAND
SAN PEDRO
1976 SHORELINE
Comparison 1872 to 1976 San Pedro Bay Shoreline

PART II

Thursday, November 18, 1976

REAL ESTATE DEVELOPMENT IN THE COASTAL ENVIRONMENT

Sherwood M. Gagliano, Session Chairman

1. "Nature and Extent of Development in Coastal Areas - Problem Definition," John Clark*

2. "Recreation Development in the Coastal Environment - the Marco Island Story," Hunter Moss*

3. "Coastal Zone Management: A Lawyers's Perspective," James T. B. Tripp

4. "The Role of Government in Real Estate Development," Paul H. Templet and Joel Lindsey

5. "Recreational Development and Coastal Ecology - Seeking the Right Balance," Jonathan S. Sutton

* Paper not available for publication

NATURE AND EXTENT OF DEVELOPMENT IN COASTAL AREAS - PROBLEM DEFINITION

John Clark
Conservation Foundation
Washington, D.C.

Paper not available for publication

RECREATIONAL DEVELOPMENT IN THE COASTAL ENVIRONMENT:
THE MARCO ISLAND STORY*

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Abstract

Marco Island real estate development, located south of Naples on Florida's west coast, is being carried out by Deltona Corporation. The total concept of Marco Island encompasses a total of 23,050 acres, all of which is on the coastal fringe and most of which requires a dredge and fill operation to create the final development. A total of 12,170 acres are to be developed and 6,770 acres preserved. When completed Marco Island will be a self-contained community for 35,000 people. It has been under development since 1964, and there has been growing opposition to the continuing of the development concept because of environmental considerations in particular.

The story that will be presented relates primarily to the controversy and emotionally charged issues that have marked the creation of an environmentally sensitive development by a first-class developer who has an enviable reputation for doing things right.

Hunter Moss, who will be making this presentation, is in no way connected with Deltona Corporation. However, he has received their permission to present the story even though they are currently in litigation, having filed a suit against the U. S. Corps of Engineers.

*Paper not available for publication.

COASTAL ZONE MANAGEMENT: A LAWYER'S PERSPECTIVE

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1. Introduction

The purpose of this paper is to develop a legal framework in which to explain, evaluate and justify a conservationist's view of coastal zone development by real estate and other activities and the role of recent federal environmental legislation in regulating that development. The coastal zone is defined in this paper to include coastal waters, barrier islands, coastal wetlands, flood plain areas, lakes, streams and estuaries, and upland areas. The conservationist view stresses conservation or restoration of the "biological, physical and chemical integrity"[2/] of the water quality and renewable water resources of the coastal zone and stringent control over all activities which claim to be of greater than regional importance,[3/] while recognizing that development can occur in coastal areas in a manner which is substantially compatible with the critical environmental resources of such areas.[4/]

In recent years, Congress has passed several environmental statutes, the purposes, policies and findings of which reflect a conservationist orientation to coastal zone, as well as other resources. This legislation includes the National Environmental Policy Act of 1969, 42 U.S.C. § 4321, _et seq_., the 1972 Federal Water Pollution Control Act Amendments, 33 U.S.C. § 1251, _et seq_., the Coastal Zone Management Act, 16 U.S.C. §1451, _et seq_., the Flood Disaster Protection Act of 1973, amending the 1968 Act, 42 U.S.C. §4001, _et seq_., and the Marine Protection Research and Sanctuaries Act, 33 U.S.C. §1401 _et seq_. Predating all of this legislation by some seven decades was the Rivers and Harbors Act of 1899, in particular Sections 10 and 13, 33 U.S.C. §403 and 407. This federal, conservation-oriented legislation, regulating real estate development and other uses of coastal resources in the coastal zone, may be evaluated from two perspectives: (1) the ineffectiveness of nuisance law in protecting property interests, dependent on conservation of coastal water resources, from the adverse impacts of real estate and other development in the coastal zone, and (2) the social necessity for legislation compensating for the impact of traditional federal water resource, development-oriented legislation which has subsidized and continues to subsidize degradation of coastal water resources.

2. Traditional Nuisance Law - Market Mechanism for Internalizing Externalities of Pollution

The proper role of recent, federal, environmental legislation providing for regulation and conservation of coastal water resources can first be analyzed from the perspective of the efficacy of traditional nuisance law in protecting those resources. A basic concept of Anglo-American property law for centuries has been that no one may use his property in a way which will injure the reasonable use of another person's property or public resources. This concept is fundamental in traditional private and public nuisance law.[5]

Under traditional private nuisance law, a raparian property owner could bring a damage or injunctive action against an upstream property owner who diverted or polluted water in a manner that demonstrably injured his own reasonable enjoyment and use of water resources adjacent to his property. In any such damage or injunctive action, the injured property owner had to establish that: (1) the upstream use was not reasonable; (2) the upstream use was in fact the cause of the damage which he was suffering; (3) he had a property interest in the use of water which was restricted by the upstream activity; and (4) he was suffering measurable damages.[6]

In the age before major government social regulation, private and public nuisance law or tort liability law was a major constraint on nontrespassing uses of property by one person which could measurably damage or injure the use of another person's property. Economists sometimes refer to water and air pollution as examples of externalities which the free market does not capture and which are not reflected in market prices and costs. Although this is widely true, traditional nuisance law, to a rather limited degree, could internalize these social externalities through the threat of substantial liability exposure. Needless to say, these externalities could only be internalized by property owners with the financial resources to use the courts to pursue relief.[7]

However, towards the advent of large-scale industrialization in the early to mid-19th century, private and public nuisance law became a decreasingly effective impediment to pollution of water and degradation of water resources. The courts generally sought to encourage economic development and therefore usually condoned many of the adverse social implications of that development.[8] Further, large numbers of industries and municipalities began discharging complex wastes into surface waters. It became increasingly difficult for any one injured property owner or even the government to prove that any one pollution source was the cause of the alleged damage. Concomitantly, although pollution might affect property values or public health significantly on a broad scale, the impact on any one person's property or health might be only marginal at any one time.[9] As a consequence, no one person could prove damages or would be willing to bear the immense costs of private litigation.

3. Traditional Nuisance Law - Ineffective in Internalizing Costs of Coastal Wetlands Destruction and Water Pollution

Scientific research is demonstrating the value of coastal wetlands, producing food for and providing spawning areas for marine organisms, protecting juvenile fish, providing flood protection and beneficially regulating the complex chemistry of coastal water quality and surface runoff water.[10/] Despite these benefits, formidable legal and technical obstacles stand in the way of effective use of traditional nuisance law to control and prevent the degradation of coastal wetlands and water quality, even where that destruction can materially affect the value and productivity of coastal fisheries. All of the standard problems of proving a nuisance are accentuated. In particular, proof of measurable damages and the cause of pollution would be immensely complex.

In addition, private persons generally cannot claim a property interest in the fish and shellfish resources of the coastal waters of the United States. With minor exceptions, all of the bottoms of our navigable coastal waters are in public ownership. Thus, persons whose property, livelihood or health might be adversely affected by coastal wetland destruction or water pollution would have to rely solely on public nuisance law, which requires proof of damages.

In a number of cases, fishermen, unlike other members of the public, have been able to demonstrate special damages and thus obtain standing to sue for damages for a public nuisance, whereas others have not. However, fishermen have successfully brought public nuisance actions for damages or injunctive relief only where they have been able to establish immediate relationship between the defendant's action, such as direct pollution of commercial fishing grounds by oil,[11/] other harmful pollutants[12/] or dredging activities[13/] and damage to the fishery resources. Fishermen have not brought such actions for damages or injunctive relief relating to coastal wetland destruction or more indirect and nonimmediate water quality pollution.

The states or the United States could assert a broad public interest in coastal fishery and other water resources so as to use traditional nuisance actions to seek damages or injunctive relief against persons who destroy coastal wetlands or degrade coastal water quality for real estate or other development. However, until very recently, most coastal states and the United States have favored development-oriented activities in coastal zones. Their legal posture may reflect the political reality that fishermen have been notoriously unorganized in American society and the fishing industry is highly decentralized compared to other commercial interests which benefit directly from and do not bear the direct costs of coastal wetland and water quality degradation.

Thus, to date, public nuisance law has not been used successfully by commercial fishing or recreational interests to limit destruction of coastal wetlands and coastal water pollution, except for discharges of pollutants directly into or near commercial fishing grounds. This could change with development of appropriate scientific, public health and economic tools. Research in the fields of ecology, marine biology, water quality modeling and natural resource economics has only very recently begun to develop the tools needed to establish quantitative biological, hydrologic and water quality nexes between the degradation of coastal wetlands or water quality, on the one hand, and reduction in the value of commercial resources, such as fish, shellfish and wildlife resources, flood-prone property and recreational amenities, on the other hand. Ideally, if science and economics could determine such precise quantifiable relationships, public and private nuisance law could internalize many of the externalities arising from adverse uses of coastal water resources. However, science is far from bringing us to this ideal state of knowledge. Even if it does, proof of damages would still be immensely difficult and the cost of private litigation immense.

Finally, public and private nuisance law could be used effectively to deter degradation of coastal wetlands and water quality only if the law facilitates proof of the secondary effects of such degradation on commercial values. The recent decision of the U.S. Supreme Court in Cappaerts et al. v. United States et al.,[14/] recognizing the secondary hydrologic effects of groundwater pumpage on the water table, could be construed as a step in this direction. Furthermore, limitations on liability for harmful discharges of oil and other toxic substances into coastal waters would have to be restricted or removed and jurisdictional obstacles overcome.[15/]

Thus, the inadequacies of nuisance law in capturing the externalities of coastal water resource degradation by developmental activities in the coastal zone explain and justify a conservationist's support of stringent implementation of recent federal environmental legislation and regulations designed to protect, conserve and restore coastal water resources.

4. Federal Environmental Legislation an Offset for Coastal Water Resource Development Legislation

From a second perspective, the conservationist assesses recent federal, environmental legislation, regulating use of coastal water resources, as a necessary, social response to traditional, commercially-oriented, federal water resource development legislation. In recent years, Congress has recognized that the destruction of coastal wetlands and pollution of coastal waters by private and public development practices is destroying a renewable resource endowment that is indispensable to the long-term quality of the nation's life. In order to evaluate this recent, conservation-oriented legislation and its role in federal resource policy, it is necessary to consider the historical role of federal water resource development legislation in the degradation of coastal water resources.

5. History of Expansion of Federal Jurisdiction over Coastal and Inland Water Resources to Encourage Economic Development

The role of the federal government in the development of coastal water resources has expanded significantly since 1800. In the 19th century and continuing unabated until very recently, the federal government has used its powers and subsidies to further the goals of commercial interests, i.e., draining, dredging, filling and channelizing coastal and inland wetlands and bottomland hardwood forests throughout the Mississippi River Valley, in order to open up coastal areas for residential, agricultural and commercial development and navigation. The courts supported this expansion of the federal role in order to encourage innovative commercial development and exploitation of fresh water and coastal resources.16/ Nineteenth century, development-oriented, commercial interests thus frequently argued for an expansionist definition of navigability and the federal government's role in regulating activities in navigable waters.

Now that the federal government has decided, in part, under the aegis of recent environmental legislation, to protect some of these coastal water resources, development interests are questioning the jurisdiction and legal power of the federal government to regulate their activities in coastal areas above the mean high water line under the Interstate Commerce Clause of the U.S. Constitution.17/ The focus of this debate is Section 404 of the 1972 Federal Water Pollution Control Act Amendments.18/

The power of the federal government to regulate activities affecting coastal water resources has never been limited just to activities below mean high water. Section 13 of the Rivers and Harbors Act of 1899, 33 U.S.C. §407, extends federal jurisdiction to all discharges of refuse into waters which are nonnavigable in the traditional navigability sense, if such pollution would affect navigable waters.19/ Similarly, Section 10 of the Rivers and Harbors Act of 1899, 33 U.S.C. §403, prohibits, without a Corps of Engineers permit, a range of activities, which may alter the course, condition, or capacity of the navigable waters. An extension of federal jurisdiction under Sections 10 and 13 of the Rivers and Harbors Act of 1899, as well as Section 404 of the 1972 Amendments, to regulate all activities throughout the entire coastal zone, whether or not those activities take place above or below mean high water, therefore logically evolves from developing hydrologic and ecological information about coastal systems.20/

6. Traditional Federal Subsidies of Real Estate and Other Development in the Coastal Zone

Since the latter part of the nineteenth century, a wide range of federal programs has encouraged, supported and subsidized residential, commercial and agricultural development throughout coastal wetland and flood plain areas. In the process, these programs have subsidized and nurtured the degradation of coastal wetlands, fisheries and wildlife and pollution of coastal waters. The most obvious federal development subsidies, which continue today, include Congressionally-authorized Corps of Engineers flood control and navigation projects, Soil Conservation Service drainage projects and federal flood insurance and disaster assistance in coastal wetland and flood plain areas.

Congress itself has now recognized that federal flood control projects induce intensified development in flood prone areas and that federal disaster aid has risen rapidly at the same time that the country has been pouring billions of dollars into federal flood control projects. Cognizant of these facts, Congress passed the Flood Disaster Protection Act of 1968, as amended in 1973, in an effort to tie the availability of federal flood insurance to land use controls on development in such flood prone areas. Unfortunately, this Act is providing increased amounts of federally subsidized flood insurance, and many local communities have been able to satisfy the flood plain regulations with generally innocuous land use ordinances which do not realistically inhibit significant development in flood prone areas. This situation may change as the 100-year flood maps get completed.

Other federal programs more subtly subsidize and induce real estate and other development in the coastal zone than direct flood control and navigation programs. These include the federal interstate highway program which, until recently, has financed construction of highways through coastal wetland areas which entail the filling in and destruction of these wetlands and induce secondary development pressure in wetland areas.[21/]

These federal subsidies, which have traditionally encouraged commercial development of coastal water resources and thus led to degradation of coastal wetlands and water quality, justify countervailing federal legislation. The recent federal, conservation-oriented legislation, the purposes of which are to conserve coastal water resources, in large measure offset and compensate for some of the degradation effects of these federal subsidies. Thus, the degree and scope of recent federal environmental legislation can be assessed and justified in terms of both the ineffectiveness of traditional nuisance law to capture the externalities of coastal water resource degradation and the effectiveness of federal, water resource, development subsidies programs in inducing such degradation.

7. Conflicts Between Old Economic Legislation and New Environmental Legislation Regarding Coastal Water Resources

The country today, therefore, has two conflicting sets of federal, legal, economic and environmental statutes and regulations governing utilization of coastal water resources. One has been grafted on top of the other without any effective effort at reconciliation by the U.S. Congress. The first set consists of all the federal, water resource infrastructure development and insurance subsidies which encourage and induce widely dispersed real estate and commercial development in coastal areas and reduce many of the risks of investments in such developments. These subsidies have increasingly weakened coastal economic arrangements characterized by a small number of large, centralized coastal ports and urban centers and centralized transportation nodes in coastal areas.

The second consists of the more recently enacted federal, environmental statutes which reflect a national need for protection and restoration of water resources, energy conservation and preservation of the country's dwindling renewable resource base. These latter statutes, including the National Environmental Policy Act, the 1972 Federal Water Pollution Control Act Amendments, in particular Section 404, and the Coastal Zone Management Act, seek to control and limit the environmentally destructive aspects of the federal water resource development program. All of these statutes emphasize the importance of "balanced" development, utilization and conservation of coastal water resources. However, none of them deals directly with the underlying economic causes for the very kinds of degradation of coastal resources which they seek to control.

Although federal Congressional and state legislative majorities can be found to endorse and enact environmental legislation designed to protect coastal resources, legislative majorities cannot generally yet be found in Congress to modify substantially the older economic programs and policies which have promoted commercial exploitation and degradation of these same resources. The result is confusion, conflict and uncertainty as to what the rules of the game are.

8. Role of Courts - The Search for a Rational Jurisdictional Principle in the Face of Conflicts

When these kinds of deepseated social, economic and environmental conflicts occur in American society, they often cannot be resolved by the U.S. Congress or state legislatures during periods of transition from one set of values to another. Thus, all concerned parties look to administrative agencies and then the courts to resolve these conflicts on the basis of some rational judicial principle.[22] That judicial principle may reflect the values of (a) the sanctity of property, (b) the unbridled discretion of government agencies to evaluate a broad range of factors in any way which they see fit[23] or (c) the maintenance and restoration of the chemical, physical and biological integrity of the nation's coastal water resources. During such a period with two conflicting sets of social legislation, real estate and other would-be developers of coastal water resources maintain that their property is being taken as a result of government regulations, without regard to the degree to which the value of their property depends on pro-development federal programs and the failure of traditional nuisance law to compel them to absorb the real costs of coastal water resource degradation. Whether representing a pro-development or pro-conservation agency position against a claim of arbitrariness, the U.S. Justice Department argues that a federal agency must have broad discretion in its decision making process if it is expected to consider every relevant social factor. Conservationists argue that no one has a right to destroy coastal water resources and degrade water quality, although the federal economic incentives for water resource degradation are still virulent.

9. The Marco Island Decision

These conflicts are clearly illustrated in the Marco Island decision. The U.S. Corps of Engineers has been and still is one of the traditional federal instruments supporting and subsidizing economic development of the country's riverine and coastal wetlands and flood plains. On the other hand, Congress has assigned the Corps the authority to regulate dredge and fill activities in coastal and other wetland areas under Section 404 of the 1972 Federal Water Pollution Control Act Amendments. Corps' regulations recognize the function of wetlands in fulfilling the objective of the 1972 Amendments of maintaining and restoring the integrity of the nation's waters.[24]

In its first major decision under Section 404, regarding applications by the Deltona Corporation for permits to fill in more than 2000 acres of coastal wetlands for finger-fill canal private housing developments at Marco Island, Florida, the Corps of Engineers denied two of the three requested permits.[25] In construing its regulations which require consideration of "whether the proposed activity is dependent upon the wetland resources," the Corps concluded that private real estate development is generically not dependent upon wetland resources.[26]

In that decision, Lieutenant General W. C. Gribble, Jr., stated:

> "(4) It is my position that a housing/recreational development of the type envisioned in both of these permit applications, which will result in almost total destruction of these wetland areas, is an

> unnecessary destruction of this wetland resource. I recognize that these two applications involve part of an overall, master planned development, and that it has been suggested that the location of this particular housing development with its related facilities is dependent on being located in this particular wetlands resource in order to complete the overall planned development. Such, however, is not the intended interpretation of this wetlands policy as the Corps perceives it. The intent, instead, was to protect valuable wetland resources from unnecessary dredging and filling operations to fulfill a purpose such as housing, which generally is not dependent on being located in the wetlands resource to fulfill its basic purpose and for which, in most cases, other alternative sites exist to fulfill that purpose."

While denying the requested permits the Corps noted that it would reconsider applications for permits for alternative development plans which would not destroy wetlands.[27]

This decision is consistent with the objective of maintaining and restoring the integrity of the nation's waters set out in the 1972 Amendments and is justified by the ineffectiveness of private or public nuisance law in limiting the destruction of coastal wetlands, despite their importance for coastal fisheries, water quality and flood control. However, it accentuates the conflict between a national policy which severely restricts private residential development in coastal wetlands in order to protect such water resources and a policy which subsidizes residential and other development via federal water resource development projects.[28]

The logic of the Marco Island decision, moreover, points to a more general conflict between water resource conservation policies of the 1972 Amendments and the Coastal Zone Management Act and federal water resource development programs, which subsidize degradation, since housing is not the only activity which is generally not dependent on coastal wetland resources. Agricultural and most commercial and industrial development is not dependent on coastal water resources since it can readily go elsewhere. Even commercial activity, such as navigation, shipbuilding and coastal oil development, which is dependent on coastal water resources, can frequently be concentrated, if justified on economic grounds, in already developed coastal areas, thus minimizing degradation of productive coastal wetland areas.

Thus, federal flood control, drainage and navigation projects, which encourage and subsidize private developments not generically dependent on coastal water resources, should logically be re-evaluated.

Such projects which, intentionally or not, serve to disperse waterborne commerce and residential and industrial development throughout coastal zones may be in furtherance of water resource objectives quite at variance with those enunciated in the Marco Island decision and the 1972 Amendments. These conflicts in federal coastal water resource policies could be resolved in many instances if federal projects were designed to facilitate concentration of development activities along a limited number of waterway arteries, coastal ports and developed areas. In the process, such a federal water resource development policy might gradually lead to the kind of coastal economic arrangements which would evolve if private and public nuisance law became an effective tool for preventing degradation of coastal fisheries, water quality and other water resources.

Footnotes

1. James T. B. Tripp, B.A. Yale, 1961; M.A. and LL.B., Yale 1966; Member of the New York Bar; formerly Assistant District Attorney for the Southern District of New York; presently counsel for the Environmental Defense Fund, Inc., 162 Old Town Road, East Setauket, New York 11733, and director of its Eastern Water Resources and Land Use Program.

2. Section 101(a) of the 1972 Federal Water Pollution Control Act Amendments, 33 U.S.C. §1251(a).

3. Section 306(c)(8) and (e) of the Coastal Zone Management Act, 16 U.S.C.§1455(c)(8) and (e).

4. For a discussion of coastal environmental management principles, see Gagliano and van Beek, "An Environmental Approach to Multiuse Management of the Louisiana Coastal Zone," Geological Society of America, Coastal Environments, Inc. (1973), and Clark, J. R., "Rookery Bay: Ecological Constraints in Coastal Development," The Conservation Foundation (December, 1974).

5. The distinction between private and public nuisance is explained in _Caldwell v. Abbott Construction Company, Inc._, 211 Kansas 359, 506 P. 2d 1191 (1973):

> "Private nuisance historically has been and is a tort related to an unlawful interference with a person's use or enjoyment of his land. The concept of a private nuisance does not exist apart from the interest of the land owner. Hence a private nuisance is a civil wrong, based on a disturbance of some right or interest in land...
>
> "The concept of a public nuisance developed as an entirely separate principle based upon an infringement of the rights of the state or the community at large..."

Caldwell v. Abbott Construction Company, Inc., continues:

> "The problem of distinguishing between public and private nuisances is further complicated by the fact that sometimes an individual may sustain an injury from a public nuisance which differs in kind from that sustained by the community in general. In that situation the injured citizen may maintain an action and recover damages for

> his particular injury... Today it is uniformly held that a private individual has no action for the invasion of a purely public right, unless his damage is in some way to be distinguished from that sustained by other members of the public."

See also The Restatement (Second) of Torts, Section 821B, for a definition of public nuisance. The existence of a federal law of public nuisance was recognized in Illinois v. City of Milwaukee, 406 U.S. 91 (1972).

6. For a discussion of private and public nuisance laws, see Prosser, Wade and Schwartz, Torts, Cases and Materials, University Casebook Series (1976), Chap. XVI, "Nuisance" and cases cited therein at p. 830-882, including Hampton v. North Carolina Pulp Co., 223 N.C. 535, 27 S.E. 2d 538 (N.C. Spt. Ct. 1943) and Morgan v. High Penn Co., 238 N.C. 185, 77 S.E. 2d 682 (1953). For further commentary on nuisance law, see Harper and James, The Law of Torts, Vol. I, Sections 1.24 to 1.30, p. 67-92.

7. Cases dealing with private nuisance law include Carter v. Lee, 502 S.W. 2d 925 (Ct. Civ. App. Texas 1973); Boomer v. Atlantic Cement Co., Inc., 26 N.Y. 2d 219, 309 N.Y. 2d 312 (1970); McFarlane v. City of Niagara Falls, 247 N.Y. 340, 160 N.E. 391 (1928); Smith v. Staso Milling Co., 18 F. 2d 736 (2d Cir. 1927); Heeg v. Licht, 80 N.Y. 579, 36 Am. Rep. 654 (1888); Campbell v. Seaman, 63 N.Y. 568 (1876). Cases dealing with the law of public nuisance include Burgess v. N/V Tamano, 370 F. Supp. 247 (D. Maine 1973) and City of Chicago v. Commonwealth Edison Co., 24 Ill. App. 3d 624, 321 N.E. 2d 4121 (1974).

8. The unwillingness of courts to use traditional nuisance law to restrict industrial activity in order to protect water and air resources is brought out in a recent decision, City of Chicago v. Commonwealth Edison Company, 24 Ill. App. 3rd 624, 321 N.E. 2d 412 (1974). In that decision, the court held as follows:

> "A public nuisance is an unreasonable interference with a right common to the general public. Earlier cases recognized that the public had a right to clean, unpolluted air and that any deprivation of that right was actionable as a private injury and indictable as a public wrong. (Seacord v. The People, 121 Ill. 623, 13 NE 194). However, the notion of pure air has come to mean clean air consistent with the character of the locality and the attending circumstances. Whether smoke, odors, dust or gaseous fumes constitute a nuisance depends on the peculiar facts presented by the case (City of Chicago v. Fritz, 36 Ill. App. 2d 457, 184 NE 2d 713). As a result of industrial expansion, the courts have utilized several factors in determining whether an industrial operation is an unreasonable

interference with a right to clean air. One of those factors is the extent of injury or harm incurred to the public health, safety, peace or comfort. Another is a comparison of the operation's methods or effects to proscribed standards outlined by applicable federal, state, or local regulations. A third factor is the suitability of the industry's location. A fourth factor involves balancing the gravity of the harm done to the public against the utility of the defendant's business to the community as a whole.

"...Courts of equity have traditionally been reluctant to enjoin an industrial operation unless it is clearly and satisfactorily proven to be a nuisance."

The Court found that Commonwealth Edison's Indiana facility "is located in a highly industrialized area. The character of the locality necessitates that unpleasant odors, smoke and filth will exist. These conditions in an industrial area have generally not been considered to be public nuisances."

9. In the City of Chicago case, ibid, n. 8, the court found that the city had failed to answer the threshold question of whether Commonwealth Edison's electric generating facility in Hammond, Indiana, caused substantial harm "so as to constitute an actionable invasion of a public right. In order to be entitled to injunctive relief, a substantial harm or injury must be clearly demonstrated..." The court also found that "the city could not clearly establish that the Edison plant was the direct cause of harmful pollution in Chicago, distinguishing the facility from other emission sources located in the area."

10. For discussion of the roles which wetlands play in ecosystem dynamics, including water quality maintenance and propagation of commercially important finfish and shellfish stocks, see Gosselink, J. G., Odum, E. P., and Pope, R. M., The Value of the Tidal Marsh. Impact of Water Resources Development, October-November. Environment Information Center, Inc., New York, New York (1973); McHugh, J. L., Are Estuaries Necessary, Commercial Fisheries Review (1968); Odum, E. P., and Odum, H. T., Natural Areas as Necessary Components of Man's Total Environment. Trans. North Amer. Wildlife & Nat. Res. Conf. (1972); Teal, J. M., Energy Flow in the Salt Marsh Ecosystem of Georgia. Ecol. 43: 614 (1962); and Woodwell, G. M., and E. V. Pecan, Flax Pond: An Estuarine Marsh. Brookhaven National Laboratory, New York (1973).

11. Burgess v. M/V Tamano, 370 F. Supp. 247 (D. Maine 1973). In that case, the court found that plaintiff fishermen had suffered damages peculiar to them and could thus sue to recover damages incurred as a result of the discharges into coastal waters of

100,000 gallons of bunker C oil from a tanker. On the other hand, the court found that owners of tourist resorts along the polluted beaches had no such peculiar interests.

12. Hampton v. North Carolina Pulp Company, 223 N.C. 535, 27 S.E. 2d 538 (S. Ct. N.C. 1943). In that case, the court held that owners of upstream fisheries could maintain an action for wrongful interference with the migratory passage of fish to their fisheries caused by discharge of toxic chemicals.

13. Potomac River Association, Inc. v. Lundeberg Maryland Seamanship School, Inc., 402 F. Supp. 344 (D. C. Md. 1975). In that case, the court found that plaintiff fishermen had standing to sue for relief from direct damages to their commercial fishing areas as a result of a dredge and fill operation, insofar as it was not permitted by the Corps of Engineers.

14. Cappaerts et al. v. United States et al., 96 S. Ct. 2062 (1976). Although dealing explicitly with concepts of water appropriation law, this decision points the way to potential expansion of nuisance law to deter destruction of coastal wetlands so as to protect coastal fisheries. In that case, the groundwater underneath a ranch owned by the Cappaerts was hydrologically connected to water in Devil's Hole, a deep cavern on federal land in Nevada containing an underground pool inhabited by unique species of fish, known as the pupfish. The court held that the Cappaerts could not pump the groundwater under their land below a certain level necessary to preserve the fish in Devil's Hole.

15. Limitations on liability for the discharge of oil and other toxic substances into waters of the United States and the contiguous zone are established under Section 311(b)(2) and (f) of the 1972 Federal Water Pollution Control Act Amendments, 33 U.S.C. § 1321(b)(2) and (f), and the Limitation of Liability Act, 46 U.S.C. 181 and 183.

16. For a discussion of the expansion of the concept of navigability in 19th century American law, see Scheiber, H. N., "The Road to Munn: Eminent Domain and the Concept of Public Purpose in the State Courts," Perspectives in American History, Volume 5 (1971). That article discusses several cases which reflect the expansion of the concept of navigability in 19th century American courts in support of commercial development, including McManus v. Carmichael, 3 Iowa 1 (1856), (Scheiber p. 347) and Bamey v. Keokuk, 94 U.S. 324 (1877) (Scheiber p. 352-353).

17. For a discussion of the jurisdiction basis for federal control over coastal and other wetland areas, see Taft, P. R., The Legal Basis for the Exercise of Congressional Control over Wetland Areas, Land and Natural Resources Division Journal, U.S. Department of Justice (December 1976).

18. Section 404 of the 1972 Federal Water Pollution Control Act Amendments, 33 U.S.C. § 1344 authorizes the Secretary of the Army to grant permits for dredge and fill activities in navigable waters of the United States. EPA is granted authority to deny proposed disposal sites to protect fish and shellfish areas, wildlife habitats, water supplies and recreational amenities under Section 404(c), 33 U.S.C. §1344(c).

19. Section 13 of the Rivers and Harbors Act, 33 U.S.C.§403 provides in pertinent part:

> "It shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers in passing therefrom in a liquid state, into any navigable waters of the United States, or into any tributary of any navigable water, from which the same shall float or be washed into such navigable water;..."

Thus, under this statute, federal jurisdiction extends to activities in tributaries of traditionally navigable waters if "refuse" discharged into any such tributary may float or be washed into such navigable waters. For a discussion of this statute, see Tripp and Hall, "Federal Enforcement Under the Refuse Act of 1899," 35 Albany Law Review 60 (1970), Environmental Law Review (1971), p. 529.

20. Although the decision in NRDC v. Callaway, 392 F. Supp. 685 (D.D. C. 1975), may have expanded the concept of federal jurisdiction under §404, 33 U.S.C. §1344, over freshwater wetlands adjacent to freshwater rivers, it did not materially extend the concept of jurisdiction of the federal government over coastal wetlands. See, for example, U.S. v. Baker, 2 ERC 1849 (S.D. N.Y. 1971); U.S. v. Ashland Oil and Transportation Co., 504 F. 2d 1317 (6th Cir. 1974); U.S. v. Howland, 373 F. Supp. 665 (M.D. Fla. 1974); P.F.Z. Properties Inc. v. Train, 393 F. Supp. 1370 (D.C. 1975); Weiszmann v. Corps of Engineers, 526 F. 2d 1302 (5th Cir. 1976); U.S. v. Moretti, 526 F. 2d 1306 (5th Cir. 1976).

21. For litigation dealing with an interstate highway which was designed to traverse coastal wetland areas, see Ecology Center of Louisiana v. Coleman, 8 ERC 1169 (5th Cir. July 11, 1975).

22. For an excellent and comprehensive discussion of efforts by federal administrative agencies and the courts to develop rational decision-making principles in the face of conflicting Congressional mandates, see Stewart, "The Reformation of American Administrative Law," 88 Harv. L. Rev. 1669 (1975).

23. The breadth and range of factors which a federal administrative agency, like the U.S. Corps of Engineers, feels obliged to consider in light of conflicting federal economic development and environmental legislation can be seen in any public notice issued under Section 404 of the 1972 Federal Water Pollution Control Act Amendments, 33 U.S.C. §1344. Such a typical public notice regarding a private application for a 404 permit circulated by the New Orleans District of the Corps of Engineers provides:

> "The decision whether to issue a permit will be based on an evaluation of the probable impact of the proposed activity on the public interest. That decision will reflect the national concern for both protection and utilization of important resources. The benefit which reasonably may be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. All factors which may be relevant to the proposal will be considered; among those are conservation, economics, aesthetic, general environmental concerns, historic values, fish and wildlife values, flood damage prevention, land use classification, navigation, recreation, water supply, water quality and, in general, the needs and welfare of the people. No permit will be granted unless its issuance is found to be in the public interest."

24. The Corps of Engineers' 404 regulations relating to proposed private dredge and fill activities, 33 CFR §209.120(g)(3), provide:

> "As environmentally vital areas, they [wetlands] constitute a productive and valuable public resource the unnecessary alteration or destruction of which should be discouraged as contrary to the public interest."

The Corps' 404 regulations which relate to the Corps' own dredge and fill projects include a similar provision, 33 CFR §209.145(e)(3), as do the EPA guidelines, 40 CFR § 230.4(a)(I).

25. Decision on the "Application for Department of Army Permits to Dredge and Fill at Barfield Bay, Big Key and Collier Bay, Marco Island, Collier County, Florida, Permit Numbers 73 G-0496, 0497, 0498 (April 15, 1976) (General W. C. Gribble, Jr.).

26. The Corps' 404 regulations require denial of a dredge or fill permit for work in viable wetlands unless the public interest requires otherwise. They provide, 33 CFR § 209.120(g)(3), that a permit may issue that would result in the destruction of wetlands only if the benefits of the proposed alteration outweigh the damage to the wetlands resource and that the proposed alteration is "necessary" to realize those benefits. In determining whether a particular alteration is necessary, the Corps' regulations require that it consider "whether the proposed activity is dependent upon the wetland resources and whether feasible alternative sites are available."

27. At the Marco Island 404 hearing in Naples, Florida, held on September 2nd and 3rd, to consider the application of the Deltona Corporation, the Environmental Defense Fund, the National Audubon Society, the Florida Audubon Society and Collier County Conservancy, with the assistance of an environmental management planning firm in Boston, Massachusetts, Sasaki Associates, presented evidence of the feasibility of an environmental management development plan for the three permit areas, Collier Bay, Barfield Bay and Big Key. The objective of such a plan would be accommodation of most or all property owners and protection of all coastal mangrove swamps. The Corps' decision is the subject of litigation, Deltona Corporation v. Hoffman et al., Civil Action No. 76-473-CIV-JT (M.D. Fla. 1976) and Deltona Corporation v. United States, No. 370-76 (U.S. Ct. Claims 1976).

28. The Corps of Engineers, Lake Pontchartrain, Louisiana, and Vicinity, Hurricane Protection Project (EIS, New Orleans District, Corps of Engineers, August, 1974), is an example of an ongoing federal subsidy to induce real estate development in coastal wetlands. The economic analysis for this project includes flood reduction benefits relating to proposed, but unpermitted, real estate development in coastal wetlands in New Orleans East, Louisiana and land intensification benefits relating to wetlands in St. Bernard Parish, Louisiana.

THE ROLE OF GOVERNMENT IN REAL ESTATE DEVELOPMENT

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Traditionally, the role of government in real estate development has been one of telling the developer how to develop, but rarely where to develop. This role is changing through the impetus of the Federal Coastal Zone Management Act of 1972 (CZMA) as local and state governments attempt to control uses which can have a direct and significant impact on coastal waters. Real estate development has been interpreted in most states to be such a use.

Most of my remarks will be concerned with real estate development in Louisiana. However, the principles enunciated here are applicable in other states.

The coastal zone of Louisiana is a vast, broad, low relief area extending many miles inland. It is composed of vast expanses of marsh, large swamps and extensive water bodies. The coastal area of Louisiana will probably be larger than that of any other state in the nation, with the possible exception of Alaska.

This vast acreage of coastal zone encompasses approximately 25 percent of the contiguous 48 states' wetlands. The combined states of Massachusetts and Delaware could be put in Louisiana's coastal zone with room to spare.

In Louisiana's coastal area, 98 percent of the state's sport and commercial fish and shellfish are nurtured. It is no coincidence that Louisiana is the largest seafood producing state in the nation in terms of total tonnage. The next nearest competitor produces half the tonnage.

Within Louisiana's coastal zone resides 41 percent of the state's population with most of the population centered around the New Orleans Metropolitan area. Other urban areas in the coastal zone are the cities of Houma, Morgan City, and Thibodaux.

The 10 million acre area within Louisiana's coastal zone is composed of 2.4 million acres of saline marsh, 2.9 million acres of brackish marsh, 1.6 million acres of fresh marsh, 1.5 million acres of swamp, and about 1.5 million acres of dry land. This last figure is extremely important when conisdering real estate development in Louisiana's coastal zone for there is not a great deal of dry land available.

In the past, real estate development in Louisiana's coastal area occurred along the highlands bordering the natural streams in Louisiana such as the Mississippi River, the Atchafalaya River, Bayou Lafourche, Bayou Teche, and others, or along cheniers (stranded beach ridges) in the western half of the coastal zone. Today all of the high land along the natural levee ridges and cheniers is being utilized for urbanization, industrialization and agriculture. As a result, the question of real estate development in the Louisiana coastal zone becomes one of wetlands modification.

In many other states the question of real estate development in the coastal zone was one of second home or leisure home development. That is not generally the case in Louisiana. There are only a few places along the Louisiana coast where access to the Gulf of Mexico is available. Second home development occurs in places such as Grand Isle, Louisiana but that is the exception rather than the rule. Real estate development in Louisiana's wetlands is a matter of camp location and urban expansion into wetlands from existing metropolitan areas.

If we are to do a reasonable job of balancing development with conservation, as the CZMA intends, there are a number of questions which the state must ask itself. The first of these is <u>who</u> controls the siting of real estate developments. In Louisiana, at the present time, the Army Corps of Engineers is the major agency permitting activities which modify wetlands for real estate development. The user makes his application for a permit to the Corps, the Corps then sends copies to other relevant federal agencies such as the Environmental Protection Agency, the Fish and Wildlife Service, National Marine Fisheries Service, and the Bureau of Land Management, and asks for their comments. They also request comments from state agencies and local governments on the project. The response from state and local agencies of government is called "a letter of no objection" in which local governments or state agencies respond to the proposed use. The major agency at the state level is the Louisiana Wildlife and Fisheries Commission which processes some 300 permits per month for various specialized applications. At the local level, the parish council or police jury (county commissioner board) responds to the request for comments. If one of these agencies, either at the state or at the local level, objects to the project, generally the Corps will not permit the project. The Corps also receives comments from other federal agencies and sometimes halts projects because of objections by federal agencies. So, at the present time, the Corps of Engineers, under Section 404 of the federal Water Pollution Control Act and under the Rivers and Harbors Act of 1899 and subsequent Acts, permits activities in Louisiana's wetlands.

If the State of Louisiana obtains an approved coastal zone management plan then some of this permit control should shift to state and local agencies of government. The Corps has indicated they would go along with the decisions of state and local governments concerning wetlands as long as there is no conflicting overriding national interest. Thus, the question of who makes the decisions about siting of real estate development may change under Coastal Zone Management if the state gets an approved plan. Federal Consistency provisions of the CZMA lend authority to that statement.

Since the State of Louisiana has no wetlands legislation as yet, I must engage in a bit of crystal ball gazing to determine just how the permitting process would work under an approved Coastal Zone Management Plan. My feeling is that the applicant would apply to the parish (county) government and to a state clearinghouse. Local government would make the decision about the siting of real estate developments unless there was an overriding state interest involved. I realize that this merely begs the question, but perhaps "overriding state interest" defines the question better. It is envisioned that under a coastal zone management plan the state would develop guidelines for the siting of real estate developments and local governments would implement the state guidelines with some discretion of their own. These guidelines would specify "overriding state interest" and develop a procedure as to how local government would implement the state guidelines. Overriding state interest could involve things such as:

1) Projects which would involve two or more parishes

2) Projects within a parish which affect another parish

3) Large projects which would result in large scale modifications of the environment.

How would state and local governments best site new real estate development in Louisiana's coastal area? As a start, the best technical information would be made available to state and local governments. The Louisiana State Planning Office is mapping a number of parameters which will go a long ways toward providing an answer to the how of siting real estate development. We are preparing atlases for use at both state and local level (at different scales) which include all of the parameters which are generally used in assessing intrinsic suitability. We hope to complete our work by the time a CZM program is ready for implementation in Louisiana. In addition to mapping the normal parameters such as vegetation, soil, elevation, flood prone areas, etc., the State Planning Office has attempted to gather information relevant to specific problems in Louisiana. For this reason land loss potential due to channel construction and soil subsidence potential have been mapped.

Louisiana's coastal area has an extensive network of canals which have been created for navigation and for access to oil well sites. Land loss potential due to channel construction will be useful information to a future resource manager charged with the responsibility of permitting new canal construction. For example, such information will allow a manager to recommend a canal alignment which will minimize adverse impact.

In siting future real estate development, soil subsidence potential will be extremely useful knowledge to a resource manager. By assigning subsidence potential (if drained) to each of the soil types in Louisiana, we can categorize these areas. By combining soil subsidence potential with some 30 other parameters, we can assess intrinsic suitability.

Intrinsic suitability is nothing more than a fancy way of saying that some areas are best suited for some uses and other areas for other uses. For example, levee ridges are more suited to development than saline marshes. The intrinsic suitability of an area is its ability to support specific uses and activities. An example might be to map the various landscapes/landforms in the Louisiana area such as upland terrace, trunk channels, natural levee complex, etc., and then rate each of those as high, low, medium for a particular use (permissible uses). Under this type of procedure, urban and industrial development would have high intrinsic suitability for upland terrace and natural levee complexes, but low intrinsic suitability for an interdistributary basin, barrier islands, active delta fronts, or marginal basins. Maps showing these kinds of considerations are being developed and will not be available for another year or so.

The next question that has to be addressed is <u>why</u> would we want to regulate real estate development under a state's Coastal Zone Management Plan? There are a number of reasons. The balance of conservation and development envisioned by the federal Act demands it. More practical reasons include savings for consumers, government and developers. A recent study in the Louisiana coastal area indicated that it costs up to $600 more per year to maintain a house built on reclaimed wetlands than one built on higher, dryer land.

Local government would also benefit from more rational real estate regulations because it has to provide services to developments on reclaimed wetlands and the services are more expensive. Cradles have to be built for sewer lines, gas lines, etc. In addition, local government has to take the brunt of law suits which may occur because of development in poorly suited areas. An example is a case which was recently settled out of court for $1 million. It arose after explosions due to breaking gas lines occurred in subsiding reclaimed wetlands in the New Orleans area.

Another benefit is that the cost to the developer can be lowered if he knows in advance what the problems of developing a particular area are, and what permit restrictions or requirements apply. He can then compare various sites for suitability for real estate development.

How Would Local and State Governments Regulate Real Estate Development?

The question of how local and state governments would regulate real estate development involves guidelines. The Louisiana Advisory Commission on Coastal and Marine Resources recommended in their final report, "Louisiana Wetlands Perspectus" that (1) the state furnish subdivision requirements based on environmental constraints of the area to be developed and (2) that permit requirements for urbanization and industrialization be formulated. That Commission also had the following recommendations concerning building in wetlands:

1. Residential and industrial developments in low-lying areas should be discouraged by flood plain zoning, insurance techniques, and other devices.

2. That heavy industrial development should not occur in substantially undeveloped wetlands when alternatives exist.

3. That feasible corridors for transportation, industrialization, or urbanization should be designated in already disturbed but stable areas.

The report went on to recommend that at the local level:

1. Flood plain lands be zoned to regulate development,

2. Subdivision regulations be developed and

3. That building and housing codes be formulated.

In order to help local governments develop coastal zone management so that they can regulate developments which occur in wetlands, we have contracted directly with local governments in 17 of the 22 parishes within our coastal zone study area. A substantial part of Louisiana's Coastal Zone Management program planning in the next year will involve assisting local governments in developing their own coastal zone management plans so that they become good coastal zone managers and develop adequate procedures for the siting of real estate development within their areas.

Orleans Parish has prepared its own coastal zone management plan. It is to the credit of the parish that they have done so in advance of the state's plan. Their approach to wetland development pressures was to formulate a coastal zone management plan in 1975 which contained a number of recommendations and policies for consideration by the Parish Council. One of the recommendations was that the parish government adopt regulations that will "permit minimal development in areas which are not experiencing severe development pressures in a manner that will not unduly strain ecological systems and not simultaniously create legal impediments". They also recommended that parish government seek public purchase of those properties most subjected to severe development pressures and when the ecological system is most strained.

In summation, the traditional role of government in real estate development is expanding and now involves the question of where developments can be situated. In Louisiana this becomes a question of wetlands modification and choosing the best areas to site real estate developments. Local governments will probably make most of the decisions regarding such sitings and the role of state government will be to provide technical assistance and to develop guidelines which local governments can implement with some state overview. Intrinsic suitability mapping is part of the technical assistance to local governments for use in siting real estate development. The balance of conservation and development envisioned by the Federal Coastal Zone Management Act can best be carried out in Louisiana by this partnership of state and local governments utilizing the latest technical information.

Jonathan S. Sutton[1]
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RECREATIONAL DEVELOPMENT AND COASTAL ECOLOGY - SEEKING THE RIGHT BALANCE

The search for the right balance between man's utilization of vulnerable coastal areas and their environmental stability can be addressed on many scales from the regional to the local, to the site-specific. The three case studies (all executed projects) from the work of Wallace, McHarg, Roberts and Todd (WMRT), Architects and Planners of Philadelphia, which are summarized in this paper represent this search for the right balance on a site-specific scale but with an acute awareness of the relationship of a particular site to the overall coastal ecosystem.

The Three Case Studies

The consistent theme of these case studies is that the landscape and its natural processes offer opportunities and constraints for land utilization. By identifying and interpreting explicit natural phenomena which contribute to a balanced ecosystem, the environmental planner is able to specify the most and least suitable land use for a particular coastal area. Using this information he is able to determine the degree to which trade-offs can be made when objectives are in conflict and structure a planning process by which the health, safety and welfare of the community is maintained.

The three case studies have been selected to reveal different tolerances of coastal sites to recreational development. They are the Plan for Amelia Island Plantation, Amelia Island, Florida, for the Sea Pines Plantation Company (1971-present), the Little Egg Harbor Wetlands Study, New Jersey for Lincoln Property (1973) and the Comprehensive Land Use Plan for the newly created City of Sanibel, Sanibel Island, Florida (1975).

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[1]Jonathan S. Sutton, AIA, ASLA, AIP is an Associate Partner of Wallace, McHarg, Roberts and Todd.

Learning to Respect the Coastal Zone

The first two projects represent work for private clients, the third a public commission. The outcome of the same planning and site analysis process was by no means similar in these three projects, however. After six months of detailed natural scientific studies, it was determined that the site for Amelia Island Plantation could accommodate a recreational community while still preserving the essential characteristics of a barrier island. The accommodation of the resort program to the site required the careful preparation of development controls and design guidelines. In the case of Little Egg Harbor Wetlands Study, on the other hand, such an in-depth scientific inventory and interpretation revealed that the environmental costs of development far outweighed the benefits. A land disposition process was then set in motion to preserve this valuable ecosystem in its undeveloped state.

The final example of a Comprehensive Land Use Plan for the City of Sanibel represents a boarder scope of work for a public client within the new coastal and land use initiatives of the State of Florida. Sanibel Island is an extremely vulnerable barrier island which can safety accommodate only limited urban growth.

The common bond between these examples then is not their planning and design outcome, not their size or their physical characteristics but their presence in the coastal zone. The obvious environmental implications of such a location is of critical importance to the environmental planner which cannot be overstressed. For the coastal zone is probably the most dynamic (with its high energy beaches) and most productive (with its biologically rich estuaries) of any natural system on the surface of the earth. The forces of climate and the sea make this "seem at the edge of continents," a battleground (as anyone who has observed the awesome surge of a hurricane can attest). As C.J. Schuberth wrote in 1971 "If man wishes to build his work on the fringes of such a battleground (the coast) he must understand that the rules of this ancient battle require the beach, the berm and the dunes to shift constantly before the assault of the sea. If man tries to change these rules, he can only fail, and in his failure undermine the fragile hold of these outposts against a powerful sea."

By seeking a balanced condition, man can continue to hold and enjoy these outposts without an excessive sacrifice of dollars or lives.

Balancing Act at Amelia Island

The whole southern end of Amelia Island, Florida including four miles of ocean frontage, 1,642 acres of high ground, and 1,000 acres of outstanding tidal marshland, was acquired in 1970 from Union Carbide Company by the Sea Pines Company of Hilton Head Island, S.C.

In January 1971 WMRT contracted with the owners to conduct an ecological planning and land-use study which would establish the guidelines for development of a large new recreational community on Amelia, 25 miles northeast of Jacksonville.

The objective set by Sea Pines Company was ambitious: to find the optimum fit between man's requirements in a new resort and the existing animal and plant ecology, and special natural features of this barrier island, southermost in a golden string along the Georgia and Carolina coasts.

WMRT chose to fulfill this objective by developing a design approach which could synthesize information from a wide range of professional disciplines, and re-focus it into a program and plan. The exceptional beauty and fragile nature of the site demanded a detail of natural science data not usually associated with land planning studies.

The planning process for the Amelia Island project was complex but rewarding. Months of study, coordination, interchange, and review was undertaken by the company's professional staff and by a diverse range of outside consultants (planners, natural scientists, engineers, market analysts, and golf course architects).[1] This environmental design team was counseled by an Environmental Planning Advisory Council comprised of nationally known experts in planning and design, as well as leaders of local citizen's groups familiar with regional conservation and planning problems.[2]

In evolving a planning method the environment was examined as a series of "two whom it may concern messages."[3] The objective was to discern as many relevant messages as possible in making decisions which had environmental impact. Some messages are more obvious than others. A hurricane surge of four-year frequency will positively determine locations to be unsuitable for house sites, whereas it is more difficult to decipher the relevance of other messages, such as the relation of various wildlife species to development locations and conservation practices. The planning method employed to decode these environmental signals had the following sequence.

Data Assembly

In many respects Amelia Island exists in a geographic no-man's land, being generically but not politically linked to the Golden Isles to the north. The coastal studies of natural scientists had generally overlooked the island, therefore much needed scientific information on the geology, soils, plants, and animals of the island had to be developed in the field by the team of natural scientists.

Recognized authorities in climatology, oceanography, geology, limnology, soils, beach erosion, dune restoration, salt marshes, ornithology, herpetology, mammalogy, and anthropology contributed specific data and interpretation to this phase of the study.[4]

Special Description of the Data

In a project of this scale it was necessary to create a comprehensive frame of reference to record each environmental message by transforming all the information into spatial data. For example, each vegetation type, soil association, or wildlife habitat defined a certain area on the site. In some cases these were very specific areas; in others they were approximate. All were mapped at a common scale and in a manner which allowed comparison and testing for coincidence of phenomena.

No static descriptive maps can accurately convey the dynamics of natural phenomena or man's ever-changing awareness of them. A series of interpretive maps, suggesting the processes of each natural phenomenon over time, was derived from the descriptive data. By recording rates of erosion or relative heights of tides or temperature gradients, such information was categorized and then reconstituted into locational values.

Creation of Locational Values

Certain costs are attached to modifying the existing landscape. These may be <u>direct costs</u>, such as construction costs or service costs (flood protection, provision of sewers, roads, and water supply). There may also be <u>indirect costs</u> in terms of resources lost with respect to maintaining wildlife habitats, natural water supply, and visual amenity. To find the development areas of least cost (both direct and indirect) was the goal of determining locational values.

This process involved interpreting the base data provided by the natural scientists and then the preparation of a series of maps ranking the attributes of each natural phenomenon for the location of all propsective land uses. For example, the maps of locational value related to the vegetation studies included the following: relative abundance of types, marsh quality, foredune quality, sand/soil stabilizers and tolerance to disturbance. Then the locational criteria was matched to the physical characteristics of the site by increasing the refinement of the analysis.

Economic and social considerations such as the relative real estate demand for different frontages (A marked preferance for marsh lots became apparent. Two lots with both marsh and fairway overlooks later sold for $103,000) or the relative accessibility of development zones were spatially displayed. The distribution of these phenomena would obviously influence the settlement pattern and cause certain trade-offs to be made within the range of options suggested from the ecological analysis.

Determination of Suitabilities

Having already mapped each environmental factor in one of several tonal values on transparent maps that represent a range of most-to-least conditions on the site, the next step was to assemble the maps relevant to the suitable location of each prospective land use and superimpose them. The darkest area indicated the maximum coincidence of all positive factors and the fewest constraints on the location for land uses in the general development program.

Still there were unresolved problems. The preceding series of Suitability Maps did not mediate between the demands of two conflicting land uses for the same site area, even though both might be suitably located according to their own criteria. This required a synthesis process which again depended greatly on mapping as the agent of discovery.

Some areas of the site exhibited only one suitability, for conservation or for development. They were less of a problem than areas where suitabilities conflicted. For example, when highest conservation value coincided with moderate development value, we proposed conservation as the highest and best land use. In the reverse situation, development in such an area might be acceptable provided that it conformed to a set of ecological management guidelines. The Final Synthesis Map determined the trade-offs which had to be made between conservation and development on a comprehensive basis and was modified by the socio-economic parameters of frontage and access referred to earlier.

The Master Plan

Admittedly there were certain biases built in the trade-off decisions leading to a Master Plan. Sizeable areas of each characteristic vegetation type on the property - such as a remarkable Cabbage Palm swamp - were preserved in their natural state regardless of their relative abundance or importance as a wildlife habitat. This was done to maintain prime examples of the rich diversity of the island landscape.

The pattern of conserved areas suggested the relationship of residential clusters to shared community facilities. Clusters were then linked to the centers by an open-space system of golf cart, bicycle, and pedestrian pathways. Although the Master Plan shows the distribution of all land uses for the entire site, specific locational decisions were made only for the initial stages of development where more refined data could be employed.

Total Area	2,693 acres
Marshbank	968 acres
Additional conservancy areas	364 acres
Resort recreation areas	646 acres
Hy. AIA right-of-way	85 acres
Net developed area	630 acres
Residential area	498 acres
Non-residential support uses	132 acres
Total Units	2,900

Refinement of the Master Plan

Previous analysis had revealed that the northern end of the site offered the most promising areas for the initial development phase on account of access and diversity of site conditions.

Detailed field surveys provided greater precision in determining constraints on the location of component parts of the residential program. Various types and densities of residential uses were related to ranges of elevation.

The distribution of vegetation characteristics also had a significant influence on the recommendations for size, density, and location of buildings. Given a choice, for example, between saving a group of larger trees, with diameter at breast height over 10" and a high canopy, or a stand of small trees (dbh less than 6") of lower canopy, the latter would be judged less important in terms of environmental value and potential for accommodating various residential types.

The ability to make value judgments at a more detailed site-planning level inspired several specific design studies, such as the particular problem of routing golf course fairways.

Although golf courses are considered as open space in recreational terms, in ecological terms their construction modifies an area far more drastically than any residential layout. Almost 80 acres of clearance is required for 27 holes and a totally new environment of open, irrigated grassland is introduced.

In routing the fairways the determination of least-cost corridors was done in the following sequence: first, locating areas of critical ecological value to be conserved and avoiding fairways near these; second, areas with low real estate amenity or other building constraints were mapped as opportunities for fairways as highest and best use. These two maps were then compared with another set showing areas where least environmental damage would occur through fairway clearance.

Once all these maps were combined, the darkest tone revealed distinct corridors on a Synthesis Map which were refined into an alignment. The alignment helped to relate residential uses to the fairways as well as to other valuable site features. Each site's value could now be established by its proximity to natural amenities such as beaches, marshes, lagoons, or to man-made amenities such as folf fairways.

Since completion of the Amelia Island Plantation Plan in 1971 and its publication, the Company has interpreted and supplemented it as development proceeds. Other planners and architects have assisted the Company in implementing the principles of the Master Plan. To have a record of those principles the company published the "Report on the Master Planning Process for a New Recreational Community."

A master plan must necessarily be dynamic, adapting to change like the processes of nature and the human society it is intended to serve. What must not change is

Jonathan S. Sutton

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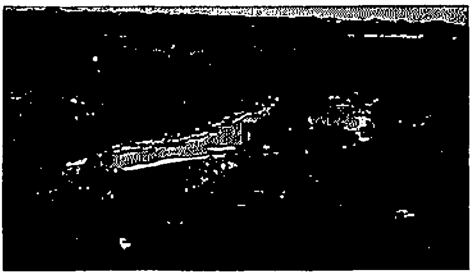
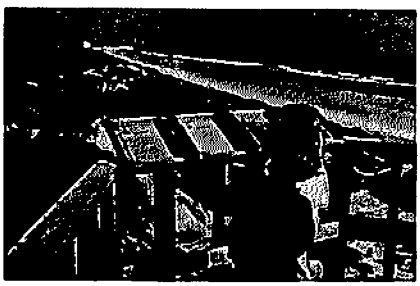
Master Plan for Amelia Island Plantation



Golf Course Fairway in Phase 1

Aerial of Oceanfront Development



Stop on "Environmental Awareness System" the commitment that ensures that man's expansion into such areas takes account of the ecological and human balance his presence is affecting.

A Different Story in Little Egg Harbor, New Jersey[5]

The Lincoln Property Company, a Dallas-based national residential developer, had acquired several thousand acres of marsh and swamp land in the Little Egg Harbor area at about the time of the enactment of the New Jersey Wetlands Act. (The State of New Jersey, recognizing the immense biological importance of its estuaries and wetlands, enacted a wetlands protection law in 1972.)

Acknowledging the new concern for the marsh areas and hoping to recoup its investment, Lincoln Property undertook coastal development which would minimize the negative ecological and aesthetic impacts the typical lagoon subdivision of the past. It was hoped that such a concerned effort would meet with approval of the New Jersey State Environmental Protection Agency, responsible for administering the Wetlands Act.

How Much Land Was Developable?

Lincoln Property hired WMRT to assist them in preparing a development plan for the tract. Immediately the firm's work focused on the question of what part of the property was actually developable (if any), with the basic assumption that no significant negative environmental impacts should result from the development. To determine what those impacts might be, a scientific study of the ecosytem in this particular segment of marsh/swamp was undertaken.

Shortly after initiating the study, WMRT realized that the existing environmental data were inadequate and the additional field studies would be necessary[6].

The Significance of the Marsh

By the third month of the study, sufficient field data in estuarine functions, ornithology, hydrology and vegetation had been analyzed to determine the great value of this section of New Jersey's coastal zone.

The property's eastern edge fronts on the Little Egg Harbor estuary. A large portion of the land consists of Spartina marsh (S. patens and alterniflora) which, in spite of being mosquito ditched several decades ago, is functioning well. The field studies showed that this area acts as a spawning and nursery ground for many fish, crustaceans, and other aquatic life. It contributes detritus to the estuary-an important food source for many of its inhabitants. The marshes are also an important resting and nesting area for many shorebirds.

Behind the marshes are cedar and hardwood swamps. They were found to be largely undisturbed and botanically exceptional in New Jersey's coastal zone. There was an unusually high number of species of herbs, shrubs and trees. These particular swamps contain such a diveristy of plant species that they could be considered a significant "gene pool", serving to produce new generations of plants (a key point in light of the destruction of New Jersey's natural environment in the post-war years.

The studies conducted by WMRT and its scientific team revealed that not only was this particular marsh area one of the finest, largest and least tampered with in ecological terms in the entire 120-mile stretch of New Jersey coastline, but also that any development of the marsh would destroy the ecosystem of the areas left undeveloped. The marsh comprises about 2/3 of the total tract. Additional studies showed that some of the remaining hardwood freshwater swamp areas (as distinguished from salt marsh) could be developed without unduly impacting the ecosystem. This was, however, a far cry from the amount of land required to be developed by Lincoln Property in order to regain its initial investment.

A Few Options Defined

The study findings, presented to Lincoln Property, gave the developer few options. The Company could proceed in an attempt to develop the land in a way which would both recoup its investment and minimize ecosystems damage; or could simply hold the land in definitely; or could make a gift to the state; or could find a buyer who would agree to keep the land in its natural state.

All of these options involved problems. The first would probably involve many years of litigation and the tough opposition of conservation groups. The second would tie up capital for an unacceptably long period of time and would serve no purpose. The third would involve a tremendous capital loss which would be too much even for a multi-million dollar firm. The fourth was difficult because there are few such buyers.

A Unique Partnership Formed

At this point WMRT suggested contacting Brad Northrup, the Conservancy's Eastern Regional Vice President, to see if the Conservancy would act as "middle man" or as a "clearing house" for possible conservation-minded buyers. Lincoln Property agreed, and WMRT met with The Nature Conservancy who sent representatives to look over the property. The Conservancy found the area to be every bit as valuable as WMRT said it was, and opened negotiations directly with Lincoln Property. After several weeks, the developer agreed to sell 3,855 acres at less than fair market value. Funds for the purchase were made available to the Conservancy through a loan provided by the Equitable Life Assurance Society of the United States. The Fish and Wildlife Service, in turn, purchased the area for inclusion in the adjacent Barnegat National Wildlife Refuge.

The result is that a large and irreplaceable tract of salt marsh and swamp has been preserved through a unique partnership between a private landowner, a planning consultant, a large financial institution, The Nature Conservancy and the federal government. The particular beneficiaries of this partnership have been the developer as well as the general public. The public has benefited because a large tract important to the ecosystem of the Atlantic seaboard has remained open. The developer has benefited because his remaining property is enhanced in value as a result of the adjacent property remaining as a permanently undeveloped wildlife preserve. His losses, if any, have been minimized through the good offices of the Nature Conservancy and Equitable Life Assurance Society and, most important, he has performed a major public service by helping to preserve this superb piece of salt marsh.

Sanibel - New City at the Edge of the Sea

Unlike the previous two case studies involving private clients anticipating or responding to public regulation, the newly created City of Sanibel, Florida, wished to determine equitable and legally supportable policies which would govern the development of their vulnerable barrier island.

Overview

Sanibel Island is noted both regionally and nationally for its seashells, beaches and wildlife. It is an island of 10,730 acres and is situated at the mouth of the Calossahatchee River fifteen miles from Fort Myers on Route 867.

Since 1963, the Island has been connected to the mainland by a causeway. Many visitors come to collect shells on the Gulf Coast beaches and visit the J.N. "Ding" Darling Wildlife Refuge in the northern half of the island. These national attractions did, however, result in certain problems for the permanent residents of Sanibel.

Sanibel was the fastest growing municipality in Lee County, an area which even on the mainland was undergoing intensive growth. In 1974, the island became a city in order to guide the nature and location of this intense development pressure.

The desire for self-determination grew from the perceived need for orderly future development of Sanibel such that the natural characteristics of the Island are preserved. The Act establishing the City includes the following language: "...in the planning for the orderly future development of an island community known far and wide for its unique atmosphere and unusual natural environment and to ensure compliance with such planning so that these unique and natural characteristics of the Island shall be preserved...." Among the several benefits and powers conferred upon the City by its charter is the power to prepare and adopt a Comprehensive Plan. This planning process was begun in May 1975.

<u>The Planning Effort for a New City</u>

The City Planning Commission was charged with the responsibility of developing a comprehensive plan for the newly formed City and the City Council would consider the plan for adoption. The Planning Commission evaluated numerous firms of planners and engineers to assist them in their work and chose WMRT, who in turn supplemented their own capability with a legal consultant, economic consultant, engineering consultant, and traffic consultants.[7]

WMRT developed a planning program that began with the ecological analysis along with documentation of social and economic factors that pointed out the problems and opportunities for the future. Fortunately the Sanibel/Captiva Conservation Foundation was able to generate sufficient support for The Conservation Foundation to undertake a separate study of Island environments which was undertaken parallel to WMRT's preliminary work. This parallel scientific investigation provided a unique and fortuitous situation because in most jobs the planner has to undertake such ecological base studies entirely within his own contract. The City urged WMRT and The Conservation Foundation to work together for as complete documentation of the barrier Island's ecology as possible because environmental protection and managed growth were the raison d'etre for the formation of the City.

The Preparation of a Comprehensive Plan for A Barrier Island

The Preamble to the Plan prepared by the Planning Commission and their consultants best summarizes tne difficult process of balancing the ecological values of a unqiue natural resource with individual development rights. The importance of the Comprehensive Plan in Florida land use law had gained added significance in 1975.

In conformity with and in furtherance of the powers of the City Charter, "the Local Government Comprehensive Planning Act, 1975 Chapter 75-257 expressly requires that through the process of planning local governments 'preserve, promote, protect and improve the public health, safety, comfort, good order, appearance, convenience, law enforcement and fire prevention and general welfare'. Of particular significance also from the intent and purpose of this Act is the intent to 'prevent the overcrowding of land and avoid undue concentration of population, facilitate the adequate and efficient provision of transportation, water, sewerage, schools, parks, recreational facilities, housing and other requirements and services, and conserve, develop, utilize and protect natural resources within their jurisdictions'.

Both the City Council and the City Planning Commission reiterated these intents and purposes in their contract with the planning consultant and in subsequent instructions and comments given in public meetings during preparation of the Plan.

For the express purpose of maximizing involvement of residents of Sanibel in the preparation of the Plan, the City Planning Commission appointed ten task forces to work with the consultant. The task forces engaged over fifty persons familiar with different aspects of the Island and assisted in gathering data, evaluated findings of the consultant and gave public input to all phases of the planning process. Task forces met regularly with the planning consultant in public work sessions to discuss goals and objectives and alternative planning recommendations for their achievement.

In addition to discussions concerning preparation of the Plan at regularly scheduled public meetings, the Planning Commission held three special public meetings for public information and inputs. It was on the basis of these discussions and the public response to planning studies that the City Planning Commission adopted policies for growth thresholds; Island-wide policies with respect to health, safety and welfare; and Performance Standards for development or management of Ecological Zones.

Previous reports and work papers submitted by the planning consultant to the City Planning Commission presented the data based of environmental and socio-economic conditions existing on Sanibel (Phase One) and the subsequent interpretation of this data as Problems and Opportunities[8] with regard to future development (Phase Two). When the Planning Commission reviewed the alternative policies to be adopted in September 1975 (Phase Three) it was abundantly evident that Lee County Zoning, and development as permitted under existing provisions were in conflict with the terms of the City Charter and also the intent and purposes of the Local Government Comprehensive Planning Act.

Furthermore, it was evident that the City government of Sanibel is faced with major difficulties in providing for the protection of health, safety and welfare of present and future population on the Island.

The Planning Commission reviewed prospective impacts of future urban growth projections and unanimously adopted recommendations of their consultants that the Plan be based upon a total of six thousand residential units or two thousand additional to those existing in 1975. Also adopted were Island-wide policies that will give protection for life and property, and also performance standards for development that would ensure protection.

The Comprehensive Plan changes Lee County zoning and development standards which allowed approximately 30,000 residential units on Sanibel with no policies or performance standards for protection of the environment. It recommends that growth to approximately 6,000 residential units is to be paralleled with capital improvements by the City so that the public welfare is protected from hurricane storms; has sufficient good quality water; has a safe and efficient circulation system, and that sewage can be disposed of without jeopardy to public health. Also it is essential that basic public services of fire protection and police service are improved and that all public services have long term planning to meet future needs.

Protection of natural environments and scenic resources are essential components of the Comprehensive Plan. In order to fully understand the Island's resources and their inter-related functions in maintaining ecological stability, the consultant planners undertook intensive environmental studies. This work was richly supplemented by a team of scientists contracted by the national Conservation Foundation and retained by Sanibel/Captiva Conservation Foundation. The findings of these collective studies confirmed that the natural environments of Sanibel are fragile and dynamic. Furthermore, they have been degraded by urbanization and if current trends were to continue, the natural amenities of Sanibel would be greatly damaged.

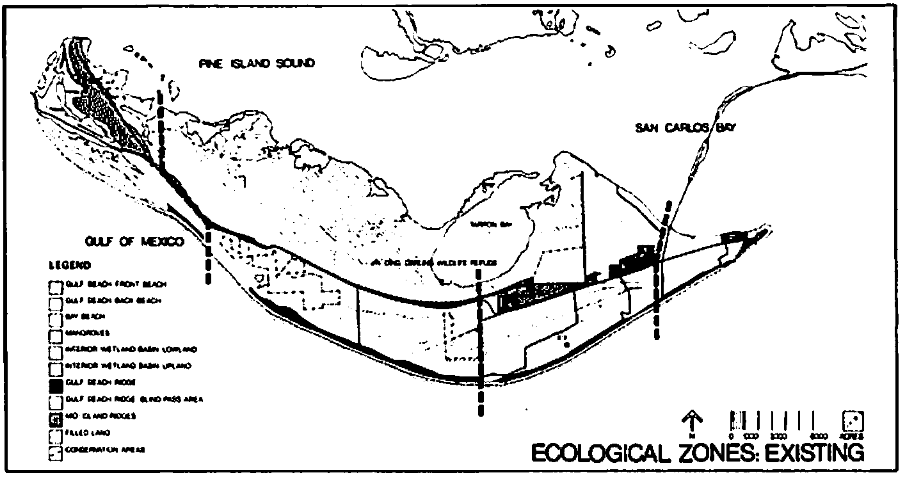
The Island was described and mapped as Ecological Zones and their relative tolerance to urban development evaluated. From this information, policies for protection were adopted by the Planning Commission and performance standards for future development are given in the Plan.

Development intensity allocation for future development is largely influenced by three factors--the tolerance of respective Ecological Zones, proximity to existing public services, and improvements made to the land to make it more suitable for development.

A formula was used to prepare a tentative allocation of development intensity. The Planning Commission then reviewed each section of the City and made adjustments designed to relieve hardship for owners of small lots and, in some cases, to preserve the character of existing neighborhoods. While these adjustments increased the number of lots available for the construction of single family homes, it is the judgment of the Planning Commission that, given the historical build-out ratio of subdivisions in the area, the total number of units actually constructed is unlikely in the near future to exceed the 6,000 units contemplated in the Plan by any substantial margin.

The Comprehensive Plan addresses immediate problems of environmental protection and urbanization on Sanibel within the terms of reference of current knowledge of existing conditions and anticipated resources to make public improvements. As parts of the Plan are implemented and new problems or resources are known, then the Comprehensive Plan may be reviewed and if necessary modified to reflect public attitudes to the new circumstances.

Well attended Public Meeting discussing the Plan



Ecological Zoning Map for City of Sanibel

This Comprehensive Plan is the first step of a continuous and ongoing planning process designed to implement the intent and purpose of the City Charter and protect the health, safety and welfare of present and future population on Sanibel."[9]

Implementation of the Sanibel Plan

The Comprehensive Plan for the City of Sanibel was adopted in 1976 following extensive local, regional and state review. It was structured on the following three levels: (1) Growth Threshold; (2) Island-wide Policies, and (3) Performance Standards by Ecological Zone. Since adoption the Plan regulations have been upheld in several court opinions.

Seeking the Right Balance

All three case studies previously discussed reached a balance between resort development and conservation appropriate to their locations in the coastal zone. The outcome was influenced by the unique opportunities and constraints of each site because results were based on an open and explicit planning process. This process gathered data, interpreted data, synthesized data, set objectives, evaluated alternatives, and made recommendations and regulations. The iterative planning process invited participation by the client (whether public or private) as well as a multidisciplinary planning team. All went through the exercise of recording and measuring of impacts, considering alternatives and moving the projects to their respective conclusions.

Because the coastal zone is such a dynamic and productive ecosystem, there is a strong need for achieving a balanced state between conservation and development. In a democratic society this balance must be based on good information, educated public action and the good judgments of those who love this "battleground".

<u>References</u>

1. Planners - WMRT
Natural scientists - see footnote 4
Civil engineers - Bassent, Hammack & Ruckman, Inc.
Soil engineers - Ardaman and Associates
Market analysis - Sea Pines Company
Golf course architect - Pete Dye

2. Environmental Planning Advisory Council:
Professor Patrick Horsbrough, Professor of Environmental Design and Planning, University of Notre Dame
Grady Clay, Editor, Landscape Architecture
Professor Vernon J. Henry, Ph.D., University of Georgia, Marine Institute, Sapelo Island, Georgia
Mrs. Helen Bird, President, Southeastern Environmental Council
Marvin Hill, executive director, Jacksonville/Duval County Area Planning Board

3. From Norbert Weiner's "Design for a Brain."

4. Natural science consultants to WMRT:
Coordinator, Jack McCormick, Ph.D.
Vegetation, Jack McCormick, Ph.D.
Richard Squiers
Climatology, Donald Bunting, M.S.
Geology, Vernon J. Henry, Ph.D.
Limnology, Richard Franz, M.S.
Soils, Ronald B. Hanawalt, Ph.D.
Dune restoration, W. W. Woodhouse, Jr., Ph.D.
Salt marshes, Robert J. Reimold, Ph.D.
Ornithology, David W. Johnston, Ph.D.
Herpetology, Howard W. Campbell, Ph.D.
Mammalogy, James N. Layne, Ph.D.
Consultants to Sea Pines Company:
Oceanography, Herb Windom, Ph.D.
Oceanography, P. Braun, Ph.D.
Anthropology, Charles Fairbanks, Ph.D.

5. Much of this section of the paper has been taken from "The Little Egg Harbor Story" written by Thomas A. Todd and Michael G. Clark of WMRT for the Fall 1974 issue of Nature Conservancy News.

6. Thomas Lloyd, a water resource planner, was asked to examine the estaurine functions of the property's marshes to determine the extent of their contribution to the ecosytem of the Little Egg Harbor estuary Frank

Gill, Chairman of the Department of Ornithology at the Academy of Natural Sciences of Philadelphia, was employed to research the kinds and relative abundance of birds frequenting the property's marshes and swamps. Lucien Brush, a faculty member at Johns Hopkins University and an expert in the hydraulic workings of marshes, sampled various parts of the site for salinity levels and other physical and chemical characteristics of the waters flowing into and out of the estuary. WMRT staff members Carol Reifsnyder and Leslie Sauer, both with considerable field experience in vegetation mapping, made a botanical survey of a portion of the property for which no botanical data existed.

7. Consultants to the Comprehensive Plan

Planners:
Wallace, McHarg, Roberts and Todd, Philadelphia
William H. Roberts, Partner-in-Charge
Jonathan S. Sutton, Associate Partner
Anne Whiston Spirn
Beth Kitchen
Carol Reifsnyder
Richard Nalbandian
Bill Rohrer
Hans Harald Grote
Ray Allshouse
William Becker
John Czarnowski
Russell Morasch
Bob Torres

Legal Consultants:
Ross, Hardies, O'Keefe, Babcock & Parsons, Chicago
Fred Bosselman
Charles L. Siemon

Economic Consultant:
Dr. J.C. Nicholas, Florida Atlantic University

Civil Engineering Consultant:
Johnson Engineering, Inc., Fort Myers, Florida
Archie Grant, President
Forest Banks, Vice-President

Traffic Consultant:
J.H.K. Associates, Arlington, Va.

Geologist-Hydrologist:
Dr. A.H. Johnson, University of Pennsylvania

Major reference for environmental studies "Sanibel Natural Systems Study," John Clark, Project Director, The Conservation Foundation.

Members of City Council:
Porter J. Goss, Mayor
Zelda Butler, Vice Mayor
Vernon G. MacKenzie
Charles R. LeBuff, Jr.
Francis P. Bailey, Jr.

City Manager:
David J. Bretzke*
William Nungester - March 1976

Assistant City Clerk and City Treasurer
Mildred Howze

City Legal Counsel
Roberts & Watson, Fort Myers
Frank Watson
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City Planning Commission
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8. See also "Sanibel Natural Systems Study" by John Clark and others for Sanibel/Captiva Conservation Foundation.

9. Quoted from the Preamble of the _Comprehensive Land Use Plan_, City of Sanibel, Lee County, Florida, 1976.

PART III

Friday, November 19, 1976

HYDROCARBON STRESS IN COASTAL WETLANDS

M. Gordon Frey, Session Chairman

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6. "Oil in Southern California Marshes," Dale Straughan

* Paper not available for publication

HYDROCARBON STRESS IN COASTAL WETLANDS

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The presence of oil in the coastal areas has been historically recorded over a long period of time. The early Greeks skimmed oil off the waters of the Aegean Sea. Here in this country, one of the earliest references to oil comes from the records of the early explorer, Hernando DeSoto. After his death in 1542, his successor, Luis de Moscozo de Alvarado, constructed several boats and sailed down the Mississippi River, and westward to the coast of what is now Texas. At a point near the site of the present day Galveston, the log of his journey reports that the Spaniards gathered slabs of tar weighing 8, 10, 12 and 14 pounds from the beach to repair their leaky vessels.

On the West Coast of the United States in the same year, 1542, Juan Rodriguez Cabrillo visited the Santa Barbara coastal area of California. The Canalino Indians, living there, were using tar from seeps to caulk their canoes, as adhesives to fix arrow points to shafts, and for mending their bowls. In 1792, Vancouver, Captain Cook's navigator, reported that the Santa Barbara Channel surface was covered with a thick, slimy substance with a strong smell of tar. In 1856 Charles Morrell, a San Francisco druggist, erected a distilling plant at Carpenteria, California, to take advantage of the seeps in the area.

Before progressing any further, let us review briefly how and where oil occurs, and why we have seeps on land and in marine waters in some areas and not in others.

To have a major seep or a commercial oilfield, the following conditions must exist:

1. An adequate thickness of sedimentary rocks.
2. Source beds to generate oil and/or gas.
3. Reservoir beds into which oil may move and migrate.
4. Migration routes from source beds to traps.
5. Traps which stop migration and cause accumulation.
6. Timing of generation, migration and entrapment.

The above conditions exist in the coastal zone of the Gulf Coast and the West Coast. Oilfields and seeps are also present in both localities.

On our East Coast, the sedimentary rock column is generally too thin and the absence of adequate source beds are responsible for the lack of seeps and oilfields there.

The sedimentary section is expected to be much thicker seaward, with the existence of more and better source beds on the offshore continental shelf. This is expected to occur in all three Atlantic offshore basins, Georges Bank, Baltimore Canyon, and SE Georgia Embayment. Some students of the subject of seeps believe that up to 95% of the oil generated escapes through seeps. Evidence of some of these huge seeps can be found in the Athabaska tar sands of Canada, the Trinidad asphalt lake in the Caribbean, and the Venezuelan tar sands.

Oil and gas seeps from fractured or faulted traps or from traps that have been destroyed or eroded by uplift or other orogenic means.

In recent times an increase of oil in the coastal and offshore marine waters has been noted. A study by the National Academy of Science was undertaken and a report issued by them in 1975. The results of that study are listed in the following table:

OIL IN MARINE WATERS

Source	Million Metric Tons/Year	Percentage
Marine Transportation	2.13	34.9
River & Urban Runoff	1.9	31.1
Coastal Refineries & Waste	0.8	13.1
Offshore Oil Production	0.08	1.3
Atmospheric Fallout	0.6	9.8
Natural Seeps	0.6	9.8
Total	6.11	100.0

From the above you can see that offshore exploration and production contribute very little to the total. Natural seeps contribute more than seven and almost eight times as much oil to the marine waters as do offshore exploration and production.

Another major source of oil pollution in marine and coastal areas occurred during World War II. In one three-month period, from May to August, 1942, 12 tankers were sunk by German submarines off the coast of Louisiana. Ten of these tankers carried almost 900,000 barrels of crude and refined oil. It was reported by Coast Guard and Naval personnel that much of the marshy coastline of Louisiana was covered by a frothy emulsified mass of oil and water up to a foot thick. No attempt was made to clean up the mess, as wartime restrictions prohibited such action. The area about Halifax, Nova Scotia, was even worse looking, as here German submarines sank many tankers involved with the convoys as they assembled for their voyage across the Atlantic to Europe. The loaded capacity of the 49 tankers lost along the Atlantic Coast was over 4,800,000 barrels of crude oil or petroleum products. Many of the famous beaches along the Atlantic Coast were covered by oil. The torpedoed tankers could be seen from the shore as they burst into flames and sank offshore.

The use of offshore to shore pipelines and the establishment of superports would do much to reduce oil pollution of coastal bays and river mouths. The lightening of large crude carriers into barges and small tankers for transportation to coastal installations is more prone to accidents and resulting pollution than pipelines and deepwater ports. There are 100 deepwater ports throughout the world. None in the United States.

I hope this will serve as an introduction to the five papers that follow in this session, "The Hydrocarbon Stress in Coastal Wetlands."

ENVIRONMENTAL CONSIDERATIONS OF THE OIL AND GAS PRODUCTION INDUSTRY IN THE COASTAL ZONE

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Introduction

The environmental laws and regulations which apply to petroleum producing industry operations are becoming increasingly more numerous and complex. This discussion centers on how these controls affect operations in the marshes and waters of South Louisiana, including both federal and state regulatory programs.

The first topic to be discussed is the federal control on water pollution which began with the Rivers and Harbors Act of 1899. The Federal Water Pollution Control Act, discussed next, is the present basis for most of the controls existing today, including the prohibition against discharging harmful quantities of oil, the EPA and Coast Guard oil pollution prevention regulations, the NPDES discharge permit program, and the Corps of Engineers' permit program for dredging projects. Louisiana's water pollution control effort is also described.

The extensive impact of these regulations will then be brought into focus by reviewing the environmental requirements and permits which must be achieved in the drilling of a wildcat well and construction of facilities to put it on production.

Water Pollution - Federal

The first significant water pollution control legislation enacted by the Federal Government was the Rivers and Harbors Act of 1899, also known as the Refuse Act. Though the main intent of this law was to control obstructions to navigation, Section 13 of this Act could also be, and in fact has been, interpreted to prohibit the discharge of refuse into navigable waters regardless of whether navigation is affected, unless a permit for such a discharge had been granted by the Corps of Engineers. Through various court determinations, the term "refuse," as used in this Act, has been defined to include waste product as well as commodities having economic value such as oil or gasoline. Thus, for over 75 years, the United States has had a law that could, according to the most recent interpretation, be used to prosecute water polluters. However, that part of Section 13 which prohibited the discharge of refuse matter into the navigable waters was not vigorously enforced, except for hindrance to navigation, and consequently proved to be unsuccessful for broad water pollution control.

Congress' answer to this ineffective water pollution control effort was the passage of the Federal Water Pollution Control Act in 1956 and its subsequent amendments which culminated with the Federal Water Pollution Control Act Amendments of 1972 - hereinafter referred to as "the Act." This law is administered primarily by the Environmental Protection Agency and is the current basis for the EPA's rules and regulations on cleaning up the nation's waters. The Act is complicated and contains numerous provisions which the courts have found difficult to interpret.

Section 311 of the Act deals with oil and hazardous substance pollution and can be broken down into three parts for the purposes of this discussion. The first concerns the prohibition against the discharge of oil in harmful quantities to the navigable waters. The second calls for oil pollution prevention regulations for non-transportation-related facilities, such as oil production facilities, and the third requires promulgation of pollution prevention regulations for transportation-related facilities, such as oil transfer facilities.

Section 402 covers the NPDES, National Pollutant Discharge Elimination System, discharge permit program.

Section 404 provides for regulation of dredged material.

The prohibition against the discharge of "harmful" quantities of oil is the most difficult aspect of Section 311 with which to deal, and is so, primarily because of the definition of "harmful quantities of oil." Through Executive Order 11735, and acting under the provisions of Section 311, the President charged the EPA with the responsibility of defining this term, "harmful quantity." In response, the EPA, by regulation, declared all discharges of oil which either, "(a) violate applicable water quality standards, or (b) cause a film or sheen upon or discoloration of the surface of the water ..." to be harmful. Discharges from properly functioning vessel engines are excluded. Thus, a film or sheen caused by a vessel engine is not "harmful" but one from a production facility is "harmful." The net effect is that practically all discharges from oil production facilities are prohibited because any small amount of oil on the water may cause a sheen. The definition of a sheen as a harmful quantity does not consider adequately the actual environmental impact that an oil spill might have. Many biological studies prove that small discharges of oil have no significant adverse impact on the aquatic environment. The sheen test was chosen as a suitable definition of harmful quantity because it is easy to detect visually and was regarded as a convenient tool for enforcement. However, visible sheens caused by municipal sewage and urban drainage have not been commonly subject to enforcement. A comparison with a recent EPA proposed regulation setting out what constitutes harmful quantites of certain hazardous substances further demonstrates that the present definition is much too restrictive regarding oil. For example, proposed regulations state that up to 100 pounds of strychnine can be discharged in a single incident before a "harmful" quantity has been released. Similarly, 10 pounds is a "harmful" quantity for certain arsenic compounds. In contrast, it has been demonstrated that addition of as little as one tablespoon of lubricating oil to a refinery's discharge can create a visible sheen under favorable lighting conditions. Clearly, a more realistic definition of "harmful" quantity of oil is appropriate.

Any discharge of oil is a violation regardless of fault, quantity, or potential for environmental harm. It automatically subjects the owner or operator of the facility or vessel from which the discharge occurred to a civil penalty of up to $5,000 for each offense. In the event of a spill, the person in charge of any facility or vessel that experiences an oil spill must immediately notify the U. S. Coast Guard. Failure to do so is a criminal offense which carries a penalty of up to $10,000, or imprisonment for up to one year, or both. Thus, an operator must be extremely careful to follow the letter of the law: whenever he spills any quantity of oil, he must immediately telephone the Coast Guard or face criminal prosecution. The Coast Guard can then take the information he supplies and use it as a basis for levying the civil penalty of up to $5,000 for spilling the oil.

In addition to the above penalties, an operator is also liable for the cost of cleaning up the spill. Though neither the Act nor the Coast Guard regulations require an operator to clean up his spilled oil, the Act does hold him responsible for cleanup costs. The maximum liabilities are $8,000,000 for facilities and $14,000,000 or $100 per gross ton, whichever is lesser, for vessels. Most companies clean up their own spills because voluntary cleanup results in quicker recovery of spills, and is the most cost-effective course to take.

The second aspect of Section 311 that is of importance to the producing industry is that which authorized the President to direct the EPA to develop oil spill prevention regulations for non-transportation-related facilities. The resulting EPA rules are commonly referred to as SPCC (spill prevention control and countermeasure) regulations, which require that an SPCC plan be prepared for each non-transportation-related facility having an oil storage capacity greater than 660 gallons in any one tank, 1,320 gallons aggregate storage, or 42,000 gallons underground storage, and from which an oil spill could reasonably be expected to reach the navigable waters. The plan must be signed by a registered professional engineer certifying that the plan was prepared in accordance with good engineering practices. The SPCC plan contains a written discussion of the oil spill potential for the facility, the spill prevention equipment in use at the facility, and of the contingency planning in the event of a spill. In addition, if there is significant potential for an oil spill into public waters and the contingency plan or facilities are deemed inadequate, then the plan must indicate an implementation plan to improve the oil spill prevention and control capabilities. The plan must be reviewed at least once every three years to evaluate its adequacy. In the event that a facility experiences two minor spills of 1,000 gallons or less (see above discussion on harmful quantities) within any twelve-month period or a single spill larger than 1,000 gallons, then the SPCC plan for that facility and information relative to the spills must be submitted to the EPA for review. EPA then evaluates the plan, possibly in conjunction with a facility inspection, and may require any changes in the plan that are deemed necessary to prevent and contain any future discharges of oil from the facility. Such changes may involve costly modifications of the facility itself and are not merely changes in a written document. Thus, if a facility's spills exceed the minimum established in the regulations, the EPA is provided with an avenue for reviewing the operations and specifying improved operating and equipment requirements to be implemented at that facility.

The EPA SPCC Rules and Regulations are of necessity general in nature and place the burden of devising a successful program upon the owner or operator because of the great diversity of types of facilities covered. Uniform national regulations in great detail would not be practicable. The third and final provision of Section 311 to be discussed here is the paragraph that authorized the

President to direct the U. S. Coast Guard to prepare oil pollution prevention regulations for transportation-related facilities. The Coast Guard's initial effort in this respect has been the promulgation of pollution prevention regulations for vessels and oil transfer facilities. Other transportation-related facilities, such as pipeline pumping stations, will be subject to another set of regulations that the Coast Guard is to issue at a later date. The regulations that are already in effect prescribe equipment requirements and transfer procedures for facilities and vessels which are involved in the transfer of oil. Only facilities which transfer oil to or from vessels having capacities of 250 barrels or more are subject to the regulations. Similar to the SPCC regulations, these Coast Guard rules require that a manual be prepared and submitted to the Coast Guard at least 60 days prior to the first transfer for each facility subject to the regulations; however, unlike EPA's rules, the Coast Guard regulations clearly specify definite equipment and operational requirements for equipment which are common to most transportation -related facilities. For example, hoses and loading arms used in the transfer must meet certain criteria, drip pans of specified capacities must be fixed beneath hose handling and manifold areas, spill containment and removal equipment must be provided, certain records have to be maintained, and a written declaration that all equipment has been inspected and found to be in proper condition for transfer must be signed before beginning a transfer.

The next section of the Act that is of considerable importance to the producing industry is Section 402 which establishes the discharge permit program known as the NPDES (National Pollutant Discharge Elimination System) program. During this discussion of Section 402, provisions of other sections of the Act will be included because certain of these requirements are implemented through the issuance of an NPDES discharge permit under Section 402. Section 402 is EPA's authority for regulating the discharges of pollutants by man from point sources. In establishing EPA's authority, it provides for the removal of the permit program from the control of the U. S. Corps of Engineers who had had jurisdiction over discharges since the enactment of the Refuse Act in 1899. The Act also provides for the states to assume the responsibility of administering the NPDES permit program as soon as the state's program is in compliance with EPA requirements.

The primary provision of Section 402 and of EPA's implementing regulations is that any person who proposes a point source discharge of a pollutant to the navigable waters from a facility must first obtain an NPDES discharge permit by submitting an application at least 180 days before such discharge is to begin. The term, "pollutant," has been defined by the Act, and further interpreted by EPA, and could include virtually any substance discharged by man, except pure water. The Act excludes from the EPA's jurisdiction the regulation of sewage discharges from vessels, giving this responsibility to the Coast Guard. Nevertheless, there are no provisions for exemptions from the permit requirements based on the minimal volume or innocuous nature of a particular discharge.

Using the NPDES permit program as a management tool, EPA is instituting a program as authorized by the Act to help clean up the nations water in various steps by eventual control of major point sources. One of the factors that EPA considers is the water quality standards that have been adopted by each state and approved by the EPA, for waters within each state. The water quality standards specify limitations on certain chemical, physical or other factors that must be maintained in the receiving waters to assure "... the protection and propagation of shellfish, fish, and wildlife for classes of and categories of receiving waters and to allow recreational activities in and on the water." Thus, water quality standards are limits that must not be exceeded in the receiving water, and that are to be achieved first by uniform national technology based effluent limitations and second by the imposition of more stringent limitations on the discharge where required for water quality needs. Before the EPA will issue a permit for a discharge the applicant must obtain certification from the state that the discharge will not violate the applicable water quality standards.

The next step or goal of the Act's water pollution control scheme is that all discharges must be using the so called "best practicable control technology currently available" by July 1, 1977. This level of control is different from the water quality consideration in that in defining best practicable technology for a discharge, the EPA does not consider the water quality-related environmental benefits to be achieved by applying such technology; rather only the practicability of implementing such technology at a facility is taken into account, including "... the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, and shall also take into account the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, nonwater quality environmental impacts (including energy requirements), and any such other factors as the Administrator (of the EPA) deems appropriate." Thus the EPA does not consider whether a pollutant, at the effluent concentrations existing before implementation of best practicable technology, is harming the environment or not. Thus, the agency is taking the approach of reducing the level of pollutants to the lowest practicable degree by July 1, 1977. It is not unexpected that major conflict arises when this concept of practicability is applied to the costs associated with a specific treatment technology, especially in those instances where minimal water quality-related benefits are gained by the application of that technology.

The third goal envisioned by Congress is the application of "best available technology economically achievable" to all discharges by July 1, 1983. The main difference between best available technology and best practical technology is that the 1983 requirement goes one step further. In defining the best available technology for a discharge, the EPA considers all of the same factors as for best practicable technology except that the expected reduction in effluent pollution concentrations does not have to be related to the costs. In other words, tremendous expense might be incurred for treating a discharge so as to reduce the effluent only a very small degree. Such expenditures could be required so long as the EPA had determined that the specified technology was "economically achievable."

The fourth and ultimate goal of the Act is "... that the discharge of pollutants into the navigable waters be eliminated by 1985." This goal is impossible for industry to meet and there is almost general agreement that it should be changed. The National Commission on Water Quality recommended that Congress redefine this goal.

There is one more level of treatment that is defined in the Act and it applies only to new sources, that is to discharges from facilities whose construction began after the EPA had issued guidelines (in proposed form) for such new sources. For these new sources, the Act requires that the "best available demonstrated technology" be incorporated as part of the facility when it is built. This technology is defined considering essentially the same factors as those used in defining best available technology - a rather sophisticated treatment scheme is usually defined.

The mechanics of this multi-phase pollution control effort were designed to work in the following manner. EPA publishes water quality criteria, and the states promulgate water quality standards for the various water bodies within each state. These standards must be approved by EPA. Information and guidelines are promulgated by the EPA, defining secondary treatment and best practicable waste treatment technology for municipalities, and best practicable control technology currently available (to be implemented by July 1, 1977), best available technology economically achievable (to be implemented by July 1, 1983), and best available demonstrated technology (for new sources) for industry. All of these treatment technologies are defined such that the EPA regional administrators can use these guidelines in establishing effluent limitations in discharge permits for individual facilities. The permits are to set out compliance schedules for each facility in meeting the limitations established as representing the effluent quality achievable through the use of the designated technologies.

The next section of the Act to discuss is Section 404 which regulates the discharge of dredged or fill material. The responsibility of issuing permits for such discharges is left with the U. S. Corps of Engineers which is required to consider the various esthetic and environmental factors associated with each proposed disposal operation before granting a permit. The EPA has published guidelines that the Corps is to use in evaluating each application. The Corps is also required to consider the comments of other federal agencies on each application, including those of the U. S. Fish & Wildlife Service and the National Marine Fisheries Service. In addition, after the Corps has decided to grant a permit for a particular discharge of dredged material, the EPA then has the authority to prohibit the specification of any defined area as a disposal site whenever it determines that the proposed disposal will have "... an unacceptable adverse effect on municipal water supplies, shell fish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas."

Until recently, the Corps exercised its authority granted by Section 404 only over the area of jurisdiction authorized by the Rivers and Harbors Act of 1899 - i.e., the traditional "navigable waters of the United States." However, a federal district court ruling (the Callaway case) in March, 1975, directed the Corps to expand its jurisdiction with respect to the discharge of dredged material to correspond to the "navigable waters," as defined in the Federal Water Pollution Control Act Amendments of 1972 and other court decisions. The Corps' response was the publication of an interim final regulation in July, 1975, expanding the area of jurisdiction in a three-phase program which culminates July 1, 1977, with the Corps' Section 404 jurisdiction extending to all waters of the United States. One of the key tests in determining whether an area is subject to the provisions of Section 404 is whether it supports aquatic vegetation. Essentially, if a land area is periodically inundated to the extent that aquatic vegetation can grow there, then the Corps will have jurisdiction over dredged material disposal projects in that area. Also, the only disposal projects within the Corps' jurisdictional area excluded from regulation are those involving less than one cubic yard of dredged material.

Water Pollution - State

Next, we come to a discussion of water pollution control requirements by the State of Louisiana.

With respect to oil spill, both the Louisiana Stream Control Commission, whose enforcement division is within the Louisiana Wildlife & Fisheries Commission, and the Louisiana Department of Conservation exercise regulatory authority. Both agencies enforce rules which prohibit the discharge of oily waste, and provide reporting procedures for oil spills.

The control of waste water discharges in Louisiana is the responsibility of the Louisiana Stream Control Commission. Discharge permit applications must be submitted early enough so that they can be acted upon by the Commission before the discharge begins. The Stream Control Commission does not exercise direct authority on the regulation of sewage discharges. The Health and Human Resources Administration's Division of Health regulates those discharges. All private sewage disposal systems must have the Division of Health's approval before installation. Generally, sewage treatment devices must provide secondary treatment.

Summary

Probably the best way to conclude this paper is to summarize, by way of example, the environmental aspects associated with a typical producing operation in the coastal marshes of Louisiana. For instance, let's look at the steps that must be taken for a successful wildcat well to be drilled and tank battery to be installed to handle the production.

Six months before drilling begins, a discharge permit application must be submitted to the EPA so that the drill cuttings and other pollutants such as sewage and deck drainage may be discharged during the drilling operation. On this same application, the produced water and deck drainage discharges from the possible future production facility should also be described to insure that EPA gets six months in which to process all discharge permit applications. A six-month lead time can give the operator very real difficulties. Such factors as rig availability and lease expiration dates interfere with the providing of such an early advanced notice.

Next, at least two months (preferably three) before drilling is to begin, a permit application must be submitted to the Corps of Engineers to dredge an access canal to the proposed location. The application is circulated for environmental review by federal and state agencies, including the U. S. Fish and Wildlife Service, the National Marine Fisheries Service, the Environmental Protection Agency, the Louisiana Wildlife and Fisheries Commission, the Louisiana Stream Control Commission, and the Louisiana Department of Public Works. In addition, approval may be required from local government bodies such as police juries, levee boards, or port authorities. Provided any objections by these agencies, or by way of the public notice that is required, are resolved, a permit will be granted by the Corps to dredge the canal and move in a drilling rig. If the well is successful, it will be completed and plans will be made to construct a production facility.

Since production for this facility is from a wildcat well, there are probably no pipelines immediately available for transporting the oil. Therefore, the crude will have to be barged out. At least 60 days before any oil transfers to a barge are to begin, a letter of intent to conduct such transfers and an operations manual must be submitted to the U. S. Coast Guard. The Coast Guard will inspect the facility to determine whether all requirements have been complied with.

At this point, if all of the above requirements have been met, the facility is fully operational with respect to satisfying all environmental regulations. However, though the facility may be started up, certain other requirements will need to be addressed. An SPCC plan must be prepared within six months of commencement of facility operation and all provisions described in the plan must be fully implemented by the end of the next six-month period, i.e., by one year after commencement of operations. Remaining obligations would then be those recurring requirements such as discharge monitoring and reviews of the SPCC plan and operations manual. In addition, there are other permit requirements by the State of Louisiana such as (1) permit to drill, (2) reports on casing setting, cementing, perforating, and completion, (3) authority to produce, and (4) authority to transport production off lease (to barge, pipeline, or truck).

As this example illustrates, the environmental regulations affecting the producing industry are complex. As the government continues to expand its jurisdictions, as authorized by various laws - for example into underground injection control, drinking water regulation, and solid waste disposal -- the whole problem will become still more complicated and will demand increasingly larger amounts of negotiations with regulatory agencies, processing of paper work, administrative personnel, and corporate expenses financed by increased costs to consumers for products.

There is no doubt that industry is under a mandate to do its part in environmental protection. It certainly must fulfill its reponsibility for protection of human health, welfare, and the natural environment. It must comply with all of the laws and regulations which are in effect. Government also has its own responsibility to be certain that its rules and regulations do not become so complex that they generate unnecessary expenses to industry and consumers or interfere with the nation's ability to meet its energy requirements. Government and industry must work more closely together to be sure that this does not happen.

PETROLEUM OPERATIONS IN THE LOUISIANA MARSH *

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Abstract

A review of petroleum operations in the Louisiana marsh and the role played by the Louisiana Wildlife and Fisheries will be discussed by Dr. Lyle St. Amant. Dr. St. Amant has been involved in the development of the oil industry in the Louisiana coastal area for many years, and is most familiar with all the problems relative to past and present operations.

*Paper not available for publication.

FIELD STUDIES ON MARINE LIFE INHABITING AREAS OF CHRONIC LOW LEVEL EXPOSURE TO PETROLEUM

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ABSTRACT

EXTENSIVE FIELD STUDIES ON THE EFFECTS OF CHRONIC LOW LEVEL EXPOSURE OF OIL TO MARINE LIFE HAVE BEEN CONDUCTED AT SANTA BARBARA; LAKE MARACAIBO, VENEZUELA; BERMUDA; AND TIMBALIER BAY, LOUISIANA, IN THE GULF OF MEXICO. NO MEASURABLE EFFECTS HAVE BEEN OBSERVED ON SUCH INDICATORS OF THE HEALTH OF MARINE COMMUNITIES AS POPULATION LEVELS OF VARIOUS ORGANISMS; SPECIES DIVERSITY; AND SIZE, GROWTH RATE, OR REPRODUCIBILITY OF VARIOUS ORGANISMS. MOREOVER, THERE IS NO EVIDENCE OF ADVERSE EFFECTS SUCH AS ABNORMAL GROWTHS AND BIOMAGNIFICATION OF PETROLEUM FRACTIONS IN THE FOOD CHAIN.

INTRODUCTION

Surprisingly, the volume of literature concerning the effects of oil on marine life is extensive. Several comprehensive summaries of the literature have been published.[1,2,3,4] Whether one reviews the literature directly or the summaries that are available, it is apparent that most of the published work concerns laboratory work. Only a few field studies have been conducted.

Laboratory work has proven generally unsatisfactory because its results correlate poorly with field observations. Fortunately, in recent years, some work has been directed toward investigating the effects of chronic exposure of oil on marine life under field conditions. The results of five such field studies are summarized below.

NATURAL OIL SEEPS
AT COAL OIL POINT,
SANTA BARBARA

Straughan and her associates at the University of Southern California recently concluded a three-year study concerning the sublethal effects of natural chronic exposure of oil to marine life. Her laboratory was the marine waters at Coal Oil Point near Santa Barbara, California, where natural oil seeps have been known to exist for centuries. The natural seepage there is 50-100 barrels per day.[5] Extensive control data were obtained from studies conducted at Pismo Beach (north of Santa Barbara), Gull Island (near Santa Barbara), and Santa Catalina Island (near Los Angeles).

The major conclusions of this study are:

1. All organisms are present that would be expected to be in that environment if oil seepage was not there.

2. Exposure to the natural oil seepage has no effect on either the growth rate or reproductivity of the resident organisms.

3. No abnormal growths in organisms were observable either by external examination or by dissection.

4. There is no evidence of bioaccumulation (increase in concentration) of hydrocarbons by transfer up the food chain.

CHRONIC EXPOSURE OF MARINE
ORGANISMS TO TAR BALLS, BERMUDA

A relatively recent phenomenon is the influx of tar balls washing ashore along the Bermuda coastline. The Bermuda Biological Station for Research has just concluded a two-year study to determine whether the influx of tar balls was having any effect upon the local intertidal life.

Control data were obtained by studying beaches that were slightly impacted. Also used were the extensive baseline data developed by annual studies extending back to the 1890's.

The major conclusions concerning marine life inhabiting the intertidal zone are:[9]

1. There is no measurable effect of tar influx on the number of organisms of any species at any locality.

2. All species identified as native to Bermuda shores prior to the tar ball influx still remain.

3. Exposure to the tar influx has no effect upon the reproductivity of the organisms.
4. Size of organisms is not affected by the exposure to tar influx.

These results provide an insight into the potential threat of offshore spills washing ashore to intertidal life. This is especially valid for spills, if they should occur, from platforms in areas 50 or more miles offshore in outercontinental shelf waters. Such potential production areas exist along the Atlantic Coast. The weathered oil that would wash ashore would be similar in composition and properties to the tar balls appearing on the Bermuda beaches.

LAKE MARACAIBO,
VENEZUELA

A three-year study was completed in 1974 by Battelle-Northwest Laboratories (Richland, Washington) on the impact of offshore production in Lake Maracaibo, Venezuela. Approximately 6500 wells have been drilled in this lake over a period spanning four decades. Sites in those sections of the lake where oil production does not occur were also studied to obtain control data.

The major conclusions from this study are:

1. Despite significant discharges of oil into Lake Maracaibo from production of oil and from natural seeps, both laboratory and field data show that the presence of oil has caused no discernible damage to the local ecosystem.
2. Although low concentrations of oil exist in the lake water, there is no evidence of a buildup of hydrocarbons in selected commercial species of fish or shrimp.
3. Although fisheries data are limited, no evidence exists that suggests this important renewable resource has yet been diminished.
4. However, discharge of nonpetroleum wastes, both domestic and industrial, are approaching such levels as to impair water quality. The biological resources of the lake may decline in future years.

TIMBALIER BAY,
GULF OF MEXICO

The Gulf Universities Research Consortium (GURC) studied the impact of offshore drilling and production of oil on the estuarine and marine environment in the coastal waters of Louisiana, specifically, in

Timbalier Bay. The study involved 23 principal scientists from the 20 Gulf Coast universities that comprise GURC. Conducted over a period of two years, 1972-1974, and at a cost of 1.5 million dollars, this study is undoubtedly the most comprehensive study concerning the effects of chronic exposure of oil to marine life ever attempted.

Timbalier Bay contains about 400 oil and gas wells. The first well was drilled in 1937. Several stations within this area were studied. Stations were also studied in adjoining areas where there never had been oil drilling or production in order to obtain control data.

Many observations and conclusions may be derived from this work, namely:[12,13,14]

1. Seasonal changes, especially in temperature and salinity, have a far more significant effect on species diversity of marine life and on the population of a given species than does the presence of low-level concentrations of oil.

2. Even the effects of other less important natural phenomena, such as floods, upwellings, and turbidity, affect the ecosystem markedly. Their influences completely obliterate whatever effect, if any, results from exposure to oil.

3. No known biological hazard could be related to any compound or material used in drilling and production.

4. Timbalier Bay has not undergone significant ecological change. Every indication of good ecological health is present.

5. Evidently, the platforms have increased the total quantity of marine life. These structures provide surfaces where planktonic larvae of organisms such as barnacles, mussels, sea anemones, and other forms of sessile marine life may settle and flourish to become high productive, complex communities.

SURVEY OF MARINE LIFE UNDER OFFSHORE PLATFORMS IN SANTA BARBARA CHANNEL

Platforms Hilda and Hazel were constructed in the Santa Barbara Channel in 1959 and 1960. During their construction, a survey revealed that the surfaces of these structures quickly became encrusted and a complex marine community including sessile, benthic and pelagic forms developed.[15]

A year's survey was initiated early in 1975 to assess the extent and complexity of the marine community under the two platforms constructed in the Santa Barbara Chennel in 1959 and 1960. This study was conducted by the Southern California Coastal Water Research Project under the direction of the Scripps Institution of Oceanography near San Diego.

The major observations resulting from this survey are:[16]

1. A highly complex community has developed under each platform. Communities on either the soft or hard bottom control areas are far less complex and far less abundant.

2. The pelagic fish population inhabiting the area under the platforms is estimated to be 20,000-30,000 per platform.

3. Positively identified are at least 50 species of fish, 110 species of intertebrates living on or near the structures, and 77 species of worms inhabiting the nearby sediments.

4. All sea life appears to be extremely healthy. Mussels 8-10 inches in length are numerous; larger ones have been observed.

5. Every available underwater surface of the platforms is heavily encrusted with mussels, barnacles, aggregate anemones, or other types of sessile sea life.

6. Drill cuttings were deposited at the base of the platform. Being sterile, they did not support marine life for two to three years after the platforms were constructed. Today this pile is covered by a depth of 37 inches of shells and now supports a teeming community of seastars, anemones, nudibranches, and other benthic organisms.

CONCLUSIONS

The major conclusions that may be derived from the field studies conducted to date are:

1. Low-level chronic exposure to crude oil has, at most, negligible effect on marine life.

2. Platforms provide a structure whereby a thriving, highly complex community of marine life can develop.

REFERENCES

1. D. F. Boesch, C. H. Hershner, and J. H. Milgram, "Oil Spills and the Marine Environment," report to the Energy Policy Project of the Ford Foundation, Ballinger Publishing Company, Cambridge, Massachusetts, 1974.

2. A. Nelson-Smith (Ed.), "Oil Pollution and Marine Ecology," Plenum Press, New York, 1973.

3. "The Environmental and Financial Consequences of Oil Pollution from Ships," Preparations for International Marine Pollution Conference 1973, United Kingdom Programmes Analysis Unit, Chilton, Didcot, Berks, 1973.

4. "Petroleum in the Marine Environment," National Academy of Sciences," Washington, D.C., 1975.

5. D. Straughan, report in preparation for the American Petroleum Institute, August 1976.

6. R. D. Wilson, P. H. Monaghan, A. Osanik, L. C. Price, and M. A. Rogers, "Natural and Marine Oil Seepage," Science, Vol. 184, pp 857-865, 1974.

7. B. F. Morris, "Petroleum Residues in the Sargasso Sea and on Bermuda Beaches," Proceedings of the 1973 Conference on Prevention and Control of Oil Spills, pp 521-530, March 1973.

8. J. N. Butler, B. F. Morris, and J. Sass, "Pelagic Tar from Bermuda and the Sargasso Sea," Special Publication No. 10, Bermuda Biological Station for Research, St. George's, Bermuda, 1973.

9. N. G. Maynard, report in preparation for the American Petroleum Institute, August 1976.

10. "Study of Effects of Oil Discharges and Domestic and Industrial Wastewaters on the Fisheries of Lake Maracaibo, Venezuela," report by Battelle Pacific Northwest Laboratories, Richland, Washington, to Creole Petroleum Corporation, Caracas, Venezuela, October 1974.

11. W. L. Templeton, E. A. Sutton, R. M. Bean, R. C. Arnett, J. W. Blaylock, R. E. Wildung, and H. J. Moore, "Oil Pollution Studies on Lake Maracaibo, Venezuela," Proceedings of the 1975 Conference on Prevention and Control of Oil Pollution, pp 489-496, March 1975.

12. "The Offshore Ecology Investigation: Final Project Planning Council Consensus Report," GURC Report No. 138, editors: J. M. Sharp and J. W. Tyson,

Gulf Universities Research Consortium, Galveston, Texas, September 20, 1974.

13. "The Offshore Ecology Investigation," Gulf Universities Research Consortium, Galveston, Texas, undated report.

14. J. W. Tyson, Testimony Prepared for Bureau and Land Management Hearing, OCS Sale No. 39, Anchorage, Alaska, August 12-13, 1975.

15. J. G. Carlisle, Jr., C. H. Turner, and E. E. Ebert, "Artificial Habitat in the Marine Environment," Fish Bulletin 124, The Resources Agency of California, Department of Fish and Game, 1964.

16. W. Bascom, A. J. Mearns, and M. D. Moore, "A Biological Survey of Oil Platforms in the Santa Barbara Channel," Proceedings of the 1976 Offshore Technology Conference, Vol. II, pp 27-36, May 1976.

COASTAL ZONE OPERATIONS IN THE GULF OF ALASKA*

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Abstract

Mr. Loeb is director of Exploration Environmental Affairs for Pennzoil Company, a Houston-based natural resources company. In 1969 he opened an exploration office for the Pennzoil Company in Anchorage, Alaska. Pennzoil participated in many exploration programs, one of which was a bottom coring program, conducted jointly with a number of other companies, on the sea floor bottom of the Gulf of Alaska. The program utilized a center well drilling vessel to penetrate a limited number of feet below the overburden into the bottom sediments. The slides Mr. Loeb will utilize were taken on a flight from Cordova, Alaska, over the Gulf of Alaska to the drilling vessel, located at one of the core test sites southwest of Kayak Island. Mr. Loeb does not plan to present a formal speech but will explain the pictures and comment on the coastal zone.

*Paper not available for publication.

OIL IN SOUTHERN CALIFORNIA MARSHES

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ABSTRACT

Data are presented from surveys in 1974, 1975, and 1976, conducted at sites just inside the entrance to four southern Californian marshes. The studies were initiated to establish a baseline for the areas. Small amounts of tar were recorded on or adjacent to all survey sites. The distribution of species recorded on these surveys appears related to the normal abiotic variables operating in the survey areas and unrelated to the small recorded amounts of tar.

ACKNOWLEDGMENTS

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INTRODUCTION

Coastal wetlands are generally considered to be one of the most important and sensitive environments to the impacts of petroleum pollution. These assumptions are based on the generally high productivity of these areas, their extensive use by many species as nursery grounds, and the low energy nature of the environment. The latter means that once oil enters the system it is retained over a long period and hence can have a prolonged impact. Most of the research on these marsh areas in the United States has been conducted on the Gulf of Mexico and east coasts. These are areas of extensive low marshlands which have regular input from freshwater and marine sources.

Marshes in southern California differ from these more studied areas in several respects which are related to major differences in physiography. Cooper (1974) in his review of salt marshes of the United States recognizes two major groups of salt marshes: those characteristic of the East and Gulf Coasts on one hand and those characteristic of the West Coast on the other. The southern Californian marsh areas are generally not extensive but they are concentrated in relatively small estuarine areas; the input of freshwater is generally on a very seasonal basis and not continuous throughout the year; in many instances the marshes are not connected to the ocean throughout the year. The latter point is particularly important not only from the aspect of the normal ecology of the area but because this means that in these particular areas, there is only a limited time of the year when oil can enter the marshes from marine sources. However, once the oil is in the marshes, its presence is prolonged because it could be one or more years before the water flow is sufficient to wash it out to sea. The oil may have to be degraded in situ in these marshes. Studies such as those by Michael et al. (1975), have demonstrated that in east coast marshes degradation can be a prolonged process taking many years if the oil becomes mixed with the sediments and that the impact of the oil on the biota can thus be prolonged for several years.

The research outlined in the present paper presents the results of ecological studies inside the entrance to marshes in southern California. These studies were undertaken to establish a baseline, thought to be prior to contamination of these marshes. However, petroleum is already present at the sites studied. The research in each case was limited to a site near the ocean entrance to the marsh and so does not account for gradients in the marsh from the sea to freshwater sources, nor does it in any way purport to describe the marsh as a whole.

The research discussed herein was conducted in Morro Bay in 1974 and in the other three sites in 1975, 1976. All four sites were surveyed during the summer (July-August) using comparable survey techniques. Ecological comparisons are based on summer data with reference to the other available data to show the variability at each survey site.

MATERIAL AND METHODS

Physiography

Four sites, representative of different types of marsh areas were studied. They were, from north to south, Morro Bay, Mugu Lagoon, Santa Margarita River, and the slough (Salt Creek) in the Torrey Pines State Park (Figure 1). Maps showing survey locations are provided in Straughan 1974, 1976.

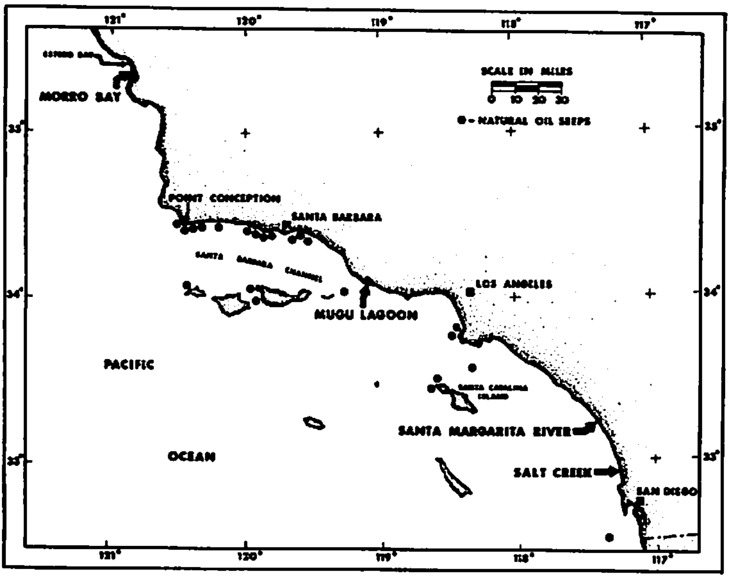

Figure 1. Map of southern California showing the location of Morro Bay, Mugu Lagoon, Santa Magarita River, and "Salt Creek" marshes as well as the location of natural oil seep areas.

Morro Bay is a large marsh area north of Point Conception. This could indicate that the biota may be representative of a different zoogeographic province than the biota at the other three sites which are south of Point Conception. The entrance to Morro Bay has been modified by the addition of artificial groins adjacent to Morro Rock and an intermittent dredging program at the entrance. This provides a safe harbor in the marsh entrance for the fishing fleet.

Mugu Lagoon, at the southern end of the Santa Barbara Channel, is an extensive marsh area within the Mugu Naval Reserve. Hence it has been subjected to little direct structural modification by man. Some periodic dredging of the entrance was conducted in the 1960s (Warme, 1970). However, it does receive the runoff from agricultural irrigation which suggests a man-made increase in freshwater influence as well as exposure to pesticides. While no data area available on the pesticide contamination it is believed that all four marshes are contaminated.

Mugu Lagoon is predicted to have the highest contamination from agricultural sources. Mugu Lagoon is currently open to the ocean throughout the year, although, the extensive sand bars at the mouth, at times, limit this to certain stages of the tide. Records from previous years indicate that there have been periods when Mugu Lagoon was not open to the ocean (Warme, 1970).

The marsh at the mouth of the Santa Margarita River is on the Camp Pendleton Marine Reserve and, as such, probably receives the least man-made interference. However, minor earth movement by heavy equipment presumably during "war games", has been recorded in the study area. This area also receives the runoff from a newly established but rapidly expanding irrigated agricultural area in the hinterland. Our observations show that this estuary is only open to the ocean periodically following rainfall. This is usually in the winter or spring but unseasonal summer rains in summer 1976 have extended this period.

The "Salt Creek" marsh at the Torrey Pines State Park has been modified at the entrance by highway construction and the construction of camping grounds. It is periodically subjected to pesticides from a mosquito abatement program. This area is probably subjected to the greatest degree of human interference of all four marshes. The "Salt Creek" marsh, like the Santa Margarita marsh, is only open to the ocean for periods following heavy rainfall, normally winter and spring.

The Santa Margarita River and "Salt Creek" marshes differ in their salinity regimes. Salinities at Santa Margarita River ranged from 20°/oo to 32°/oo in 1975, 1976, while at "Salt Creek" they ranged from 35°/oo to 40°/oo (Straughan, 1976).

Sampling

Field sampling methods have been described in detail by Straughan (1976). These methods involve sampling from high tide mark to low tide mark using a stratified quadrat regime. Cores are taken at randomly selected points in the quadrats and sieved to collect the organisms (1.5 mm mesh). Other samples are collected in the quadrat for grain size analysis and moisture and organic content of sediments. Plants collected in the cores and other additional species observed in the quadrat are collected for later identification. Other measurements taken in the field include:

intertidal profile (Emery, 1960)
air temperature
substrate temperature
water temperature
salinity

All tar collected in the cores or observed in the survey area is collected for later weighing. Grain size analysis is determined by settling tube and pipette analysis while moisture and organic content of sediments were measured using an Ohaus moisture meter.

RESULTS

A summary of the abiotic parameters measured at each site is provided in Tables 1 and 2. The Morro Bay site differs from the other three sites in several respects. The water and air temperature (15.0, 15.5°C) are several degrees cooler than at the other sites (18.0 to 21.0°C); the average moisture and organic content of the sediments are higher than at the other three sites; the average mean ϕ indicates that the sediments are generally finer than at the other sites; the effective tidal range shows there is a greater tidal fluctuation than at the other sites.

The salinity data indicates that there was some freshwater drainage from the Morro Bay marsh at the time of the summer survey (32°/₀₀). In summer 1975, conditions at Mugu Lagoon approximated to that of seawater (35°/₀₀) while at Santa Margarita River the salinity was below that of seawater (26°/₀₀) and at Salt Creek it was above that of seawater (38°/₀₀). While Mugu Lagoon, Santa Margarita River and Salt Creek were on the average drier than Morro Bay (1.38-1.80% average moisture content of sediments compared to 21.0% average moisture content), all survey sites had some areas that were in shallow water and in these instances the moisture content was in the order of 20%.

There was less plant material in the sediments at the three southern sites (0.18 to 0.24%) than at Morro Bay (0.80%). The Ohaus method of determining organic content by weight difference before and after heating does not measure organic materials that are part of the sand. The coarsest and most variable sediments were found in Mugu Lagoon (mean ϕ 1.36). At the other site the variability in the mean ϕ was ± 0.2 while at Mugu Lagoon it was ± 0.5. All sites have long gently sloping areas. However, the channels at the survey sites at Mugu Lagoon and Salt Creek were relatively shallow (less than 2 feet of water) and in both instances surveys were conducted across the channels and included a relatively steep bank as well as a gently sloping bank.

There was no tidal influence in either the Santa Margarita River or Salt Creek at the time of the summer survey. The tidal influence at Mugu Lagoon was limited to the upper part of the tidal cycle by low sand bars at the mouth of the lagoon. Similar sand bars completely close the Santa Margarita River and Salt Creek marshes off from the ocean seasonally.

TABLE 1. ABIOTIC PARAMETERS ON EACH SUMMER (JULY-AUGUST) SURVEY

Site	Morro Bay 1974	Mugu Lagoon 1975	Santa Margarita River 1975	Salt Creek Torrey Pines 1975
Air temperature (°C)	15.0	19.0	21.0	19.0
Water temperature (°C)	15.0	18.0	20.0	21.0
Salinity (^{o}/oo)	32	35	26	38
Moisture Content (Average %)*	21.0	1.71	1.80	1.38
Organic Content (Average %)*	0.86	0.24	0.18	0.20
Grain Size (Average mean ϕ)	2.54	1.36	2.01	1.97
Intertidal Slope	1:63	1:90** 1:20	1:40	1:80** 1:10
Effective Tidal Range (Feet)	7.0	3.0	3.0***	3.0***
Length (Feet)	440	370	120	400

* Measured by Ohaus Balance.

** Profile extends from one side to another and there is one steep and one gently sloping bank.

*** There was no tidal flow at the time of the survey and this is the difference in height between the old high tide mark and water level.

TABLE 2. TOTAL WEIGHT (g) OF TAR IN SURVEY AREA

Site	1974 Winter	1974 Summer	1975 Summer	1975 Fall	1976 Winter	1976 Spring
Morro Bay*	0.0	0.0				
Mugu Lagoon			0.0	0.0	18.8	4.7
Santa Margarita River			28.2	15.6	0.0	9.9
Salt Creek (Torrey Pines)			2.2	2.6	0.0	0.6

* = Tar recorded on rocks at edge of sand on both surveys.

Tar was recorded on the survey area at Mugu Lagoon, Santa Margarita River and Salt Creek during 1975, 1976 (Table 2). However, no tar was recorded on the Mugu Lagoon survey area in summer 1975. Likewise no tar was recorded on the Morro Bay survey area in summer 1974. However, in both instances several small pieces of tar were seen within 100 yards of the survey area. In all except the spring surveys, the tar was in small pieces (less than 2 inches in diameter) and was externally dry, suggesting this was weathered tar. In the spring (April 1976) surveys the tar was soft and sticky suggesting that it was discharged into the ocean only a short time before collection. All of the tar collected at these survey sites was on the substrate surface. None was recorded in the sand samples sieved for animals.

Over 180 species were recorded in the surveys conducted in these marshes (Table 3). It should be noted that this number includes generalized categories where only portions or young of an organism were recovered, as well as different stages in insect development. One-hundred and fifty is probably a more realistic species number. Since the survey sites are just inside the entrances to the marshes, it is not surprising to find a percentage of characteristically open coast sandy beach species living in the survey areas. For example, the sandy beach isopod, Exocirolana chiltoni, was found in upper intertidal areas at Morro Bay, Mugu Lagoon, and Salt Creek. Likewise, the sandy beach worm, Notomastus tenuis was found in Morro Bay, Mugu Lagoon, and in Santa Margarita River when it was open to the ocean in spring. However, both Morro Bay and Mugu Lagoon are populated by ghost shrimps, Callianassa, and their associated marsh species. These, however, were not recorded from the other two areas where salinities fluctuated from that of seawater.

TABLE 3. LIST OF SPECIES IN SURVEY AREAS

VERMES	Morro Bay	Mugu Lagoon	Santa Margarita	Salt Creek
Arabella	(+)			
Armandia bioculata		(+)	+	
Axiothella rubrocincta	(+)	(+)		
Boccardia hamata		+		
Boccardia proboscidea			+	
Capitella capitata		(+)	(+)	(+)
Capitellidae	(+)	(+)		
Cirriformia spirabrancha	(+)			
Diopatra ornata	+			
Eteone dilatae	(+)			
Euzonus dillonensis				+
Euzonus mucronata	(+)			(+)
Glycera branchiopoda	(+)			
Glyceridae		(+)		
Haploscoloplos elongatus	(+)			
Harmothoe forcipata	(+)			
Hemipodus borealis		(+)		
Hesionidae	(+)			
Hesperonoe complanta	(+)			
Hesperonoe laevis	+			
Lumbrineridae	(+)			
Magelona pacifica	(+)			
Magelona pitelkai	(+)			(+)
Magelona sacculata	+			
Magelonidae	(+)			
Maldanidae	(+)	(+)		
Mediomastus sp.	(+)	+		
Neanthes brandti		(+)		
Nemertean sp.		+		
Nemertean sp. A	(+)			
Nemertean sp. B	(+)	(+)		(+)
Nemertean sp. C		+		
Nemertean sp. D				(+)
Nephtys caecoides	(+)			
Nephtys californiensis	(+)	(+)		(+)
Nephtys ferruginea	(+)			
Nephtyidae	(+)			

( ) = Recorded in Summer.

TABLE 3 (CONTINUED). LIST OF SPECIES IN SURVEY AREAS

VERMES	Morro Bay	Mugu Lagoon	Santa Margarita	Salt Creek
Nereidae		+		
Nerinides acuta	(+)			+
Notomastus lobatus		(+)		
Notomastus lineatus		+		
Notomastus tenuis	(+)	(+)	+	
Oligochaeta		+		+
Ophelia assimilis		+		
Ophelia magna		(+)		
Opheliidae				+
Orbinia johnsonii	(+)			
Orbiniidae	(+)			
Paraonides platybranchia	+	+		(+)
Pareurythoe californica	(+)			
Phoronis sp.		+		(+)
Phyllodocidae	(+)			
Polydora ligni			(+)	(+)
Polydora socialis			+	
Pseudopolydora paucibranchiata		+		
Pygospio californica	(+)			
Scoloplos acmeceps	+			
Spiochaetopterus costarum	+			
Spionidae	(+)		(+)	(+)
Spiophanes missionensis		+		
Thalenessa spinosa	(+)			
Travisia gigas	(+)			
PLANTS				
Carbrotus edulis			(+)	
Compositae		(+)		
Distichlis spicata			(+)	+
Enteromorpha			(+)	
Frankenia grandiflora				(+)
Grass			+	(+)
Jaumea carnosa		+		
*Macrocystis sp.				(+)
*Phyllospadix sp.			+	(+)

( ) = Recorded in Summer.
* = Stranded algae.

TABLE 3 (CONTINUED). LIST OF SPECIES IN SURVEY AREAS

PLANTS	Morro Bay	Mugu Lagoon	Santa Margarita	Salt Creek
Ruppia maritima			(+)	
Salicornia virginica		(+)	(+)	(+)
ECHINODERMATA				
Echuroidea (unidentified)	(+)			
Dendraster excentricus		(+)		
PISCES				
Clevelandia ios		+	(+)	
Quietula y-cauda			(+)	
CRUSTACEA				
Callianassa californiensis	(+)	(+)		
Callianassa juvenile		+		
Callianassa sp.		(+)		
Corophium acherusicum			(+)	
Corophium c.f. venei		+		
Eohaustorius sawyeri	(+)			
Eohaustorius washingtonianus				+
Exocirolana chiltoni	(+)	(+)		(+)
Hemigrapsus oregonensis		(+)		
Littorophiloscia richardsonae		+	(+)	(+)
Orchestia juvenile				+
Orchestia georgiana			+	
Orchestia traskiana		+	(+)	(+)
Orchestoidea benedicti	(+)			(+)
Orchestoidea columbiana	(+)			+
Orchestoidea juvenile			(+)	(+)
Orchestoidea minor				(+)
Pachygrapsus crassipes		(+)		
Pachygrapsus juvenile		+		
Paraphoxus epistomus	(+)	+		
Pinnixa longipes		(+)		
Pontogenia c.f. rostrata			+	
Porcellio littorina			(+)	
Porcellio sp.			+	
Scleroplax granulata	(+)	(+)		
Sergestidae	(+)			

( ) = Recorded in Summer.

TABLE 3 (CONTINUED). LIST OF SPECIES IN SURVEY AREAS

CRUSTACEA	Morro Bay	Mugu Lagoon	Santa Margarita	Salt Creek
Tylos punctatus		+		(+)
MOLLUSCA				
Acteocina inculta		(+)	(+)	(+)
Bulla gouldiana		+		
Cerithidea californica		(+)		
Chione undatella		(+)		
Cingula sp.			(+)	
Cryptomya californica	+	(+)		
Diplodonta orbella		+		
Heterodonax pacificus		+		
Lacuna unifasciata				+
Laevicadium substriatum				(+)
Leporimetis obesa		(+)		
Macoma inquinata		+		
Macoma nasuta		(+)		
Mitrella carinata			+	
Neverita recluziana		+		
Nutallia nutalli		(+)		
Olivella biplicata	(+)	+		
Pelecypoda sp.		+		
Petricola californiensis				(+)
Protothaca staminea		(+)		(+)
Siliqua patula	(+)			
Solen rosaceus				(+)
Tagelus californianus		+		
Tagelus subteres		+		(+)
Tresus nuttalli	+			
Tivela stultorum	(+)			
INSECTA/ARACHNIDA				
Acalyptrate			+	
Aculeata (Specidae?) cocoons with larvae			(+)	
Aegialia contorta punctata			+	
Anthomyiidae			(+)	(+)
Ataenius sp. larvae			(+)	

( ) = Recorded in Summer.

TABLE 3 (CONTINUED). LIST OF SPECIES IN SURVEY AREAS

INSECTA/ARACHNIDA	Morro Bay	Mugu Lagoon	Santa Margarita	Salt Creek
Bembidion sp.		(+)	+	+
Bradycellus nitidus		+		
Carabidae larvae				(+)
Chironomiidae larvae			(+)	
Cinindela sp. larvae			+	+
Coccinella californica			+	
Cocnagrionidae			+	
Coelopidae			+	+
Coelopidae larvae				+
Coelopididae larvae				+
Coelus sp.				(+)
Colletes gypicolens				(+)
Colletes gypicolens pupae				(+)
Cryptadivs inflatus			+	+
Curculionidae larvae			+	
Cyclorrhapha			+	
Cyclorrhapha larvae		+		+
Cyclorrhapha pupae			+	+
Dolichopdidae			+	
Dolichopodidae larvae		(+)	(+)	
Drapetes			+	
Epeolus sp.				(+)
Ephydra millbrae			(+)	
Ephydra millbrae larvae			(+)	
Ephydra millbrae pupae			(+)	
Ephydra sp.			(+)	
Ephydra larvae			+	
Ephydridae (Mosillus tibialis?) pupae				(+)
Ernephala puncticollis			+	
Galercinae				+
Hemiptera				(+)
Hydrophilidae			(+)	
Hydrophorus aestuum				+
Lepidoptera (Cosmopterigidae?)			+	
Lamproscatella quadrisetosa pupae	(+)			
Mistharnophantia sonorana				+
Muscidae			(+)	(+)

( ) = Recorded in Summer.

TABLE 3 (CONTINUED). LIST OF SPECIES IN SURVEY AREAS

INSECTA/ARACHNIDA	Morro Bay	Mugu Lagoon	Santa Margarita	Salt Creek
Oedemeridae (Copidita?) larvae			(+)	(+)
Oedemeridae larvae			+	
Orthoptera nymph				(+)
Phaleria sp.				+
Phycitinae				(+)
Psammodius sp.			+	
Psammodius mcclayi			+	+
Pseudoscorpionida				+
Sarcophagidae			+	
Sesiidae				+
Staphylinidae			(+)	(+)
Staphylinidae larvae			(+)	(+)
Tabanidae				+
Tabanus			+	
Tenebrionidae (Eusattus sp.?) larvae				+
Trigonoscuta sp. larvae			(+)	

( ) = Recorded in Summer.

Several species of marsh plants, including Salicornia virginica were recorded at the southern sites. While none of these were present in the area surveyed at Morro Bay, marsh plants were abundant further inside this marsh where the water was shallow.

The Morro Bay and Mugu Lagoon sites were dominated by polychaete species while the Santa Margarita River and Salt Creek sites were dominated by insect species (Table 4). The difference is probably related to the more stagnant water conditions at the latter two sites compared with the twice daily flushing at Morro Bay and Mugu Lagoon.

The most species (45) were recorded at Morro Bay while the least species (32) were recorded at Santa Margarita River on the summer surveys (Table 4). In the summer surveys, each site had more species unique to it than in common with the other sites (Table 5). For example, 30 species were found at Morro Bay that were not found in summer at other sites. Salt Creek and Santa Margarita had the most species in common (12) while Morro Bay and Mugu Lagoon had nine species in common. There was less similarity in species composition when the species were compared in other site combinations. Using the data from all surveys, no species was found at all four sites and only six were found to be common to the three southern sites. Fewer species were found in common at other combinations of three sites.

DISCUSSION

The data indicate that each site is at least exposed to small amounts of tar. In most instances this tar was dry suggesting a lack of associated lighter and generally more toxic components, but in spring at the three southern sites, sticky tar was recorded. Hence, there may be some exposure to light components. While this sticky tar has not been analyzed to date, it is suggested that it may originate from natural oil seepage along the southern Californian coast because there often appears to be a seasonal increase in deposition of tar from natural seepage in intertidal areas in late winter and spring.

The amount of tar recorded at these sites is low compared to records on the open sandy beaches of southern California. In some instances over 1,000 gms have been recorded in the survey area (Straughan, 1976). However, sandy beaches in the Estero Bay region seldom bore visible tar (Straughan, 1974). The difference in the amount of tar on these beaches is probably related to the presence of large numbers of natural oil seeps south of Point Conception (Figure 1). Four sandy beaches in the Santa Barbara Channel were surveyed in 1972 and 1973 and the tar analyzed to determine its origin (Straughan, 1973). In all instances when the tar was not too weathered to determine the origin, the tar was determined to have originated from natural oil seeps.

TABLE 4. NUMBER OF LIVING SPECIES RECORDED ON SUMMER SURVEYS

Site	Vermes	Crustacea	Mollusca	Insecta	Echinodermata	Pisces	Flora	Total
Morro Bay (1974)	33	8	3	0	1	0	0	45
Mugu Lagoon (1975)	13	7	8	3	1	0	2	34
Santa Margarita River (1975)	3	5	2	15	0	2	5	32
Salt Creek (Torrey Pines) (1975)	9	7	6	14	0	0	5	41

TABLE 5. NUMBER OF LIVING SPECIES UNIQUE TO EACH SITE AND COMMON TO PAIRS OF SITES IN SUMMER SURVEYS

	Morro Bay	Mugu Lagoon	Santa Margarita	Salt Creek
Morro Bay	30	9	1	7
Mugu Lagoon		18	5	6
Santa Margarita River			18	12
Salt Creek				21

The biota varies from survey site to survey site both apparently in response to differences between the marshes and differences in the physiography of the site surveyed in each marsh. It is predictable that the most species would be recorded on the long gently sloping area with the finest sediments, and highest organic and water content, that is, Morro Bay. The differences between the other sites are smaller and less easy to interpret. For example, based on grain size parameters one would predict the fewest species at Mugu Lagoon which has the coarsest grain size. Thirty-four species were recorded at Mugu Lagoon and 32 species were recorded at Santa Margarita River in the summer. However, over the four surveys conducted at these two sites 50 species were found at Mugu Lagoon and 60 species at Santa Margarita River. Neither the abundance of species nor the species composition at these sites to date indicates the effects of a stress such as oil pollution.

It is also unlikely that the small amounts of tar recorded in these marsh surveys would impose a significant impact on the biota. As noted previously, many typically sandy beach species extend into the marsh entrances. Studies on numerous sandy beaches exposed to different amounts of tar in the survey area including over 1,000 g, have not revealed a significant impact on the overall biota that could be attributed to this tar (Straughan 1973, 1976). Studies on a sheltered sandy beach at Santa Catalina Island showed that some of the marsh species occurred in a survey area where over 1,000 g of tar were recorded.

REFERENCES

[1]. Cooper, A.W. (1974). Salt Marshes In Coastal Ecological Systems of the United States 11: 55-98, Ed. Odum, H.T., Copeland, B.J., and McMahan, E.A. Pub. The Conservation Foundation, Washington, D.C.

[2]. Emery, K.O. (1961). A Simple Method of Measuring Beach Profiles. Limnol. Oceanog., 1: 90-93.

[3]. Michael, A.D., Van Raatle, C.R., Brown, L.S. (1975). Long-term Effects of an Oil Spill at West Falmouth. Massachusetts. In: Proceedings 1975 Conference on Prevention and Control of Oil Pollution, 573-582.

[4]. Straughan, D. (1973). The Influence of the Santa Barbara Oil Spill (January-February, 1969) on the Intertidal Distribution of Marine Organisms. Report to the Western Oil and Gas Association, Los Angeles, 77 pp.

[5]. Straughan, D. (1974). Intertidal Survey at Estero Bay, In Applicants Draft Environmental Impact Report. Estero Bay Deep-water Terminal and Estero Bay to Richmond Pipeline Project by Standard Oil Company of California "Corporation Engineering Department". Appendix K. Marine Biological Baseline -Estero Bay Morro Bay: K-60 - K-106.

[6]. Straughan, D. (1976). Baseline Study of Sandy Beaches and Sloughs in the Southern California Borderland, 1975-1976. Submitted to Science Applications, La Jolla, 242 pp.

[7]. Warme, J.E. (1970). Paleoecological Aspects of the Recent Ecology of Mugu Lagoon, California. Unpublished Ph.D. Thesis. University of California, Los Angeles, 379 pp.

PART IV

Friday, November 19, 1976

PIPELINES, DIKING, AND GROINS IN THE COASTAL ZONE

H. J. Walker, Session Chairman

1. "Impact of the Marsh Buggy on the Wetlands," Randall A. Detro
2. "Changes in Marsh Environments Through Canalization," Donald W. Davis
3. "The Galveston Bay System - A Multi-Stressed Environment," J. M. McCloy and R. J. Scrudato
4. "Erosion Defense Structures on the Puget Sound Shoreline," Thomas A. Terich
5. "Ediz Hook: Past, Present, and Future," Maurice L. Schwartz
6. "Human Induced Stress on the Caucasian Coast of the Black Sea," C. S. Alexander and V. P. Zenkovich
7. "Shoreline Protection in Japan," H. J. Walker

IMPACT OF THE MARSH BUGGY ON THE WETLANDS

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ABSTRACT

Since prehistoric times, Louisiana's coastal wetlands have benefited the local "Cajun" inhabitants. Although the complex nature and value of the marsh-swamp resources were not thoroughly understood, their benefits to local settlers were appreciated. Man's imprint was primarily visible as the result of his exertion in chopping trainasses (pirogue trails) for hunting, trapping and fishing purposes. Until the twentieth century, therefore, man's influence on the marsh landscape was minimal. Coastal inhabitants were--more-or-less--in balance with their environment.

South Louisiana folks are credited with numerous inventions which make life better and easier in their wetlands habitat. Notable is the marsh buggy. Existing in both a wheel and track model, this vehicle has had a definite impact on the marsh. One inventor stated that he developed his machine to make it possible to "dig a better trainasse" and "transport cattle with ease from one ridge to another."

As the buggy became more sophisticated and with discovery of valuable hydrocarbons, demand for this unique vehicle mushroomed. Today, it is distributed throughout coastal Louisiana, and within similar environments worldwide.

Principal uses are for geophysical and geological surveys, petroleum-related logistic support operations, canal and watercourse dredging, telephone and power-line construction, ditchdigging and transportation for recreational purposes.

Until recently, the economic value of the coastal zone was not adequately recognized; therefore, little thought was given to the marsh buggy's influence on this fragile environment. Attention is now being directed to this problem.

INTRODUCTION

Man has occupied Louisiana's coastal zone for approximately 12,000 years. Early folks lived on the "bounty of the land" and left a visible imprint.

European man was quick to appreciate wetland resources. He began to harvest fur and food. Like the Indian occupants, he settled on the coteaus and moved about on foot and by pirogue. To facilitate passage through areas where he could not walk, he dug countless trainasses. "The term is derived from a French word meaning 'to drag,' but is used [in Louisiana] to indicate a 'trail cut through the marsh grass for the passage of a pirogue'" (Davis, 1976, p. 349). These trapping ditches average about 1.5 meters (5 feet) wide and 15.2 to 30.4 centimeters (6 to 12 inches) deep. They are dug by hand--using a pirogue paddle, "crooked shovel," (a shovel bent like a hoe), marsh rake, and "sweeper" (a long-handled, steel-bladed knife).

From initial European occupance until about 1935, the coastal wetlands were valued primarily for their agricultural, fish and fur products. Man's imprint was minimal. Permanent inhabitants of the region were few; primarily 'Cajun' trappers and Orientals living on shrimp-drying platforms. Trappers occupied the marsh on a seasonal basis--living in camps and on houseboats.

THE CHENIER PLAIN--INITIAL APPEARANCE OF THE MARSH BUGGY

In the 1930's, trappers in the Mermentau Basin begin to use a new mode of transportation to assist them in running their lines. This was the initial appearance of a vehicle which came to be called the "Marsh Buggy." Among the early designers in western Louisiana are Edward Arpent, the Crain brothers, Carney Hall, Bernell Kock and Isaac Segura (Morgan, 1976, personal interview; O'Neil, 1976, personal interview). The Crain brothers built a model which became widely used west of the Atchafalaya Basin. Their rig was basically a lightweight long-chassis Model T Ford truck with extended axles. Wagon wheels, fitted with wooden slats and lugs about 1.5 meters wide (5 feet), replaced the truck wheels. These slat-wheel buggies were ideal for the firm grassland of the Chenier Plain--a marsh with a turflike foundation over a clay pan. The formation and development of the Chenier Plain can be attributed to the silts and clays moved westward by longshore currents away from the Mississippi's deltaic lobes. "The marsh, dominated by couch or wiregrass (*Spartina patens*), is essentially land" (Davis and Detro, 1975, p. 92). As this buggy was not buoyant, it could not function in ponds, alligator holes or new and soupy marsh. In these muck environments, it did not float, had no traction, and when the engine and chain drives became wet--it was hopelessly stuck.

THE DELTAIC PLAIN--APPEARANCE OF THE MARSH BUGGY

East of Vermilion Bay is the Deltaic Plain. It resulted directly from sediment accumulation laid down by the Mississippi River as it formed seven deltaic lobes. Colonizing the basins within this environment are two dominant plant communities, flotant and roseau (Phragmites communis). Flotant or "trembling prairie" is quagmire underfoot and cannot be walked easily. It is distinguished by an abundant "plant species tolerant of frequent and sustained flooding," is "anchored in a relatively thin, matted layer of decomposing vegetable debris that is truly floating on water or supported by highly aqueous organic ooze" (Russell, 1942, p. 78-79). Roseau marsh is essentially land, is dominated by tall grasses and reeds, and can be walked with ease. The buggy did not make its appearance in the Deltaic Plain in any number until the end of World War II. Early inventors were Andrew A. Cheramie, Romain Guidroz and John M. Poche. Members of the Ritchey and Tassin families initiated several buggy attachments and adaptive uses. Andrew Cheramie designed and put into commercial production a model ideally suited for the "trembling marsh." His "amphibious tractor" has a deck 4.2 x 3.3 meters (14 x 11 feet) mounted on large pontoon wheels measuring 2.4 meters (8 feet) high by 1.5 meters (5 feet) in width. It is powered by two Ford V-8 engines--each engine drives two wheels, one front and one rear. These buoyant pontoons provide a combination wheel--with a ribbed and troughed tread--which when power driven in water functioned as a marine propeller and on land as a traction wheel. Side slippage in water and on land is reduced to a minimum (U. S. Patent Office, 1949, p. 6; U. S. Patent Office, 1954, p. 4). This buggy operates with ease in or on any land, water or semi-marine environment. "Under ideal conditions, with a few inches of water covering the grassy marsh, the Marsh Buggy can achieve remarkable speeds of approximately 48.3 kilometers per hour (30 miles per hour). Ordinarily, however, for operating, they plug along at considerably slower speeds depending upon the work being performed and the terrain. In water, the Buggy can obtain speeds up to 16.1 kilometers per hour (10 miles per hour)" (Andrew A. Cheramie Marsh Buggies, Inc., n.d., p. 3). Andrew Cheramie developed his machine in order to "dig a better trainasse" and to "transport cattle with ease from one coteau to another" (Cheramie, 1976, personal interview).

DISCOVERY OF HYDROCARBONS IN THE COASTAL WETLANDS

While wetland natives refined and utilized the buggy for purposes associated with their valuation of marsh resources, outside interests discovered hydrocarbons throughout the coastal zone. Demand for buggies mushroomed and exceeded supply to the point that petroleum and seismograph companies designed and manufactured their own vehicles. Models were produced by at least nine petroleum related firms. Fisher-Reynolds of Houston, Texas, a seismograph company, designed a model involving tracks revolving around flotation pontoons (Diedrich, 1976, personal interview). Geophysical Service, Inc., in collaboration with Texas Eastern Transmission Corporation, produced a wheeled model equipped with Goodyear flotation-type Terra-tires" (Big tires... , 1964, p. 190). The Gulf Oil Corporation, in its Pittsburgh research laboratories, designed a rubber-tired wheeled-vehicle known as the "Gulf Marsh Buggy" and/or the "balloon buggy-boat" (U. S. Army, 1956, p. 1). Higgins Shipyards, New Orleans, fabricated two models. First came the "Mud Hopper;" it was refined into a metal-wheeled vehicle which was coined the "Swamp Skipper" (He's done it again, 1946, p. 17). The McCollum Exploration Company of Houston improvised a "marsh buggy" of six welded sheet-steel wheels riding on continuous tracks (Williams, 1939, p. 58). This model evolved from an earlier air-drive buggy (They thought ... , 1938, p. 14). Shell Oil Company produced a 'tractor' equipped with metal drum-like wheels and/or flat rubber-cleated tires; it was named the "David Buggy" (Strange buggies ... , 1958, p. 55). Stanolind Oil and Gas of Dallas, Texas, designed a wheel-model for their own use--the wheels were buoyant arc-welded steel drums. It was simply called the "marsh buggy" (Simons, 1940, p. 71). United Gas Pipe Line Company's 'bayou buster' was one of the strangest appearing marsh buggies to appear. It was a wheeled buggy with a different design for the front and rear wheels (Miller, 1942, p. 44). Each manufacturer's design varied; the majority, however, were wheeled. A few designers began to experiment with the caterpiller track over flotation pontoons.

The coastal wetlands--inadequately mapped--were suddenly gridded, crossed and crisscrossed with seismograph crews on marsh buggies--towing their equipment on sledges. Though landowners welcomed the income from oil and gas--a "range war" broke out between trappers and geophysical survey crews. Trappers claimed that buggy wheels badly damaged the marsh, destroyed "sets" and crushed muskrat and nutria habitat. To minimize their problems, trappers insisted that buggy drivers follow the same trail repeatedly. In some environments this created an entire new set of problems--erosion, ponding, salinity changes, vegetation regime alteration and canals which enlarged into bayous. Buggy tracks may be visible for periods ranging from one to ten years--dependent upon several environmental factors. Many observers feel that once imprinted, they endure forever. Though trappers and hunters decried buggies to some extent, they employed them to dig trainasses, boundary canals and to "mash out duck ponds" (O'Neil, 1976, personal interview).

THE TRACKED BUGGY

As wetland residents and oil companies evaluated the impact of buggy tracks on the marsh surface, they observed that the experimental tracked vehicles trail did not cut as deeply or endure as long. Rather than dig into the surface, the caterpiller tracks lay down vegetation in layers which then spring back rather rapidly. In 1952, Quality Marsh Equipment of Thibodaux put into commercial production a marsh buggy which employs caterpiller tracks revolving around flotation pontoons--completely amphibious equipment with sufficient buoyancy to keep all machinery well above the marsh surface and/or water level.

They dubbed their buggy "The Wizard of Ooze" (Quality Industries, n.d., p. 1).

About 1950, environmentalists and ecologists brought to everyone's attention the tremendous value of the coastal estuarine environments contribution to the food chain. By 1960, all buggies operating in coastal Louisiana were of the tracked variety. Again, man's evaluation of the coastal environment was rethought.

Without a doubt, man would have developed and harvested the resources of the coastal zone. One who witnessed the saturation geophysical surveying stated: "Oil companies would have conquered the marsh even if they had had to crawl in muck up to their necks" (Diedrich, 1976, personal interview).

MARSH BUGGY ATTACHMENTS AND APPLICATIONS

The Marsh Buggy--with various attachments and accessories--definitely made the job of conquering the marsh easier.

At first, the buggy was used alone to transport trappers, hunters and seismic crews across the marsh. An early Cheramie model--weighing 4800 pounds--could carry a full exploration crew of thirty men and their equipment--about 9600 pounds.

Survey crews soon learned to mount portable drilling rigs and recording instruments on towed sledges as well as directly on the buggy. Geologists employed the same procedure for drilling rigs which they used in the lower delta to unravel delta history and mudlump evolution (Morgan, 1976, personal interview).

Designed originally to dig trapping ditches, the marsh plow was attached to buggies as early as the mid-1930's. The model currently marketed measures about 3.04 meters (10 feet) wide--from stabilizing wing to stabilizing wing. The plow itself is about 1.5 meters (5 feet) wide. Preceded by a large rotary disk, it cuts a ditch about .9 to 1.2 meters wide (3 to 4 feet) by .9 meters deep (3 feet). To assist in ditching and filling, the backhoe and roto-boom is attached to buggies.

Ditching, canal construction and laying pipeline was greatly facilitated when draglines were mounted on buggies. For pipeline work, a procession of amphibious vehicles may be seen. In the lead, buggies lay out the route. Other buggies equipped with draglines excavate canals for the pipe which is "shoved" or "pushed" by the lay barge into the depression (Novel Barge ... , 1937, p. 99). Additional buggies follow--filling the channels.

With the new Quality hydraulic rotary ditcher, a deflector sprays spoil over a lateral distance of 9.1 to 12.1 meters (30 to 40 feet) thereby reducing the build up of artificial levees. Other buggies manufactured by Quality Marsh Equipment are designed specifically as cargo carriers, hydrocranes, drill rigs, loggers, swamp cats and the wheeled buggy which is only marketed outside the United States.

CONCLUSION

The marsh buggy is the vehicle which opened "the wetlands frontier" to hydrocarbon exploration. It transported men and equipment on all wetland surfaces with ease. As man sought to apply management techniques to production of marsh resources, he became aware of the harmful environmental effects of the buggy. Trappers first noticed damage to their "sets" and muskrat and nutria nests. They also recognized land loss and vegetation changes from deeply incised wheeled buggy tracks. Where turf became exposed or broken open water areas increased and salinity changes occurred. The tracked buggy wrought fewer changes yet it brings about breaks in natural barriers. Tidal scouring within tracks accelerates salt water intrusion and changes in vegetation regimes. Water-control structures partly alleviate these problems. Man now seems to comprehend adequately the wetlands. Marsh managers will, no doubt, employ the buggy in their constant efforts to monitor their actions in the coastal plain.

REFERENCES CITED

1. Andrew A. Cheramie Marsh Buggies, Inc. [Promotional Brochure]. Cut Off, Louisiana, n.d.
2. "Big Tires Lick Swamp Problems." Oil and Gas Journal. Vol. 62, August 17, 1964, pp. 190-92.
3. Cheramie, E. Andrew A. Cheramie Marsh Buggies, Inc. Personal interview conducted May 22, 1976.
4. Davis, D. W. and R. A. Detro. "Louisiana's Marsh as a Recreational Resource," in Coastal Resources, H. J. Walker (ed.), Geoscience and Man, Vol. 12, 1975, pp. 91-98.
5. Davis, D. W. "Trainasse." Annals of the Association of American Geographers. Vol. 66, No. 3, 1976, pp. 340-359.
6. Diedrich, G. H., Jr. Quality Industries, Chairman of the Board. Personal interview conducted November 10, 1976.
7. "He's Done it Again!" New Orleans: Times-Picayune Magazine. November 3, 1946, p. 17.
8. Miller, H. "The Swamp Buggy at Work," Gas Age. Vol. 89, May 7, 1942, pp. 44-45.
9. Morgan, J. P. LSU (Baton Rouge) Geology Professor. Personal interview conducted October 19, 1976.
10. "Novel Barge Buries Pipe in Mud." Oil and Gas Journal. Vol. 36, September 16, 1937, p. 99.
11. O'Neil, T. Louisiana Wild Life and Fisheries Commission. Personal interview conducted October 26, 1976.
12. Quality Industries. The Wizard of Ooze. [Promotional Brochure]. Thibodaux, Louisiana, n.d.
13. Russell, R. J. "Flotant," Geographical Review. Vol. 32, 1942, pp. 74-98.
14. Simons, H. F. "Marsh Buggy for Use in Gulf Coast Fields," Oil and Gas Journal. Vol. 38, February 22, 1940, p. 71.
15. "Strange Buggies Conquer Mud; David Buggies." Oil and Gas Journal. Vol. 56, August 25, 1958, p. 55.
16. "They Thought Jules Verne did it!" New Orleans: The Progress. September 23, 1938, p. 14.
17. United States Army. Transportation Research and Development Command. Test and Evaluation of the Marsh Buggy. (Research Technical Memorandum 12). Fort Eustis, Virginia, The Author, 1956.
18. United States Patent Office. Patent No. 2,671,519. Amphibious Tractor. Washington, D. C.: The Author, 1949.
19. United States Patent Office. Patent No. 2,823,637. Pontoon Wheels. Washington, D. C.: The Author, 1954.
20. Williams, N. "Marsh Buggy for Geophysical Crew," Oil and Gas Journal. Vol. 38, August 17, 1939, p. 58.

REFERENCES

1. "Auto-Tractor-Boat in One Aids in Oil Exploration." National Petroleum News. Vol. 28, December 23, 1936, pp. 52-56.

2. Ayo, D. J. and B. Cheramie Ayo. Andrew A. Cheramie Marsh Buggies, Inc. Personal interview conducted October 16, 1976.
3. Bilbo, W. R. "Construction is Different in Marsh-Water Areas." Petroleum Engineering, Vol. 29, February 1957, pp. 25-8.
4. Boudreaux, E. J. "The Impact of the Petroleum Industry on the Geography of the Terrebonne Parish, Louisiana." Unpublished master's thesis, University of Southwestern Louisiana, 1969.
5. Chamberlain, J. L. Influence of Hurricane Audrey on the Coastal Marsh of Southwestern Louisiana. Baton Rouge: Louisiana State University Coastal Studies Institute.
6. "Do You Know What a Marsh Buggy Is?" Illustrated London News. Vol. 233, August 16, 1958, pp. 280-81.
7. Ebdon, J. F. "Southern Natural Slushes Through Louisiana Swamps." Gas, Vol. 34, July 1958, pp. 87-96.
8. Flude, J. W. "Exploring in Marsh and Water Areas of Louisiana and Texas Gulf Coast." Oil and Gas Journal, Vol. 34, No. 48, 1936, pp. 142-43.
9. "For Rent: Marsh Buggies." Fortune. Vol. 46, November 1952, p. 216.
10. Griebling, R. T. "Boat or Buggy?" Marine Engineering. Vol. 42, June 1937, pp. 40-41.
11. "The Gulf Marsh Buggy." Rubber Age. Vol. 40, February 1937, p. 292.
12. "Irrepressible Marsh Buggy." Louisiana Conservation Review. Vol. 7, Winter 1938/39, p. 7.
13. Ivey, W. T. "Pipelining in Marsh, Swamp and Open Water." Civil Engineering, Vol. 28, September 1958, pp. 640-43.
14. "Larose Garage Man Builds New Type of 'Marsh Buggy.'" New Orleans: Times-Picayune. February 19, 1939, Section 2, p. 7.
15. "Latest Type of Marsh Buggy is All-Steel." Marine Engineering. Vol. 44, March 1939, p. 105.
16. McGhee, E. and C. Hoot. "Mighty Dredges, Little-Known Work Horses of Coastal Drilling, Producing, Pipelining, now 25 Years Old." Oil and Gas Journal, Vol. 61, No. 3, 1963, pp. 150-152.
17. McIntire, W. G. Prehistoric Indian Settlements of the Changing Mississippi River Delta. Baton Rouge: Louisiana State University Press, 1958.
18. "Marsh Buggy." Engineering. Vol. 144, September 3, 1937, pp. 270-71.
19. "Marsh Buggy." Scientific American. Vol. 156, February 1937, p. 111.
20. "'Marsh Buggy,' An Unusual Vehicle, Runs Equally Well on Land or Water." Iron Age. Vol. 138, December 24, 1936, p. 100.
21. "Marsh Buggy Crosses the Swamps." Engineering News. Vol. 118, January 28, 1937, p. 131.
22. "Marsh Buggy Important in Louisiana Development." Oil and Gas Journal. Vol. 40, January 1, 1942, p. 51.
23. "'Marsh Buggy' Makes Exploring for Oil Thorough in Louisiana." New Orleans: Times-Picayune. December 4, 1941, p. 18.

24. "The 'Marsh Buggy' Travels on Land and Water." Automotive Industry. Vol. 75, December 19, 1936, p. 843.
25. Myers, L. D. "Sixty Miles of 36-in. Pipe Laid Across Louisiana Marshes." Civil Engineering, Vol. 32, May 1962, pp. 52-5.
26. "Quality in Swim of Things With Vehicles That Don't Bog Down." New Orleans: Times-Picayune. July 15, 1976, Section 4, p. 11.
27. Reed, P. "How Marshy Can a Pipe-Line Route Get?" Oil and Gas Journal, Vol. 50, June 14, 1951, pp. 76-7.
28. "Shell's Line Pushed Through Swamps." Oil and Gas Journal. Vol. 56, December 15, 1950, p. 81.
29. Williams, N. "Drilling for Oil in World To Itself." Oil and Gas Journal, Vol. 28, December 19, 1929, pp. 40-1.

CHANGES IN MARSH ENVIRONMENTS THROUGH CANALIZATION

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ABSTRACT

Louisiana's marsh-swamp complex is criss-crossed by an intricate system of artificial waterways. Some are wide and some narrow, but they have in common a straight course, or other characteristic that distinguishes them from natural features.

Creation of ways of ingress into the wetlands began with the earliest European settlers and continues to the present. They were necessary because of the impossibility of constructing roads to exploit the region's natural resources: timber, fur, hydrocarbons, and even grazing and agriculture. If the canals have been a boom to transportation, they have also created problems, such as altering flow regimes and water chemistry and increasing saltwater intrusion into previously freshwater areas. The most obvious effect is the direct conversion of land to water.

From this construction activity a region larger than Connecticut and Delaware combined has been ringed, cut, and bisected by a massive network of canals. To understand the geographic growth, development and environmental influence of these waterways, they have been classified into five categories: drainage and reclaimation, transportation, trapping, logging, and petroleum. In analyzing these items, the discussion begins in 1720 and continues into the petroleum period, where dredging is necessary to simplify drilling, maintenance and logistics.

All these manmade transportation routes have combined to create a distinct patterned landscape. Until recently, new channels were added constantly, but old ones were rarely filled in; thus, the system continues to intertwine and expand. Once canals are cut, they endure Theoretically, their duration is finite, but some have enlarged into bayous. These waterways are now significant elements in the progressive change in the physical appearance of the alluvial wetlands.

INTRODUCTION

In the United States, the nineteenth century, was a period of increased regional specialization, when an efficient transportation system was tantamont to expanding local markets. Although railroads have been hailed as the most significant force behind economic growth, evaluations by Ransom (1964, p. 365) suggests canals have also been important. The impact of the Delaware, Erie, Ohio and other Atlantic seaboard "coal canals" was enormous. The same is true, at a smaller scale, for canals in south Louisiana.

Today a flight across the marsh-swamp complex reveals the intricacy of the patterned landscape. One cannot help but be impressed by the complex web of interconnecting channels. Some are wide and some narrow, but they have in common characteristics that distinguish them from natural waterways.

Canalization of the alluvial wetlands began with the earliest European settlers and continues to the present. Since construction, in the early 1700's, of Louisiana's first drainage project, manmade waterways have advanced unchecked in the economic development and utilization of the region's natural resources: timber, fur, hydrocarbons and even grazing and agriculture. If the canals have been a boom to transport, they have also created problems, such as modifying flow regimes and water chemistry, and increasing saltwater intrusion into freshwater areas. The most conspicuous effect is in conversion of land to water--altering the coastal zone's natural appearance. In one oil and gas field there are 67 kilometers (42 miles) of petroleum-related canals, representing removal of at least 3.3 million cubic meters (4.4 million cubic yards) of spoil. These waterways connect into an extractive area covering 178.71 square kilometers (69 square miles).

From this type of construction activity a region larger than Connecticut and Delaware combined has been criss-crossed, ringed, cut, bisected and otherwise dominated by a massive network of manmade waterways. Until recently, new channels were added continually, but old ones are rarely filled in; thus, the complex intertwines and expands into a well-defined pattern. Once cut a canal endures. Theoretically, its duration is finite, but some have enlarged into straight-channeled "bayous."

Barrett (1970, p. 1) measured 7,358 kilometers (4572.6 miles) of canals south of the Intracoastal Waterway, and suggests 171 square kilometers (66 square miles) of surface area were lost to canalization. Gagliano's (1973, p. 5) analysis of historical maps, determined land loss amounted to 490 square kilometers(189.1 square miles). The calculations differ due to technique and area studied, but the figures document land loss and the canal system's approximate size.

To understand the canal patterns geographic growth and development, they have been classified into five categories: drainage and reclamation, transportation, trapping, logging, and petroleum. These categories, arranged historically, show the developmental sequence of resource use and suggest changes that have occurred in the exploitation of the wetlands.

DRAINAGE AND RECLAMATION CANALS

Marsh and swamp drainage ditches were excavated by the French as early as 1720. In a practical sense they were part of a great land reclamation project designed to aid planters drain potential agricultural and pasture land. In many cases these channels became significant transportation routes. Like other canals of the period, they were multifunctional units serving as drainage and access waterways. Today, several of these "ditches" are major transportation arteries, transcending their original function.

Drainage channels are confined generally to areas suitable for agriculture, especially the natural levee land. Farmers drained the "high" ground to produce indigo and cotton. By 1880 sugarcane had replaced cotton, becoming the most significant agricultural commodity (Sitterson, 1953 p. 9). With change in crop emphasis, planters recognized the value of clearing, draining and planting all arable land. They were "challenged from the very start to institute flood control and drainage measures" (Gagliano, 1973, p. 11) and became enthusiastic supporters of these programs. The projects were, in effect, a form of land reclamation. Flood and water control methods extended the cultivated land beyond the natural levees down the slope into the backswamps.

Technological problems precluded development of large, well-organized reclamation projects. These were not initiated until after 1900, when enterprising investors purchased extensive tracts for polderization, but their efforts were unsuccessful. Of approximately 50 attempted schemes (Okey, 1918, p. 3), five are still utilized for agriculture. Only the distinctive canal patterns remain as evidence of the abandoned farms.

Even though reclamation was a failure, swamp and natural levee canal systems continue to multiply as new land is cleared, diked and drained. Water levels are controlled from pumping stations, continuing the procedures begun in the 1700's. As the region's population agglomerated, new subdivisions often required the establishment of drainage or flood control measures. "Guide levees" protect the near sealevel communities from the excess water frequently accompanying summer thunderstorms. Whether for agriculture or urban expansion, drainage canals and ditches have contributed to the consolidation of the linear communities paralleling the bayous and established an easily identified boundary between the marsh and man's reclamation activity.

TRANSPORTATION CANALS

Movement of goods by water has long been an integral part of the coastal zone's transportation geography. From the days of the pirogue and bateau, to the present, people have depended on the entangled network of rivers, bayous, lakes and deep channels to move their commodities to market. Natural waterbodies were traditional shipping routes. To increase the systems efficiency and reduce travel time, canals were dredged.

Louisiana's drainage patterns are generally oriented in a north-south direction, making east-west movement difficult. To rectify this navigational inconvenience, canals were excavated as connective links between streams. These additions improved the transportation system and became important traffic corridors.

To evaluate the expansion of transportation canals is difficult, because by law all manmade waterways are potential arteries of commerce. Only a few were built exclusively for commercial traffic; most were constructed for other purposes. That is their primary function was to aid in developing agricultural, mineral, forest, and fur resources. They served, secondarily, as transport routes.

Between 1880 and 1945 numerous transportation-oriented watercourses were built or improved. By 1930 the coastal landscape was marked by a number of transportation canals. The system was small, but adequate, providing local inhabitants with regional connectivity. With the United States involvement in World War II, and the increased demand for petroleum, Congress approved the financial support necessary to complete the Gulf Intracoastal Waterway -- the nation's most important canal. When finished, this system in conjunction with the Mississippi River made Louisiana the center for war-time Gulf Coast petroleum traffic.

The World War II experience demonstrated the value of the country's navigable waterways. Petroleum and related industries continue to employ these routes in the low-cost movement of their commodities, with crude and refined petroleum products dominating the statistics. As bulk cargoes, they cannot be shipped profitably by alternate methods, hence the use of channelized waterways.

Transportation canals are easily identified by their wide, straight, spoil-laden banks. They provide open-ended links between points and extend for miles along well-defined courses. While the Gulf Intracoastal Waterway is the best known, many routes predate it, but they all serve the same function -- connectivity. Each transportation artery influences the regional economy, attracts industry, and alters land use patterns along the right-of-way. Due to their constant use, many have eroded into large watercourses.

TRAPPING CANALS: A TRAPPER'S ACCESS TO THE MARSH

People living at such isolated communities as Bassa Bassa, Cheniere au Tigre, Isle Jean Charles, Manila Village, Pecan Island and others dug a unique canal type known as a <u>traînasse</u>. A term derived from a French word meaning "to drag," but used locally as a "trail cut through the marsh grass for the passage of a piroque" (Read, 1937, p. 74). These trails were hacked out by the region's trapper-fisher folk, using a piroque paddle, "crooked shovel,"(a shovel bent like a hoe), rake, and "sweeper" (a long-handled, steel-bladed knife). Later the ditch digger, mud boat, and marsh buggy were employed to cut the 1.5 meter(5 feet) wide and 15.2 to 30.4 centimeter (6 to 12 inch) deep channel. Although small, these trails are more than canals used for irrigation or drainage. They are a significant factor in the marsh dwellers' systematic exploitation of the environment and a prominent element in this process.

About 1915 muskrat became a fashionable fur. Prices increased with demand -- from eight cents a pelt in 1914 to 50 cents in 1922 (Chatterton, 1944, p. 194). Before this upswing, hunting was more profitable than trapping, with a brace of ducks selling for 25 cents. The 500 percent increase in the pelt's value convinced local people to change their winter subsistence activity from hunting to trapping. In so doing, they extended their hunting <u>traînasses</u> into areas of high animal production. They added methodically a unique element to the coastal zone.

To trap the land efficiently, a large number of ditches were chopped through the marsh, creating a massive array of waterways. Marsh dwellers dug their trails large enough to avoid depending on a current for channel completion and protected the route from erosional enlargement by damming their <u>traînasses</u>. This reduced the environmental damage connected with drainage, saltwater intrusion, and erosion. As the number of people trapping increased, the trails coalesced into their current chaotic pattern. Additional ditches allowed individuals to trap larger areas, but many of the original safeguards were abandoned.

In that land owners never placed restriction on the number of trails built, trappers had complete freedom to dig as many <u>traînasses</u> as needed. When large tracts were leased to fur-buyers and "outsiders," ditches were cut indiscriminately between bayous and through ridges. The resulting system was often over 500 kilometers (310 miles) in length, with no dams across the channels to protect the productive muskrat, and later nutria, habitats.

The coastal lowlands presented no serious problems to canal construction. Taking advantage of the situation, trapper-fisher folk built an immense number of artificial waterways. The pattern of ditches they created has become a significant part of the alluvial wetlands. More importantly, they represent the first large-scale canalization.

Many channels began as small pirogue trails that allowed the trapper to work the wetlands successfully. Through repeated use, storms, and current flow, they enlarged into permanent elements in the coastal geography of south Louisiana.

<u>Traînasses</u> have become a vital part of the transportation network and are a visible landscape element. They have affected drainage patterns, influenced salinities, and are a reminder of man's abilities to change the natural system. Created for specialized use, the <u>traînasse</u> has survived.

THE RADIAL PATTERN OF LOGGING CANALS

The swamp, unlike the marsh, was significant for its forest resources --particularly cypress. With repeal of the Homestead Act of 1866, lumber companies purchased large tracts of forested wetlands for 25 to 50 cents an acre. To harvest the swamps, the firms needed to solve two problems: access and removal. The approach issue was resolved by excavating canals to the logging site. Removal of the cut timber was accomplished by using a pull-boat to drag the logs into the dredged channels (Norgress, 1935, p. 43).

Canals were excavated to provide pull-boats with an entrance into work areas. They were essential to the logging operation and supplied the necessary connectivity to the timber resources. Logging canals were large enough to allow a pull-boat to maneuver in dragging timber from the swamp. To remove the cypress, the canal pattern included a series of intersecting channels with fan-shaped paths radiating out from points along the access routes. These radial designs are a by-product of the pull-boats as they "snaked" the logs into the central channel. This distinctive pattern can be detected on aerial photography and is an accurate record of the intensive lumbering operations.

Logging canals are still a part of the landscape. For over 50 years the channels were essential to the forest industry, but as cypress were depleted woodcutting operations were terminated. Only the canals and pull-boat scars remain. In a larger sense, they are indicative of the once important cypress industry--now an exhausted resource.

PETROLEUM CANALS: A MASSIVE SYSTEM OF MANMADE CHANNELS

Concomitant with the logging period, oilmen began to consider the coastal zone's hydrocarbon potential. To exploit the subsurface mineral wealth has been a challenge. Many promising sites remained untested until drilling procedures, equipment and geophysical techniques were developed to capitalize on the recoverable resources. Once the engineering and logistics issues were solved, the wetlands became a major hydrocarbon province. Successful use in 1934 of a submersible drilling barge marked the start of expanded drilling activity. To maximize the floating unit's potential the industry needed to dredge canals into exploratory and development sites. McGhee and Hoot (1963, p. 151) claim in 1938 a barge-mounted dragline dug "the first drilling site ever prepared by floating equipment." Actually, the oldest petroleum-related canal was built 12 years earlier at Venice (Villere, 1971, personal interview). Ironically, the Venice field is now identified by a 13 kilometer (8 mile) canal, outlining a circle 4 kilometers (2.5 miles) in diameter and encompasses 4,076 hectares (10,071 acres). Over 50 slots join the circle, each represents a drilling site (Anonymous, 1955, pp. 122-123). The canal pattern maps a subsurface salt dome and has become one of the coastal zone's best examples of canalization.

In that marsh soils present no serious engineering problems, powerful suction dredges, bucket dredges, spud barges and marsh buggies have been able to excavate the required petroleum access, pipeline, and transportation waterways. Dredging contractors produced a system that opened the coastal lowlands to hydrocarbon development. In the process the largest number of canals were added to the landscape. The interconnecting routes have become permanent features. Through additions the patterns enlarge into a complicated net of coalescing channels. Densities are intensified and thus effect land-water ratios, flow regimes and saltwater intrusion.

To develop a field, the oil company first cuts a series of primary service routes, then adds supplementary passages as warranted. These tributaries filter into the central traffic arteries, guaranteeing well access. Through time the pattern dominates the landscape, with each appendage representing a new well; it is a one well, one canal system. The design grows rapidly, influencing even larger areas.

Well approaches are cut approximately 21 to 27 meters (70 to 90 feet) wide and 2 to 3 meters (8 to 10 feet) deep. Each kilometer (mile) adds more than 83,296 cubic meters (100,000 cubic yards) of spoil, creating new land adjacent to the channel. Once in use, the distinctive straight-sided canals often erode into a cuspated form. Some fields become so canalized over 20 percent of their surface area is devoted to these features, contributing to more than just erosion.

In a productive field, a pipeline network is constructed to move the mineral resources to market. The overwhelming number of these linear features has prompted some people to describe the systems as a "spaghetti bowl." "Although the pipelines are controlled by surface features...their location is rarely influenced by surface...morphology. Rather, they take the straight-line route to...the tank battery or master pipeline connection" (Gagliano, 1973, p. 73). The "Muskrat line," for example, stretches 563 kilometers (350 miles) and follows a nearly perfect compass course.

To complete a pipeline requires a canal 12 meters (40 feet) wide by 2 meters (6 feet) deep to accommodate the pipe lay barge. As pipelines are layed through the marsh their routes cut across the region's natural waterbodies. To minimize saltwater intrusion and circulation changes petroleum companys build dams and weirs along the right-of-way to reduce the environmental damage.

A field may have developed over a period of years, with the canals and appendages interlocking into a well-defined complex. The increased densities frequently unite into small lakes and bays. Unless sediment or fill is added, the land is permanently lost. The manmade network extends as tenacious features across the landscape, producing extractive patterns covering from under 4 (10) to over 16,000 hectares (40,000 acres). In the process land/water ratios are changed. Gagliano and van Beek (1970, p. 131) reported approximately 16.5 square miles of coastal Louisiana's land is lost annually - about 25 percent is atrributal to petroleum industry dredging.

CONCLUSIONS

In no other part of the United States, or the World, other than the Netherlands, is there such a record of variety of resource exploitation expressed in canal systems. A logical method of dealing with a distinct wetlands environment, it nevertheless has modified drainage patterns, altered flora and fauna, changed salinity regimes and contributed to land loss. The available quantitative data are too incomplete to estimate the total effect canals have had on the environment. Field investigations show, and nearly all informants note, changes are occurring.

Whether the canal is the narrow trapper's <u>traînasse</u>, or the complicated system of petroleum access routes, they have had a decisive and cumulative impact on the environment. Crops of Engineers regulatory activity has slowed the growth, but it must be emphasized some canals are over 100 years old. They are permanent landscape features.

Petroleum companies will còntinue to augment their systems by adding new channels to existing oil fields. As hydrocarbon demands increase, new fields will be developed. In these areas canals will be dredged to aid the exploration and production process. This will be undoubtedly the most continuous source of new channels.

Past history indicates clearly the zealous activity of the canal builders. The landscape shows how the system has modified local habitats. While it is difficult to assess total change, some of which may have been detrimental, canal construction in Louisiana appears to be a constant variable in environmental modification. The canal patterns will endure even when the resources are exhausted. Their longivity will be a visible example of man's ability to change unknowingly the natural system.

REFERENCES

1. Anonymous. "An unusual canal system facilitates Field Operations in Louisiana's Marshes...Venice field's circular waterway outlines an oil-rich structure." <u>The Oil and Gas Journal</u>. Vol. 51, July, 1955, pp. 122-123.
2. Barrett, B. <u>Water Measurements of Coastal Louisiana</u>. New Orleans: Louisiana Wild Life and Fisheries Commission, 1970.
3. Chatterton, H. J. "The Muskrat Fur Industry of Louisiana." <u>The Journal of Geography</u>. Vol. 43, No. 5, 1944, pp. 185-195.
4. Dabney, T. W. "Gift of the Waterways." <u>Jefferson Parish Yearly Review</u>. 1941, pp. 86-90.

5. Davis, D. W. "Logging Canals: A Distinct Pattern of the Swamp Landscape In South Louisiana." Forests & People. First Quarter, 1975, pp. 14-19; 33-35.
6. Davis, D. W. "Trainasse." Annals of the Association of American Geographers. Vol. 66, No. 3, 1976, pp. 340-359.
7. Gagliano, S. M. and J. L. van Beek. Geologic and Geomorphic Aspects of Deltaic Processes, Mississippi Delta Systems, Vol. 1, part 1. Baton Rouge: Coastal Studies Institute and Department of Marine Sciences, Louisiana State University, 1970.
8. Gagliano, S. M. Canals, Dredging and Land Reclamation in The Louisiana Coastal Zone, Rept. No. 14. Baton Rouge: Coastal Resources Unit, Center for Wetland Resources, Louisiana State University, 1973.
9. Lowery, G. H. The Mammals of Louisiana and Its Adjacent Waters. Baton Rouge: Published for the Louisiana Wild Life and Fisheries Commission by the Louisiana State University Press, 1974.
10. McGhee, E. and C. Hoot. "Mighty Dredges, Little-Known Work Horses of Coastal Drilling, Producing, Pipelining, Now 25 Years Old." Oil and Gas Journal, Vol. 61, No. 3, 1963, pp. 150-152.
11. Norgress, R. E. "The History of the Cypress Industry in Louisiana." unpublished master's thesis, Louisiana State University, 1935.
12. Okey, C.W. Wet Lands of Southern Louisiana. Washington, D.C.: United States Department of Agriculture Bulletin 652, 1918.
13. O'Neil, T. The Muskrat in the Louisiana Coastal Marshes. New Orleans: Louisiana Wild Life and Fisheries Commission, Tech. Rept., 1949.
14. Ransom, R. L. "Canals and Development: A Discussion of the Issues." American Economic Review, Vol. 56, 1964, pp. 365-389.
15. Russell, R. J. "Flotant," Geographical Review. Vol. 32, 1942, pp. 74-98.
16. Sitterson, J. C. Sugar Country: The Cane Sugar Industry in the South, 1753-1950. Lexington: University of Kentucky Press, 1953.
17. St. Amant, L. S. "The Petroleum Industry as it Affects Marine and Estuarine Ecology." Journal of Petroleum Technology, April, 1972, pp. 385-392.
18. Surrey, N. M. The Commerce of Louisiana During the French Regime, 1699-1763. New York: Columbia University Press, 1916.
19. Villere, Walter. President W. P. Villere General Contractor. Personal interview conducted April 15, 1971 in New Orleans.

THE GALVESTON BAY SYSTEM - A MULTI-STRESSED ENVIRONMENT

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The Galveston Bay system is located in the southeast portion of the State of Texas on the Gulf of Mexico. The climate is subtropical with an average annual precipitation of approximately 45 inches per year and an average annual temperature of 70 degrees fahrenheit (Fisher, et al, 1972).

The astronomical tide is mixed and ranges from one to two feet; wind tides range from minus four feet to a maximum storm surge of plus 15 feet in relation to mean sea level. Westerly currents prevail along the coast while bay currents are induced by winds and tides and therefore vary considerably in time, direction, and magnitude (Ibid).

The earliest available accurate chart for baseline data was developed in 1851 by the United States Coast Survey to indicate proposed sites for lighthouses (Bache, 1851). The bay system outline is today little changed from the 1851 chart (Fig. 1); there is a barrier island and a peninsula breeched by San Luis Pass on the west, Bolivar Roads, the main channel to the bay and stabilized by jetties, and the man-made Rollover Pass to the east; this configuration is backed by lagoons which evolve into a major estuary. The bay complex averages about six feet in depth and all natural depths are less than 12 feet; the area occupied is 553 square miles (Fisher, et al, 1972).

Isohalines for bay waters show the salinity in the lower portion ranges from a low of 14 parts per thousand to a high of 30 parts per thousand, or near ocean normal; gradually the salinity grades into a low of one part per thousand to a high of 20 parts per thousand in the uppermost reaches of the bay near the major fresh water sources, the San Jacinto River to the west and the Trinity River on the east (Ibid). In general, the bay waters are naturally turbid. The relative effects of surface runoff, wind, mixing, and evapotranspiration vary locally and seasonally in moving and mixing the water as well as having the greatest influence on water level fluctuations (Ibid).

The bay is bordered by low-lying coastal plains, marshes, and swamps. Fresh water marshes and swamps are found along the northern bay margins. Along the bay margins relief is usually less than five feet, which allows extensive flooding during hurricane storm surges. In 1900 the low-lying island of Galveston suffered a storm surge of approximately 15 feet above mean sea level and 6,000 people were lost; the greatest loss of life in the United States from a single natural event (Scrudato and McCloy, 1976; Graham, 1945). Storm surge height registered for hurricane Beulah in 1967 was 3.2 feet at the Texas City Dike, 4.4 feet at Kemah-Seabrook, and 3.0 feet in East Bay; during hurricane Carla (1961) storm surge heights of 9.7 feet at the Texas City Dike were recorded; 14.2 feet at Kemah-Seabrook, and 15.0 feet at the entrance to Buffalo Bayou (Fig. 1). Both hurricanes made landfall to the west of the bay complex and therefore are not indicative of what could occur should there be a direct hit by a scale 4 or 5 hurricane (Saffir/Simpson Hurricane Scale; Hebert and Taylor, 1975).

Central to the theme of environmental stresses to the Galveston Bay system is regional population growth; the significant increase from 2,266,074 in 1970 to a projected population of 4,765,017 by 1990 leaves little doubt that as a result of population pressure alone, the stresses will increase. Further, the major population increases will be in areas already heavily populated; the east side of the bay is projected to remain rural (Houston-Galveston Area Council, 1975).

Certainly in the past 125 years, since the lighthouse chart was surveyed, this estuarine-lagoon system has been appreciably altered and in the process has become more complex and stressing agents continue to exert influences on system processes. The region developed for a number of reasons and primary among them was the natural harbor

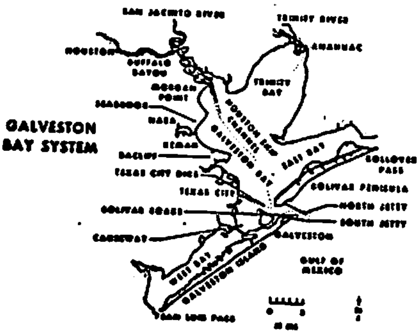

Fig. 1 - Present day configuration of the Galveston Bay System
Courtesy of NASA, Houston, Texas

in Galveston; the dredging of the Houston Ship Channel which bisects the bay in a north-south direction; the intensive agriculture in the surrounding hinterland; enormous quantities of surface and subsurface water resources; commercial fin and shell fishing; the advent of the oil and gas era; the development of the offshore petroleum industry based in Houston; and water-related recreational activities.

The bay system is large and complex and there are a multitude of environmental stresses. It would be impossible to address all the stressing agents affecting the bay system, therefore, an arbitrary selection was made to illustrate the scope of the problem. Significant features of several geographic locations are discussed, moving northward from Galveston Island, disposal, leveeing, diking, and subsidence are discussed as representative of stressing agents to the bay complex.

A significant portion of the eastern end of Galveston Island was changed subsequent to the devestating 1900 hurricane when the County of Galveston constructed a 17-foot high seawall fronting the Gulf of Mexico as protection to further wave attack and inundation by storm surge. The wall was constructed in segments until the present length of 10.3 miles. To entrap sediment a series of 15 groins were constructed approximately 1,500 feet apart, oriented normal to the shoreline. After the seawall construction commenced the citizens of Galveston had materials dredged from Bolivar Roads, Offatts Bayou, and Galveston Bay to raise the grade of the island behind the seawall to protect property against hurricane storm surges; grade raising from 10 to 17 feet above the previous natural elevations was not uncommon.

Dredging within the Port of Galveston is on-going to maintain the channel at a 40-foot depth. The dredged channel material is deposited on adjacent Pelican Island, as has spoil from several other dredging operations, thereby creating an island approximately three square miles in size constructed almost entirely of dredge spoil materials.

Sewage effluent impacts Galveston Bay significantly as untreated, or partially treated, sewage is discharged into the bay because the systems are frequently overtaxed. There are approximately 267 source points for sewage discharge into the bay and they inject a daily average total of about 1.57×10^9 gallons into the waters of the bay (Texas Water Quality Board, 1975). Because of bacterial contamination, much of the bay is closed to oyster harvesting (Texas Department of Health Resources, 1975).

Wetland residential development is not extensive in Galveston Bay, but there are several locations which have, and are, undergoing rapid development for year-round residences and second homes. Concommitant with home construction is the bulkheading and filling of marsh areas, canalization, and dredging of access channels to the bay proper. Primary locations of these real estate developments are the west end of Galveston Island and the mainland adjacent to the Galveston Island Causeway. This activity eliminates areas of primary productivity and wetlands needed for maintenance of the life cycle of estuarine-dependent fauna. This acreage has previously provided nursery grounds, food sources, and protective habitats for these fauna.

The Gulf Intracoastal Waterway (ICWW), traverses the northern shore of West Bay and the northern shore of Bolivar Peninsula; it is dredged to a depth of 12 feet and 125 feet in width. The ICWW has an average siltation rate of approximately one foot a year in the Galveston Bay segment. This results in a dredging frequency of 24 months and a spoil discharge of 750,000 cubic yards (Atturio, Basco, and James, 1976; U.S. Army Corps of Engineers, 1975). Spoil from channel and maintenance dredging is deposited on bay margin marshlands as either contained or uncontained deposits. Often, as is the case on the north shore of West Bay, the spoil pile is uncontained on the bay side of the waterway and completely covers previously healthy, marsh, and also spills back into bay waters. In West Bay, on the mainland side of the waterway, there are levees on the inland side of the disposal piles; dredged materials are therefore available for sloughing action back into the ICWW. The waterway dredged material on Bolivar Peninsula is usually contained, thereby preventing the spoil from reentering the waterway as well as the bay waters. However, in some isolated sites on the Peninsula there are private properties that have uncontained spoil piles and the materials wash over the marsh and back into the ICWW.

When the waterway traverses open water it is frequently cost effective to leave the spoil in the bay; this practice is often considered to be more environmentally detrimentel than land disposal because it disrupts current patterns and the materials are available for transport back into channels. Further, open bay disposal can cover fishery resource habitats. Bottom dwelling organisms will be covered; high turbidities will characterize dredging and disposal sites and resuspended pollutants may adversely affect water quality. Postulated benefits include continued access to back bays for recreational purposes; creation of bird nesting areas; oyster development on submerged disposal mounds; escape and migration routes and refuge areas for fish (U.S. Army Corps of Engineers, 1975). Water circulation may be improved, but at other times the bay becomes compartmentalized and the natural current patterns and flushing action within the lagoon-estuary complex are disturbed (Ibid).

Hurricane levees in the Galveston Bay area and the Galveston Seawall are two primary forms of protection against storm surges. Texas City, the site of a massive petrochemical complex, has a large system of hurricane protection levees built by the Corps of Engineers; this system is constructed to a height in excess of 15 feet above mean sea level; openings for navigation, rail, and automobile access are gated and the area within the seawall provided with pumps to discharge collected waters. Another hurricane protection feature, the Texas City

Dike, intersects the Texas City levee system on the southeast side of the city (Fig. 1). This five-mile long structure was completed in 1915 to protect Galveston Island from the northern windset. Bayward of the levee, there are industrial waste ponds that are not enclosed by the Texas City levee system and during high storm surges their contents will become available for distribution into bay waters.

As the population increases, primarily on the western and northern shores of the bay, there will be a need to increase electrical power output. There are presently two major thermal effluent source points and the contrasting water mass temperatures are clearly denoted on infrared imagery of the outfall. These two major source points discharge in excess of 1.7×10^9 gallons a day of heated effluent (Texas Water Quality Board, 1975).

In contrast to the rapid growth and development on the western and northern shores of the bay, the eastern shore remains primarily agricultural with little industrial or residential pressure. This area is intensely farmed and produces large amounts of rice. Total agricultural effluent injected into the bay complex, such as biocides, herbicides, etc., is difficult to estimate as the reporting system is voluntary, but it is known that within the approximate 715 mile long Trinity River drainage, approximately 1.6×10^5 pounds of pesticides were distributed for agricultural purposes in 1971 (U.S. Army Corps of Engineers, 1975). During the same period, in excess of 27,000 gallons of herbicides were also used on agricultural lands in this drainage (Ibid).

The northwest area of the bay is the most highly stressed portion of the system with the commercial-industrial complexes at Baytown and the Buffalo Bayou - Houston Ship Channel region. The development of these areas was initiated by the dredging of the 51-mile long Houston Ship Channel, begun in 1902 and completed in 1908 to a depth of 18.5 feet; it is today maintained at 40 feet and a width varying between 300 and 400 feet. As the ship channel passes from the bay proper into the mouth of the San Jacinto River and Buffalo Bayou it traverses low-lying marsh lands that have been diked and filled to accomodate commercial development; the previously shallow Buffalo Bayou has been dredged into the Houston urban area to create the Port of Houston.

The major activity which encouraged this industrial and urban development is the proximity of oil and gas fields and associated refining activities; parts of the northern bay are densely covered with oil and gas drilling and production platforms. This area is the largest producer of petrochemical products in the United States and also has the greatest chemical pipeline system in the world (Fisher, et al, 1972).

Total industrial discharges into the Galveston Bay system amount to about 1.8 x 10^9 gallons a day of process and cooling waters from approximately 293 source points, of which 206 are located along Buffalo Bayou - Houston Ship Channel (Texas Water Quality Board, 1975). These industries and municipalities have discharge permits amounting to approximately 54,000 pounds per day of combined mercury, chromium, zinc, lead, copper, and cadmium (Bernard Johnson, Inc., 1975).

Houston area industries have drawn heavily from the extensive ground water resources from the region and coupled with municipal withdrawal, and oil and gas extraction, it has resulted in extensive land subsidence throughout the area. According to Wagoner (1976), after the State of Texas authorized the creation of the Harris-Galveston Coastal Subsidence District in 1975, an analysis of the first 1,400 permits for withdrawal of groundwater in the jurisdictional area showed that agriculture accounted for 14 percent of the groundwater withdrawal; industrial pumpage 31 percent; municipal and public water supply pumpage 55 percent. The extensive groundwater withdrawal from the highly industrialized and populated northwest portion of the bay has resulted in extensive land subsidence throughout the area (Gabrysch and Bonnett, 1975). According to Charles Krietler of the Texas Bureau of Economic Geology (1976), maximum subsidence of about 8 feet has occurred directly where the largest industrial complexes are located, along Buffalo Bayou and the Houston Ship Channel; during the past decade 3.5 feet of subsidence has been recorded for this area. Indications of the subsidence are manifest in the reflecting pool of the San Jacinto Monument located adjacent to the bayou and near the center of maximum local subsidence where one can see the old walkway adjacent to the reflecting pool which is now covered with three to four feet of standing water. According to Wagoner, (1976):

> "The State of Texas has expended in excess of four million dollars for bulkheading and rebuilding roads and facilities at the San Jacinto Monument Park. In addition to the direct dollar outlay, in excess of 130 acres of the original 445 acres of the Park are now inundated and lost to the public's general use."

In the Kemah-Seabrook area (Fig. 1), subsidence is clearly evident. In order to stem the resultant effects of subsidence, bay area residents and local governmental agencies have resorted to localized, piecemeal, and unstructured activities such as raising street grades; raising yard grades; construction of various types of bulkheads; filling of wetlands with riprap and other debris; and building makeshift groins to hopefully entrap sediments moving alongshore.

The Galveston Bay system is in fact a multi-stressed environment and will continue to be stressed by the acceleration of those activities discussed, and others, that have affected the region to date. Though there has been a regional subsidence district established, one cannot help but wonder what the effects of dredging, leveeing, and filling activities of the bay system, coupled with localized subsidence, will be when a hurricane similar to the magnitude of "Carla" makes landfall near the area. It must be noted that there are continued pressures being imposed by local proponents for expanding industrial and port activities, as well as residential development in the wetlands that will continue to impose serious and prolonged stresses.

BIBLIOGRAPHY

Atturio, John M., Basco, David R., and James, Wesley P., 1976, Shoaling characteristics of the Gulf Intracoastal Waterway in Texas; College Station, Texas, TAMU-SG-76-207, 93 p.

Bache, A.D., 1851, Preliminary sketch of Galveston Bay indicating proposed sites for lighthouses; United States Coast Survey, A.D. Bache, Superintendent, Galveston, Texas, Rosenberg Library, photocopy, 42.5 x 49.5 cm.

Bernard Johnson, Inc., 1975, Regional Assessment Study, Houston Ship Channel, Galveston Bay, Vol. 2, prepared for National Commission on Water Quality.

Fisher, William L., et al, 1972, Environmental geologic atlas of the Texas coastal zone, Galveston-Houston area; Austin, Texas, Bureau of Economic Geology, 91 p., and maps.

Gabrysch, R.K., and Bonnett, C.W., 1975, Land-surface subsidence in the Houston-Galveston region, Texas; Austin, Texas, Texas Water Development Board Rept., no. 188, 18 p.

Graham, S.B., 1945, Galveston community book; a historical and biographical record of Galveston and Galveston county; Galveston, Texas, Arthur H. Cawston, 438 p.

Hebert, Paul J., and Taylor, Glenn, 1975, Hurricane experience levels of coastal county populations - Texas to Maine; Washington, D.C., U.S. Department of Commerce, NOAA, National Weather Service Community Preparedness Staff and Southern Region, 153 p.

Houston-Galveston Area Council, 1972, Regional atlas; Houston, Texas, 61 p.

Krietler, Charles, 1976, Personnel communication; Austin, Texas, Bureau of Economic Geology

Scrudato, Ronald J., and McCloy, James M., 1976, Galveston Coastal Resources, Galveston, Texas, Galveston Marine Affairs Council, 147 p.

Texas Department of Health Resources, Division of Shellfish Sanitation Control, 1975, Classification of shellfish harvesting areas of Galveston, Trinity, and East Bays, Austin, Texas, map order no. MR-26.

Texas Water Quality Board, 1975, Galveston Bay Project, Summary Report, 99 p.

Texas Water Quality, July, 1975, Water Quality Management Plan for the San Jacinto Basin, prepared by Gulf Coast Water Disposal Authority and San Jacinto River Authority, 557 p.

U.S. Army Corps of Engineers, 1975, Final environmental statement maintenance dredging Gulf Intracoastal Waterway, Texas section, main channel and tributary channels; Galveston, Texas, U.S. Army Corps of Engineers, Galveston District, v. 1, 171 p., and appendicies.

Wagoner, Ed L., 1976, Subsidence - Can it be stopped?, Houston, Nov., 4-5 p.

EROSION DEFENSE STRUCTURES ON THE PUGET SOUND SHORELINE

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ABSTRACT. Localized beach erosion forces individual property owners around the Puget Sound shoreline to construct erosion defense structures. Little information or help is available to assist their needs. This results in an array of erosion defense installations that often fail and mar the natural beauty of the beach.

INTRODUCTION. Wet climate, unstable glacial debris and the waves of Puget Sound often lead to hazardous conditions for shoreline property owners. The U.S. Army Corps of Engineers has identified many erosion sites along segments of the Puget Sound shoreline. Nearly all of these sites have been classified as "non-critical" by their standards. What is classified as "non-critical" may be very critical to the individual whose property is washing away.

Beachfront property owners around Puget Sound employ a variety of techniques to combat the erosional loss of their land. The purpose of this paper is to illustrate a few of the techniques used with the hope that such exposures will show their plight.

The materials most commonly used in the fight against shore erosion are logs, wooden planks, concrete walls, and concrete or rock rip rap. The structures made from these materials often have two detrimental effects: (1) They visually blight the natural scenic beauty of the shoreline, and (2) collectively, the structures tend to aggravate erosion problems along adjoining beaches.

Drift wood is commonly found in large quantities on the Pacific Northwest beaches. It is plentiful, free and often used to defend one's property from wave attack. It may be found piled, stacked or chained into position (fig. 1). Unfortunately, under high wave conditions, loose logs can become the very tools of erosion and structural damage to beachfront homes.

Fig. 1. Drift logs piled at the base of an eroding bluff.

One innovative individual employed logs, wooden planks, and old tires to defend his receding bluff from further wave attack (fig. 2). The structure, from his point of view, appeared quite substantial. Unfortunately, the next storm season proved his structure to be not as sound as he had hoped (fig. 3.).

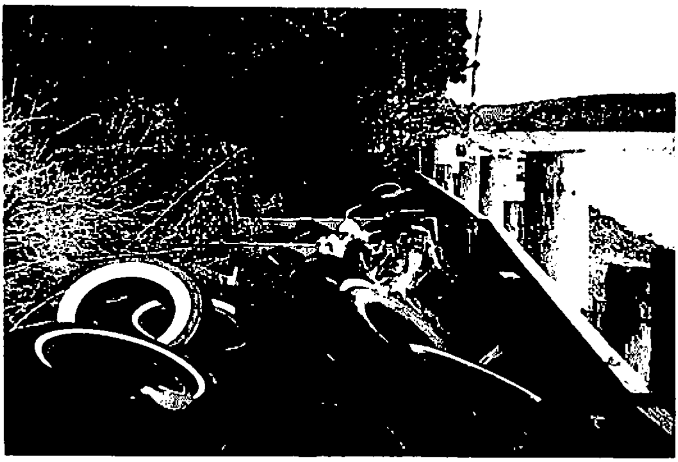

Fig. 2. A wooden seawall with old tires for support

Fig. 3. Failure of the structure with the next storm season

Concrete and rock rip rap is not often found as a defense against beach erosion. Occasionally, broken pieces of concrete are dumped or placed at the base of eroding cliffs. The effectiveness of this material is questioned in light of the haphazard methods placement.

One individual used a variation from the normal use of rock or concrete rip rap. He fabricated approximately one hundred two and one-half feet square concrete blocks and placed them at the foot of his rapidly eroding bluff (fig. 4.). The blocks lie in two rows and are laced together with one-half inch steel cable welded to a steel hook on the top of each block.

Fig. 4. Concrete blocks at the base of an eroding bluff

The blocks have been long standing, but the bluff continues to recede. Large logs deposited by past waves, lie on top of the blocks clearly showing that storm waves mount the low lying blocks and continue to attack the bluff at a higher level.

Concrete and wooden seawalls are the most popular type of erosion defense structures found around the shoreline of Puget Sound. Most people consider concrete walls as the ultimate answer to their erosion problems. Some stand for many years, while an equal number fail shortly after installation. Common failures result from wave excavation of wall footings and from tension cracking within the wall as soil and water pressures build on the landward side. To counter these typical problems, some seawalls have appended to them buttresses and groins (fig. 5.). The buttresses help support the shore side of the wall and the groins retain beach sediment along the base of the wall. Log laden storm waves often destroy the supports, perhaps to the benefit of adjoining property owners, for the structures impede the free movement of beach sediment increasing the likelihood of downdrift beach erosion.

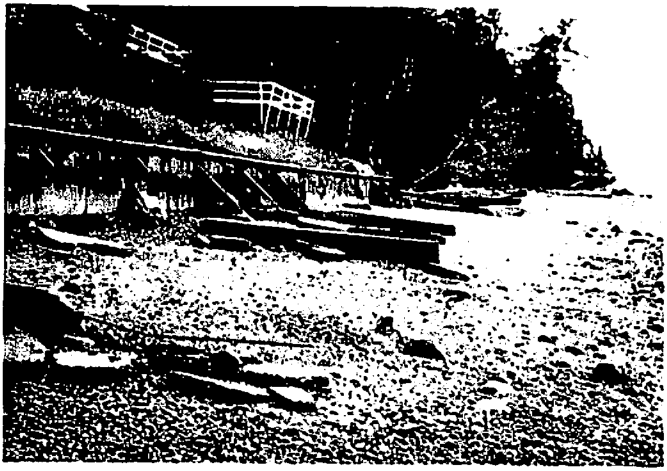

Fig. 5. Seawall with buttress supports and groins

In one seemingly peaceful bay, conditions are not always so peaceful. Storm waves that occur in conjunction with a high tide become a threat to beachfront homes. Bulkheads, rip rap and groins shroud much of the shoreline. Neighbors have become competitors for beach sediment.

Fig. 6. Three types of defenses against wave attack

Several property owners have installed three types of defenses against wave attack--rip rap, bulkheads and plywood sheets that may be lifted in position on top of the bulkhead (fig. 6.).

SUMMARY. Although Puget Sound is a relatively small body of salt water, wave energies do approach sufficient strength to cause localized shoreline erosion problems. Erosion is not regionally severe, but is locally distressing to beachfront property owners. Washington State's Shoreline Management Program begins to address the plight of the property owner. It is hoped that the state in cooperation with local and federal authorities will strive to provide assistance so that beaches and the beauty of the Puget Sound shoreline can be preserved.

EDIZ HOOK: PAST, PRESENT, AND FUTURE

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Ediz Hook is a three-and-a-half mile long spit located near the city of Port Angeles, on the north coast of Washington's Olympic Peninsula (Fig. 1). The outer two-thirds of the spit belongs to, and is occupied by, the U. S. Coast Guard, while the inner portion is heavily industrialized. The inner harbor, provided protection by the spit, is the only deepwater port on the U. S. side of the Strait of Juan de Fuca. Within the harbor there are facilities for overseas shipping, as well as a boat basin for fishing and pleasure craft. The port has been mentioned frequently, too, as a possible monobuoy terminus for petroleum shipments from the North Slope oil fields. It is estimated that, in one way or another, half of the local labor force depends on the existence of Ediz Hook for employment (Anonymous, 1974). And yet, the spit is in danger of being truncated near its base in the near future, and eroded away completely in the future.

The Hook was developed in post-Pleistocene times by the eastward drift of sediment along the shore (Corps of Engineers, 1976). The sources for this sediment were mainly the Elwha River delta and the nearby sea cliffs. Ocean swell approaches this coast from the Pacific, to the west, through the Strait of Juan de Fuca. In addition, the predominant locally generated wind waves are from the west; and the greatest fetch is also in that direction. These factors combine to provide net sediment drift to the east. With a rising sea level during the Holocene, the spit, once established, received a continual and abundant supply of sediment, developing the hook out into the Strait and eastward to the size and position in which we find it today.

However, construction of the Lower Elwha Dam, completed in 1910 or 1911, greatly reduced the sediment load provided to the delta and shore region. Another dam, the Upper Elwha Dam, built in 1925-1928, upstream from the first, has had, obviously, no effect on the amount of bedload transported to the coast. It has been estimated that the sediment load was 50,000 yards^3/year prior to the building of the first dam. Present bedload estimate is 1/10 of the original pre-1911 volume, or about 5,000 yards^3/year (Corps of Engineers, 1971a, 1976).

The sea cliffs or bluffs located between the Elwha River delta and Ediz Hook had been eroding landward in recent years at a rate of

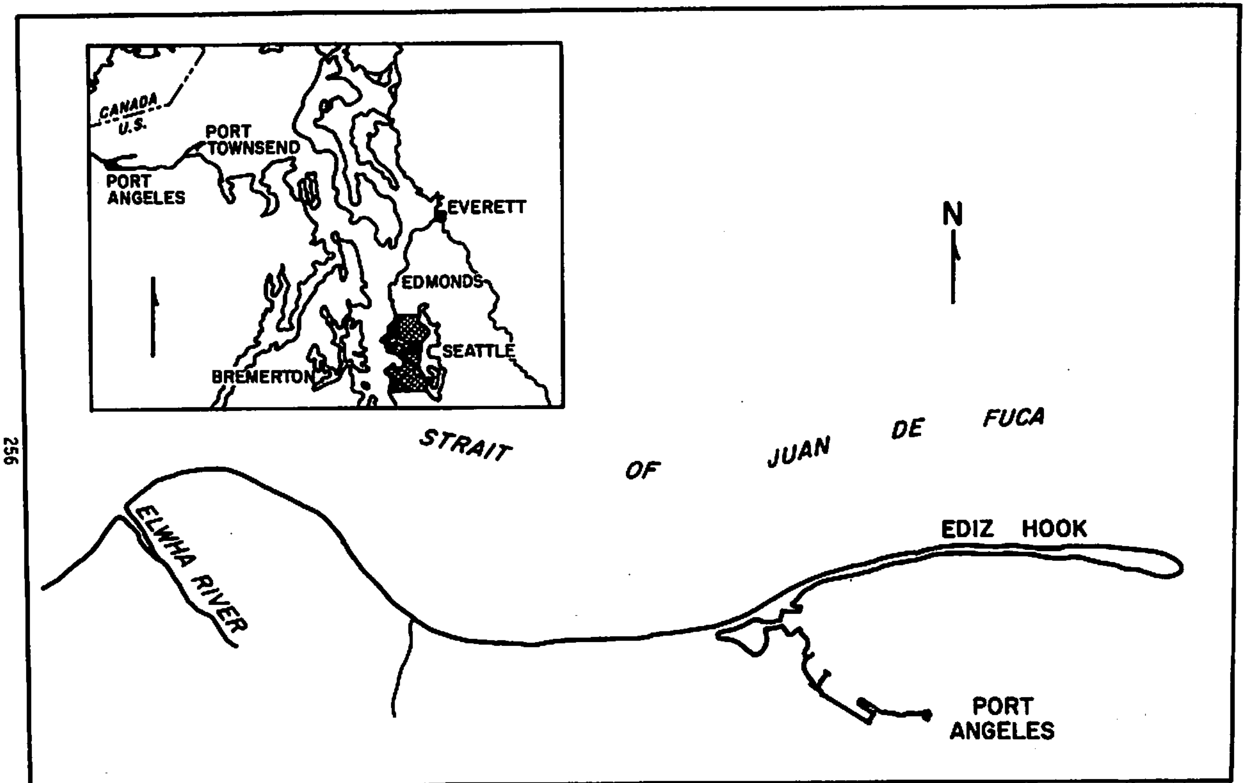

FIGURE 1. Ediz Hook location map (after Corps of Engineers, 1971).

approximately 4 to 5 feet annually, providing a sediment supply of 290,000 yards^3/year (Corps of Engineers, 1971a, 1976). In 1930, a water supply line, protected by 2,400 feet of bulkhead, was laid along the beach at the foot of the cliff. This reduced the rate of cliff recession somewhat, but some erosion did continue nevertheless. Then, between 1958 and 1961, 6,800 lineal feet of riprap was added. The total effect of the bulkhead and riprap construction was to cut the shore drift sediment supply from the cliff to 95,000 yards^3/year in 1930 and to 40,000 yards^3/year by 1961.

Though some sediment still comes to the spit from elsewhere along the coast, the supply has effectively been reduced from an estimated 350,000 yards^3/year, prior to any form of man-made interference, to a present load of 90,000 yards^3/year. Corps of Engineers (1976) wave analyses indicate that there is a transport capacity of 270,000 yards^3/year in the vicinity of the base of the spit. It is thus readily apparent that with such a net loss of sediment along the shoreward base of the spit, serious erosion is bound to occur at that point. This had indeed been the case, with erosion and wave overtopping becoming increasingly serious hazards. Meanwhile, there has been a slight concomitant growth at the bulbous distal end of the spit. The natural tendency is for Ediz Hook to become a form of a migrating barrier island!

The landward end of the spit has shown signs of severe erosion for many years. Since 1936 there have been piecemeal efforts to stem this erosion, mainly through sporadic and individual projects. Among the various techniques employed there have been: log bulkheads, rock and timber groins, installation of riprap, and localized beach nourishment. All of these were to no avail as wave action continued to cut into the beach profile, break up parking and roadway pavement, and even overtop the crest of the spit at times.

The serious erosion at Ediz Hook was first studied by the Corps of Engineers in 1939. In 1970, at the request of the local population, the Corps renewed its investigations, this time with the hopes of arriving at a final solution to the problem. With authorization from Congress to proceed with this study, the Corps undertook the necessary field observations and measurements and came up with thirteen alternative possible courses of action. These were outlined in a series of public brochures which were widely distributed at the time. The suggested alternatives were as follows:

1. No action
2. Concrete seawall
3. Offshore breakwater
3a. Liberty ships in lieu of rubblemound offshore breakwater
4. Groin field with periodic beach nourishment
5. Rock revetment with periodic beach nourishment
6. Elevated roadway
7. Beach nourishment
7a. Interim measures

8. Relocate industrial water supply pipeline and remove its existing protective works
8a. Remove all man-made structures
9. Porous-walled breakwater
10. Industrial fill on the north side of Ediz Hook

The pros and cons of each of these alternative plans were solicited from government agencies, private organizations, and the public at large and a series of public meetings were held to discuss these views. A final version of the brochure (Corps of Engineers, 1971b) listed these pros and cons, outlined the cost-effectiveness of each alternative, outlined the alternative selected by the Corps for further detailed study, and gave a rationale for rejecting other alternatives. For those interested in a more detailed inspection of one of these brochures, a volume edited by the author (Schwartz, 1972) is recommended. The fourth edition of the Corps' public brochure is reprinted there.

Alternative 5, rock revetment with periodic beach nourishment, was the alternative finally chosen for implementation. This plan appears to offer the best form of protection for the coast (approximately $7,850,000) with a minimum disruption of the environment. The rock revetment will extend 11,600 feet along the outer side of the spit, from near the landward end to the Coast Guard Station, and will consist of 344,000 tons of armor rock. Starting at MLLW, the revetment will extend an elevation of 16 or 18 feet above that datum level. The initial beach nourishment will be approximately 180,000 yards^3, followed by about 13,000 yards^3 per year. The source of the beach fill material will be Pleistocene gravel deposits quarried on land in the vicinity of Port Angeles. In the spring of 1975, a beach-feed test program was initiated using three different size ranges of material. The final stage of revetment construction and beach replenishment is planned to begin in 1977.

As outlined here, the building and then near-destruction of Ediz Hood has been a lengthy and complicated process. A final solution to the problems brought on by man's interference with natural conditions has been a long time in coming. Hopefully, the approach now being undertaken will stabilize the spit and satisfy the needs of all concerned. What the future holds for Ediz Hook remains to be seen.

References Cited

Anonymous, 1974, An Ediz Hook story: Pacific Northwest Sea, v. 7, p. 4-7, 12-14.

Corps of Engineers, 1971a, Ediz Hook Erosion Control Study: Seattle, U.S. Army Engineers District, 8 p. + 19 plates.

Corps of Engineers, 1971b, Erosion Control, Ediz Hook, Port Angeles, Washington: Seattle, U. S. Army Engineers District, 34 p.

Corps of Engineers, 1976, Ediz Hook Beach Erosion Control: Seattle, U. S. Army Engineers District, 26 p. + Tables, Exhibits, Plates and Appendices.

Schwartz, M. L., ed., 1972, Spits and Bars: Stroudsburg, Dowden, Hutchinson, & Ross, 452 p.

HUMAN INDUCED STRESS ON THE CAUCASIAN COAST OF THE BLACK SEA

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ABSTRACT

Human induced stress on the Caucasian section of the Black Sea Coast results from exploitative as well as remedial actions. Under natural conditions the interplay of climate, hinterland topography and shore zone morphology appears to have been capable of maintaining a well-developed shingle beach. Serious anthropogenic interference to the general beach system commenced some 40 years ago. Recreational facilities were constructed on an increasingly large scale. Gravel was removed from the beach for construction purposes, moles were built for harbors and dams were constructed on the rivers leading to the shore. Much of the subsequent remedial work intensified rather than alleviated the problem. This paper describes the physical setting of the coast, paying attention to its vulnerabilities, analyzes the human induced stress and the subsequent corrective measures, and attempts to evaluate the future success of those measures.

INTRODUCTION

The Caucasian coast of the Black Sea is one of the most important rest and recreation areas in the Soviet Union. Great numbers of people visit the area every year to swim and be on the beach. But, providing accommodations for these visitors places great stress on the major attraction--the beach. Beach deterioration prompted a variety of remedial actions, some successful, others unsuccessful.

PHYSICAL SETTING

Along the Caucasian section of the Black Sea Coast the mountains are close to the shore and the continental shelf is usually narrow. The coastal rocks are composed mainly of Tertiary sediments whereas those in the interior are primarily crystalline and metamorphic. Ample precipitation in the mountains plus snow melt in the spring result in abundant runoff. This plus steep stream gradients and steep terrain bring about a large delivery of alluvium to the coast. The composition of the beach shingle indicates that this alluvium is the main source of beach sediment. The beaches can be classed, according to the material upon which their sediment rests, into three general types: 1) an accumulation of shingle on a rock bench, 2) shingle on a 2 to 4 meter thick layer of sand that in turn rests on a bench, and 3) shingle on deltaic deposits where there is no firm base (Zenkovich, 1973).

Following the Holocene sea level rise the drowned, lower parts of large valleys rapidly filled with stream sediment while the intervening headlands were trimmed by wave erosion. A strong longshore current to the southeast resulted from the combination of the straight shore, the structurally determined NW-SE trend of the coast and the prevailing eastbound sea waves (Zenkovich, 1976).

Despite the current, the alluvium accumulated faster at the mouths of large rivers than it could be carried away by littoral drift. As a consequence, cusp-shaped deltas encroached upon the sea until their margins extended to the edge of the continental shelf. Also, the submarine margins of the deltas are the sites of submarine canyons, the headward portions of which frequently reach close to the shore (Zenkovich et al., 1976).

Six long-shore sediment circulation cells, similar to those described by Inman and Brush for California (1973), occur on the Caucasian coast (Fig. 1). Each system can be defined by the rock type in the shingle and the kinds of light and heavy minerals in the sand (Kiknadze, 1976). The cells result from the interaction between stream sediment supply, littoral drift and submarine topography. These cell systems commence with an inflow of sediment from rivers and end where submarine canyons are cut into the delta margins or where the deltas intersect the edge of the shelf. Here the sediment bearing long-shore current is deflected into the deeper water offshore (Kiknadze, 1976). Under natural conditions the sediment flows probably kept the beaches in a state of dynamic equilibrium. Even though much of the material in the flows was destroyed by attrition or lost to deep water, enough was deposited on the beaches to make up for natural losses.

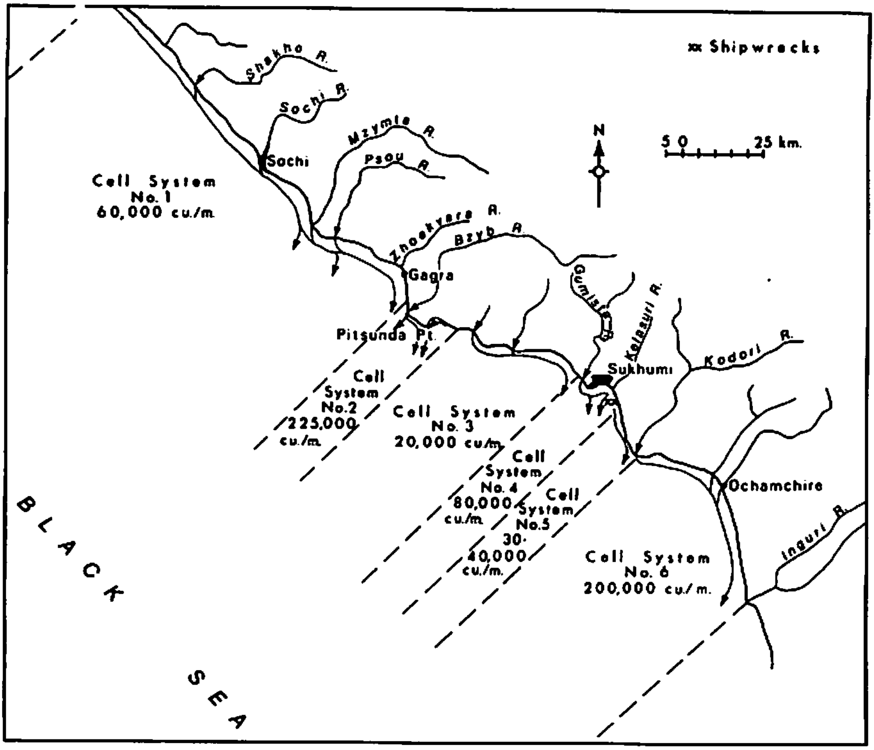

Fig. 1. Littoral circulation cells on the north-eastern Black Sea Coast and their approximate sediment loads (from Zenkovich, 1973, 1976; Kiknadze, 1976; and Belova et al., 1976).

The amount of sediment transported by the long-shore drift in each cell has been determined by the use of luminescent tracers and porous pebbles impregnated with colored liquid cement or by natural intergroin filling (Kiknadze, 1976; Belova et al., 1976). The northern most flow annually carries some 60,000 cu/m of pebble sediment along the Sochi coastal section (Zenkovich, 1976). Down the coast, reduction in volume of transported sediment occurs as the consequence of pebble attrition and subsequent loss of the fine material to deep water along the western margins of the Adler Delta. At Adler, the sediment flow is replenished by large amounts of debris delivered by the Mzymta and Psou Rivers. Even so only about 20,000 cu/m reaches Gagra (Kiknadze, 1976; Zenkovich, 1976). Much of the material provided by the two rivers appears to be discharged into numerous submarine valleys along the margin of the Adler Delta (Zenkovich, 1976). Continuing pebble attrition along the Gagra shore reduced the sediment flow further so that only about 5,000 cu/m is delivered to the area near the Bzyb River mouth.

The second sediment flow system has been the subject of a careful study (Belova et al., 1976). The Bzyb River initiates the flow with an average discharge of 280,000 cu/m of beach material per year. The finer portion of sediment fraction is carried away by submarine canyons immediately in front of the river mouth. The remainder, about 225,000 cu/m per year, is removed to the southeast by the long-shore current. However, about 2.5 km from the Bzyb mouth approximately 80,000 cu/m of sediment is lost to deep water via the Shark submarine canyon. The remainder of the sediment load, increased by sediment derived from beach erosion to 180,000 cu/m, is carried towards Pitsunda Point. Of this, about 90,000 cu/m is lost down the steep submarine slope around the bend of Pitsunda Point. Of the remainder, some 55,000 is deposited in the near shore zone at the eastern end of Pitsunda Peninsula. By the time the long-shore drift reaches the head of Pitsunda Bay, about 12 km from the Bzyb mouth, its sediment load is exhausted (Zenkovich, 1976; Kiknadze, 1976). There is a small, short counter flow of sediment (about 10,000 cu/m) in the lee of Pitsunda Point (Belova et al., 1976).

Another drift system develops southeast from Pitsunda Bay (Mjussera Hills) as several small rivers recharge the long-shore current with sediment. At its maximum the flow is thought not to exceed 20,000 cu/m per year. The sediment flow terminates near the mouth of the Gumista River (Kiknadze, 1976) where it is apparently dissipated down the steep submarine slopes of the Gumista Delta.

A new flow system (the fourth) starts with the discharge of about 80,000 tons of beach forming sediment by the Gumista River. This flow is also relatively short. Large amounts of sediment are lost on the steep submarine slopes on the down drift edge of the Gumista Delta. A residual flow reached as far as the Kelasuri River mouth until 1942 when it was interrupted by two large ships that were sunk near the shore of Sukhumi Bay (Zenkovich, 1976; Kiknadze, 1976).

Several km southeast of the sunken vessels another flow system, about 20 km long, is initiated by the Kelasuri River. Augmented by the sediment discharge of other rivers, the flow's sediment load eventually grows to about 30-40,000 cu/m per year. However, upon reaching the Kodori River Delta most of the load is lost down submarine canyons (Zenkovich, 1976; Kiknadze, 1976).

The final flow system on the Caucasian Coast starts with the Kodori River discharge of over 700,000 cu/m of sediment (Lontiev and Safianov, 1973). Of this about 200,000 tons of beach forming sediment is carried to the southeast. This sediment flow, of about 60 to 70 km in length, like the others, virtually terminates at the Inguri Mouth as the result of losses down the steep submarine slope and canyons associated with the Mouth (Zenkovich, 1976; Kiknadze, 1976).

Though the rivers along the Caucasian coast discharge large amounts of beach forming sediment, about ninety percent of it is lost down the submarine canyons (Kiknadze, 1976). It has been further estimated that only about five percent of the beach forming sediment supplied by Georgian rivers is stored in the beaches (Zenkovich, 1976). Much of the remainder is irretrievably lost to deep water. The limited capacity of the littoral drift systems to supply sediment to the beach results in a vulnerable natural beach system.

HUMAN INDUCED STRESS

The relatively fragile Caucasian shore has been subject to several types of debilitating human behavior over the last 40 years or so. Gravel was taken from the beaches for construction, dams were built on the rivers, and harbor-protecting moles were built in several places. Deterioration of beaches quickly followed.

Perhaps the first interference with the beach system began with the removal of sediment for highway construction in the early 1890s and was continued during the period of coastal railway construction between 1914 and 1928. Removal was intensified after 1945 when the resort and recreation activities started to expand rapidly (Romashin and Shulgin, 1976). Mining of beach sediment continued until forbidden by law in the 1960s. By that time many million cu/m of beach material had been consumed by the building industry (Zenkovich, 1976).

However, the great demand for construction gravel resulted in immediate mining of flood plain alluvium. Within a very short period well over a million cu/m of sediment was removed from the flood plains on the Tuapse-Gagra section of the Caucasian coast (Romashin and Shulgin, 1976). This activity also is now forbidden by law.

Other activities deleterious to beach preservation started more or less contemporaneously with this onset of intensive mining of beach and flood plain sediments. A 150 m mole was built directly north of the Zhoekvara River some time prior to 1927. Larger moles were also constructed at Sochi and north of Ochamchire between 1937 and 1939 (Fig. 2). Dams were built on several rivers--on the Tuapse in the 1930s, the Zhoekvara in the late 1940s, the Mzymta in the 1950s and, just recently on the Inguri River. The dams reduced the sediment discharge to the coast and the moles seriously blocked the flow of sediment along the coast (Kiknadze, 1976; Romashin and Shulgin, 1976; Zenkovich, 1973, 1976).

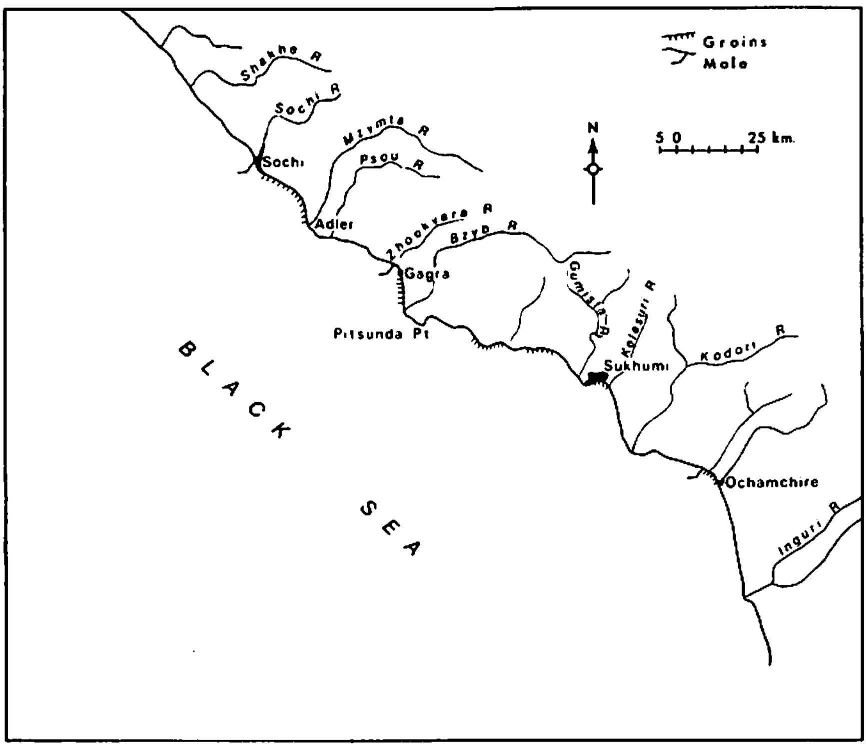

Fig. 2. Location of groins and moles on the north-eastern Black Sea Coast (from Zenkovich, 1976; Kiknadze, 1976).

The combination of mining, damming and blocking has had disastrous effects on the Caucasian beaches. In 1976 Kiknadze observed that there is virtually no natural beach aggradation along the entire coast of the Georgian Republic and that some coastal areas have no beaches at all. For example, the beaches down drift from the Sochi and Ochamchire moles have been greatly narrowed or destroyed by erosion. In the case of the Sochi mole its negative effects were felt to the mouth of the Mzymta River (Zenkovich, 1976). South of the Ochamchire mole beach destruction extended to the town where shore erosion caused serious problems (Kiknadze, 1976).

REMEDIAL ACTIONS AND THEIR EFFECTS

A variety of remedial actions has been taken to resolve these problems. The actions include the construction of sea walls, groins (along with intergroin filling) and submerged breakwaters. Some of these remedial attempts simply exacerbated the situation. The earliest protective effort on the Caucasian coast was probably the construction of sea walls to protect the railroad built between 1914 and 1928. These sea walls, however, need frequent repair. When waves approach a wall directly they are reflected and the backwash erodes the beach sediment. This may eventually lead to the collapse of the structure. Waves approaching the coast obliquely interact with the wall to form very strong long-shore currents that can quickly remove beach sediment and again undercut the wall. Shores protected by walls more than a kilometer long may eventually be stripped of their beaches (Zenkovich, 1973).

Groins have been installed at many places along the coast in order to protect the beaches from erosion caused by the sea walls or by the moles at Sochi and Ochamchire (Fig. 2). Because of the special qualities of the Black Sea coast, some experimentation was necessary before suitable groins were developed. Initially low, short cement groins were installed. These proved unsuccessful, especially in areas lacking firm foundation. Here the groins sagged and the shingle simply drifted over the landward ends of the groins and beach erosion continued (Zenkovich, 1973, 1976). Longer and higher stepped groins were then tried and these were usually successful in checking beach drift on those coastal sections with a rock bottom. Where the beach is underlain by unconsolidated sediment, very large groins (70 m long and 4 m high at the base) have been installed. These were made of concrete casings set about 10 m into the beach sediment and filled with stone and concrete.

But, because these new designs proved effective in checking long shore sediment flow, downdrift beach erosion intensified (Zenkovich, 1976). For example, at Ochamchire, beach erosion caused by the mole was so severe that the concrete sea walls subsequently built to protect the town failed thrice. These were replaced by groins of appropriate design that proved to be successful in protecting the town. However, their installation caused serious coastal erosion down to the mouth of the Inguri River.

Further experimentation has shown that the improved stepped groin design when combined with artificial filling between groins and the strategic use of submerged breakwaters between groins virtually eliminates local, groin induced beach erosion. The combination permits a relatively uninterrupted movement of drift past the groin combs and has been installed with apparent success at several places on the coast (Zenkovich, 1976). However, beach stabilization along the entire coast will require the installation of many such groin systems. Furthermore, it is estimated that the addition of approximately two million cu/m of gravel will be required to make up the deficit that presently exists in the beach-littoral drift systems. Once the deficit is balanced a continuing annual supply of some 200 to 300,000 cu/m will be required to replace sediment lost to deep water by natural means (Zenkovich, 1973).

FUTURE

Even though the remedial efforts described may bring the Caucasian beaches back to a state of approximate equilibrium, relatively large annual additions of gravel will be required for an indefinite period. This is due to the continuing constant loss of sediment to deep water while the natural supply of sediment by streams has been reduced by the dams built on several of the larger rivers. Unless some means is devised whereby sediment may be pumped up from some of the more shallow canyons or passed around the dams obtaining suitable gravel from outside sources will become necessary. Indeed, already some of the material used in filling concrete casings is being imported from the north side of the Caucasian Mountains (Zenkovich, 1973).

REFERENCES

Belova, N.; Orlova, G.; Peshkov, V.; 1976, Shore dynamics of Pitsunda Peninsula. 23rd International Geographical Congress Symposium "Dynamics of Shore Erosion," Tour K-25, USSR, 19-25 July, pp. 173-176.

Inman, D. L.; Brush, D. M.; 1973, The Coastal Challenge. Science, Vol. 181, pp. 20-32.

Kiknadze, A. G.; 1976, Dynamic systems and the budget of alongshore sediment flows of the georgian Black Sea Part. 23rd International

Geographical Congress Symposium, "Dynamics of Shore Erosion," Tour K-25, 19-25 July, pp. 244-246.

Leontiev, O. K.; Safianov, G. A.; 1973, Canyons under the sea, Ed. House MYSL, Moscow, 260 pp. (In Russian).

Romashin, V. V.; Shulgin, Ya. S.; 1976, Transformation of the Black Sea coasts caused by technological effects. 23rd International Geographical Congress Symposium, "Dynamics of Shore Erosion," Tour K-25, 19-25 July, pp. 227-229.

Zenkovich, V. P.; 1973, Geomorphological problems of protecting the Caucasian Black Sea Coast, Geog. Journal, Vol. 139, pp. 460-466.

___________; 1976, Excursion Guide. 23rd International Geographical Congress Symposium, "Dynamics of Shore Erosion," Tour K-25, USSR, 19-25 July, pp. 124-169.

Zenkovich, V. P.; Menshikov, V. L.; Safianov, G. A.; 1976, Effect of submarine canyons of the eastern part of the Black Sea on littoral zone morphology. 23rd International Geographical Congress Symposium, "Dynamics of Shore Erosion," Tour K-25, USSR, 19-25 July, pp. 244-246.

SHORELINE PROTECTION IN JAPAN*

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ABSTRACT

Although tetrapods are used in many countries around the world, probably no nation has used them so extensively as Japan. They, and other shore protection structures, have been used on subsiding and low cliff coasts, in harbors, along sand and shingle beaches, and on coasts subjected to ice action. Although tetrapods are mainly used in shore defense, they also have other uses such as enclosing specific areas for aquaculture, creating artificial currents in estuaries, and as submerged offshore barriers for the purpose of creating new beaches.

The tetrapod (patented by the Nippon Tetrapod Co., Ltd.) has many variants. In Japan, for example, weights presently used range from 4 to 50 tons. Usually before the size to be used is specified, model tests are conducted in laboratories.

New types of structures are continually being developed in Japan. One of the most recent additions is what has been labeled the "Igloo." It is a wave dissipating wall in which vertical moving waves are converted into horizontal waves by curved vertical plates within the structure. In 1975, Igloos were constructed along 4 separate coasts in Japan and to date have proven very effective. Also, according to the company, they are "in harmony with the environment," a claim one could hardly make for tetrapods. If such "environmental blending" proves acceptable to the public, one of the stresses which has received additional attention in recent years, the visual stress, will be lessened greatly.

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*This paper is a slightly revised version of "Tetrapods, Igloos, and the Coast of Japan," published in the ONR Tokyo Scientific Bulletin, Department of the Navy, Office of Naval Research.

INTRODUCTION

Japan, with an area three times that of Louisiana has a coastline that is 31,382 km long. This length provides an exceptionally favorable value of one km of coastline for each 14 km^2 of area. Nonetheless, population density is so great (275/km^2) that each kilometer of its highly varied coastline is shared by nearly 4,000 people.

In many places hills and mountains rise directly out of the sea and peninsulas and small islands are numerous. Some coasts are volcanic; others are earthquake prone and extensive earthquake-generated landslides are not uncommon. There are other coasts however, which are low; some have long beaches, others have sand bars and/or sand dunes, and still others have abrasion platforms. Coral reefs occur in the south and lagoons are common along many coasts. Some lagoons, such as Hachirogata in northern Honshu (Fig. 1), have been reclaimed. Formerly Hachirogata lagoon was the second largest body of water in Japan, but during the 1960's much of it was filled in order to increase the country's rice production (Noh and Gordon 1974).

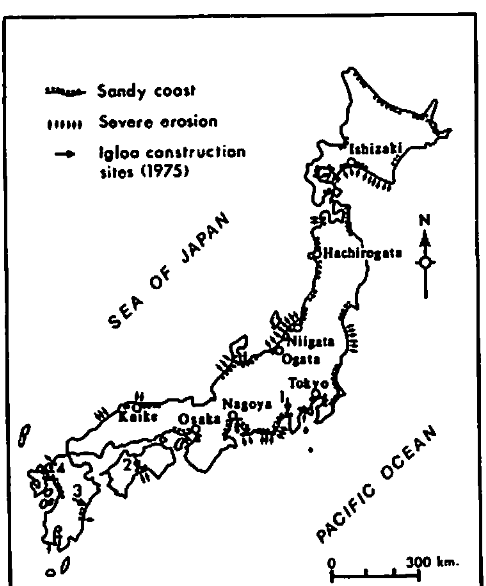

Fig. 1. Japan and coastal characteristics. Locations at which Igloos are under construction are:
1. Numazu, 2. Kochi,
3. Hosojima, and 4. Karatsu.
Adapted from Sunamura, 1973.

Marine generated coastal processes are equally as varied. They include erosion by ice on the shore of the Sea of Ohkotsk in Hokkaido, by monsoon generated waves on the coast of the Sea of Japan, and by typhoon and tsunami generated waves along much of the Pacific shoreline. Although exposed coasts are lengthy and bear the brunt of waves which frequently have an extremely long fetch, there are many relatively protected lagoon, bay, and sea (as in the Inland Sea) coasts.

The fact that the coasts of Japan are important in the lives of the Japanese people is well known. Fishing has been traditional and prosperous and fishing villages dot the coast. Coastal catches, however, have recently decreased--partly because of local overfishing and partly because many fish are now being caught in deep waters before they reach the coast. Another important factor is the increase in pollution of coastal waters (Matsuishi 1975). Pollution has progressed to such an extent that the cultured-pearl industry is suffering. Nonetheless, the coastline and its numerous bays and harbors is still important for its abundant biotic resources. Further, increasing attention is being given the development of aquaculture--a lagoonal and coastal enterprise. Fish farming techniques have been developed to the point that they are among the best in the world (Takeuchi 1975).

In addition, Japan is one of the world's leading industrial nations. However, it differs from most of the rest of the industrial nations in that its industry is based almost entirely upon imported raw materials. These materials, once converted into manufactured goods, are exported. Most large industrial complexes are located in the lowland along coasts and especially along coasts on the country's Pacific side where the best harbors are found.

The physical nature of the land, a fishing heritage, and an industrial emphasis have combined with other factors to attract great concentrations of people to coastal areas. Today, some 80% of the over 100 million population of Japan are so located.

COASTAL RESPONSIBILITY

Of the 31,382 km coastline, it has been calculated that 15,020 km or 47.9% needs protection of some kind (Fig. 2) and that 10% suffers from severe erosion (Fig. 1). This 15,020 km is under the control of three Ministeries although in actuality only 12,327 km has been officially assigned (Fig. 2). A little over half (8,080 km) has some protection at present, i.e., one quarter of the coastline of Japan has been modified to some extent by man.

The three Ministeries that control the protection efforts along the coast of Japan are those of Construction, Agriculture and Forestry, and Transportation (Fig. 3). Each has responsibility for lengthy shores with the longest belonging to the Construction Minestry. Nearly half of the shoreline needing but not yet protected, is under its jurisdiction.

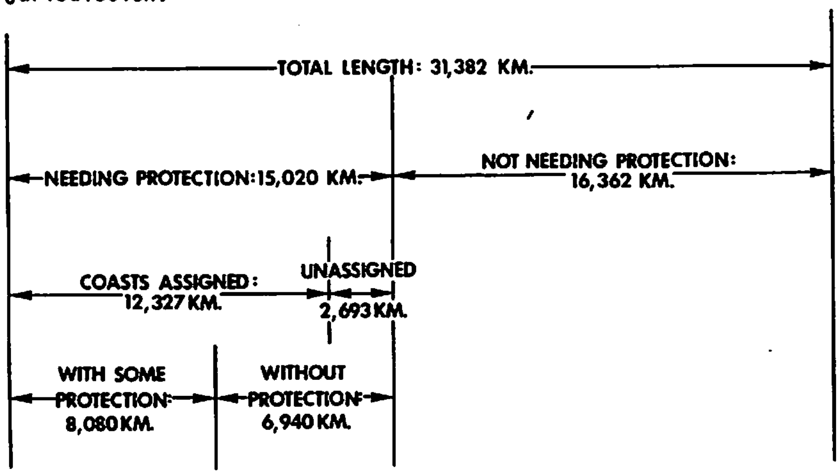

Fig. 2. Coastal protection characteristics.

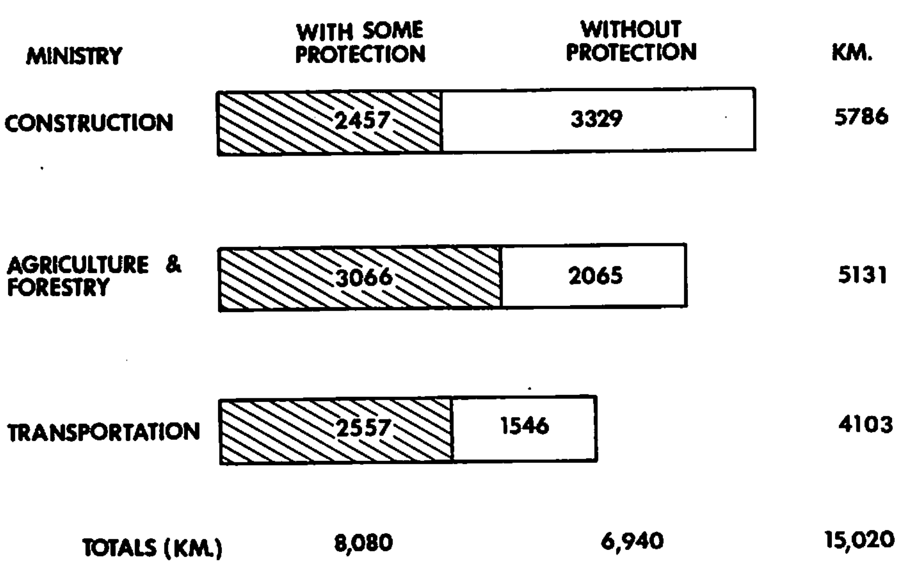

Fig. 3. Ministries and coastal responsibilities.

In recent years the increase in monies for coastal protection has been rapid. In 15 years the amount has increased eight times from 9.1 billion yen in 1961 to 76.1 billion in 1976 (Fig. 4), i.e., a value of about $260 million (National Coastal Association 1976).

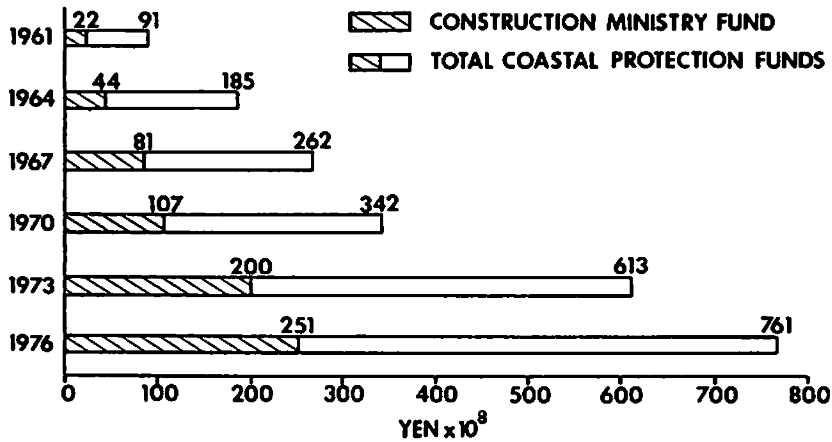

Fig. 4. Government funds allocated for coastal protection.

CLIFFY COASTS

Although cliffy coasts are common in Japan, only recently have they begun to attract scientific attention; an attention that has resulted from the construction of scenic highways and atomic power stations (Sunamura 1973). Indeed, some of the erosion-prone cliffs, especially those adjacent to railroads and highways, are now protected by artificial coverings. Prior to such aesthetic and energy related interest, the severe erosion that occurs along cliff coasts was of little concern. Erosion rates along many cliff coasts range to over 2 m/year with rates depending mainly on rock strength and wave energy. Whereas the beaches along sandy coasts can be restored by artificial nourishment with some success, cliffs, once eroded, are gone and can hardly be returned to their original state.

SUBSIDENCE

Subsidence began to receive serious attention only recently in Japan, just as in the United States. In Japan it had become an important problem before World War II because of the rapid advance of Japan's industry after World War I. Overpumping the ground water and/or natural gas, especially that associated with the industrial areas in Osaka, Tokyo, Nagoya, and Niigata, resulted in much subsidence (Nakano 1970). In all of these cities there are now large areas of land below the "zero-meter line" (as the Japanese refer to their non-marine land presently situated below sea level). The areas involved are sizable; the largest is in Nagoya where over 200 km^2 are below sea level. The rate of expansion of subsided areas has also been rapid; e.g., in Tokyo the zero-meter region increased from 35.2 km^2 in 1960 to 61.5 km^2 by 1970.

Osaka provides an interesting and informative example of change in subsidence rates with changing conditions. One hundred years ago the coastal part of Osaka was used for rice cultivation. Between WWI and WWII much of this area was converted into a massive industrial complex. Ground water was pumped in great quantities and subsidence followed. During WWI, however, the factories were destroyed, ground water consumption decreased, and subsidence ceased. After the war, industrial development was reinitiated, groundwater consumption again increased, and subsidence began anew. This condition continued until the 1960's when laws were enacted restricting groundwater usage resulting in stabilization of the land surface.

Subsidence aggravated disasters in the past in many locations in Japan. A typhoon in 1959 was responsible for heavy flooding in Nagoya, flooding which killed more than 5000 people. Much of this disaster occurred in the zero-meter region. In Niigata, it was a severe earthquake in 1961 that brought about flooding in the subsided area. These two disasters led to the construction of seawalls not only in Nagoya and Niigata but also in Tokyo, Osaka, and other areas where subsidence has been severe.

SEA WALLS

In all coastal areas where subsidence has been severe, lengthy seawalls have been constructed. Indeed, the retaining wall--of which the seawall is a marine version--is one of the most conspicuous and wide spread artificial forms to be seen near water in Japan. Artificial levees, for example, border most rivers whereas seawalls are found along many low-lying coasts. Some seawalls are very old and many display several stages in their development. Heightening and widening seawalls along some coasts appears to be an almost continuous effort. Along some shorelines, especially those where typhoon waves are likely to be accentuated, seawalls are more than 15 m high. At other locations seawalls merge with river mouth retaining walls and at these locations serve the double purpose of preventing encroachment of the sea and controlling river flow.

GROINS AND DETACHED BREAKWATERS

From the standpoint of loss of life and property the retaining wall is undoubtedly the most important of the man-made coastal modifications. Great amounts of money, time, and scientific effort have been expended in attempting to control beach erosion, as well.

Sand removal from coasts is a natural process, and has been since the still-stand of sea level was reached some 5,000$\pm$ years ago. However, it has become aggravated along many coasts of the world because of a variety of human activities--especially those activities related to altering the discharged sediment load of rivers through the construction of dams and river linings. Along the Niigata coast, for example, shoreline sand starvation, because of modifications of the Shinano River, has been so great that the beach has receded more than 300 m during the past 50 years.

The groin has been the structure most commonly used to prevent coastal beach loss and to trap sand formerly lost due to longshore drift. Groins have not always been successful and other methods such as detached breakwaters have recently been introduced.

The experiences at Kaike Beach in southern Honshu is an excellent example of man's effort in Japan to not only stop beach erosion but to re-establish eroded beaches (Toyoshima 1973). Kaike Beach faces the Sea of Japan which is notorious for its rough seas during the winter monsoon season. This beach has long suffered from severe erosion and local peoples, using pine logs and sand bags, were unsuccessful in their attempts to control it. Between 1946 and 1956 groins were constructed along the beach and although the beach was initially reestablished slight changes in wave regimes and unrepaired wave-damaged groins again led to loss of the beach by the early 1960's.

The next attempt at Kaike was the construction of 3 detached breakwaters 150 m offshore. The dissipated wave energy not only reduced the erosive nature of the waves but also brought about the formation of tombolos between the shore and the breakwaters reestablishing the beach.

Additional benefits have accrued from the use of detached breakwaters as exampled at Ishizaki, a fishing village on the south coast of Hokkaido. In 1960-61 seawalls were built at the back of the beach. The sand in front of these seawalls was stripped from the bedrock eliminating the beach. Plans at first called for groin construction but it was decided to use detached breakwaters instead. In all 12 of these structures were built and all served the purpose of re-establishing the beach in the form of tombolos, an additional benefit accrued. Because of the nature of these breakwaters, the sand on the bottom seaward of the structures was transferred to their innersides.

This transfer exposed the rocky sea bed in front of the breakwaters, a surface upon which an important type of seaweed grows well. Because this seaweed is a desirable food item, its presence serves as an additional and now a very important source of income to local fishermen and their village (Toyoshima 1973).

TETRAPODS

Although seawalls are usually solid concrete they sometimes are buttressed by other materials, frequently tetrapods. Tetrapods have been used in Japan for over 20 years. One of the first structures made from them was an offshore breakwater at Niigata. Taking several years to construct, it required nearly 90,000 tetrapods before completion. Most of these tetrapods (being among the first made) weighed only 4 tons. Today they come in many sizes, the largest now being used weigh 50 tons.

One of the most common uses of tetrapods is for breakwaters in connection with harbors as at the ports of Abashari and Rumoi in Hokkaido, and Kuji, Sandai, Fukushima (in connection with a nuclear power plant), and Akita in Honshu. Most structures use a variety of sizes, e.g., the breakwater constructed for the Tokyo Electric Power Co., Ltd. at Fukushima took 5 years (1966-1970) to complete and required 820 - 8 ton, 3,482 - 10 ton, and 5,827 - 25 ton tetrapods.

The tetrapod is patented by the Nippon Tetrapod Co., Ltd., headquartered in Tokyo. It and other companies have developed a variety of forms since WW II. Many coastal sections have several types present and represents either different models used by the same company or models from different companies.

Today, prior to the actual construction of most systems, model tests are conducted. The Nippon Tetrapod Co., for example, has a large, modern, well equipped laboratory near Tsukuba, the new research center for Japan about 60 miles north of Tokyo.

IGLOOS

An additional function of this laboratory is the development of new models for use in shore defense systems. Better coastal defense and lower cost of construction and maintenance are major objectives in this research. An additional reason, and one that is increasing in importance as social attitudes change in Japan, is the increasing demand for an aesthetically pleasing design--the need to decrease visual pollution.

One of the most recent developments is the "Igloo." It is a wave dissipating structure which can serve as a retaining wall and even a wharf (Palmer 1975). The structure is made of a series of concrete components (Fig. 5) which are produced in 6 standard sizes varying in weight from 20 to 40 tons. When the individual components are combined, a wall is formed which is composed of a series of vertically

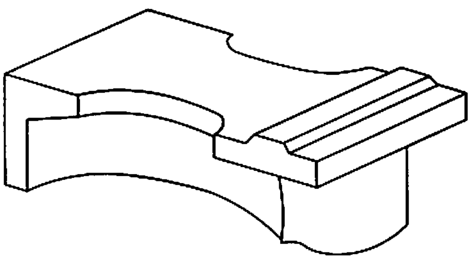

Fig. 5. Perspective drawing of an Igloo component.

interconnected circular chambers. As a wave strikes the vertical front its water is separated into layers by the horizontal plates which join the tiers of the igloos together. Each layer of water is separated by the vertical rounded pillars into water jets. Each jet flow is divided into counter rotating whirlpools within the chamber and with a loss of energy because of friction. The connection between the tiers of igloos permits vertical flow resulting in turbulence and further loss of energy. The water descends through these connections to discharge seaward into the following wave trough.

Construction of this type of wave dissipating wall was begun at 4 different locations in Japan (Fig. 1) during 1975. When completed these 4 walls will be 950 m in combined length. The prospects for the construction of other structures of this type are excellent. The igloo's major asset is the obvious one of energy reduction--however, another benefit is that it meets the recent demand in Japan that man-made structures also "be in harmony with nature and the environment" (Palmer 1976).

ACKNOWLEDGMENT

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REFERENCES

Matsuishi, Hideyuki, 1975. "General view of coastal development in Japan," In The Symposium on Human Environment and Coastal Zone, The International Ocean Development Conference, Tokyo, Japan, pp. 97-116.

Nakano, Takamasa, 1970. "Lands below sea level due to land subsidence in the urban areas of Japan," Japanese Cities: a Geographical Approach, The Association of Japanese Geographers, pp. 237-243.

National Coastal Association, 1976. General Summary of the Coast, in Japanese, 6 pp.

Noh, Toshio and D. H. Gordon, 1974. Modern Japan: Man and Land, Teikoku-Shoin Co. Ltd., Tokyo, Japan, 146 pp.

Palmer, R. Q. 1975. Igloo, Nippon Tetrapod Co. Ltd., Tokyo, Japan, 6 pp.

Palmer, R. Q. 1976. Vertical wave dissipating wall, examples of Igloo application No. 1, Nippon Tetrapod Co. Ltd., Tokyo, Japan, 22 pp.

Sunamura, Tsuguo, 1973. "Coastal Cliff erosion due to waves--field investigations and laboratory experiments," Journal of the Faculty of Engineering, the University of Tokyo, Vol. 32, pp. 1-86.

Takeuchi, Hiroshi, 1975. "Desirable future trends in coastal development," In The Symposium on Human Environment and Coastal Zone, The International Ocean Development Conference, Tokyo, Japan, pp. 73-81.

Toyoshima, Osamu, 1973. The Detached Breakwater System, 16 mm color motion picture, Ministry of Construction, Tokyo, Japan.

PART V

Saturday, November 20, 1976

CURRENT CRITICAL DEVELOPMENTS AND ISSUES OF THE COAST

1. "Problems in the Adoption of New Ideas and Practices," Larry de la Bretonne, Jr.

2. "Information, Criteria, and Guidelines to Improve Coastal Wetland Management," William H. Queen*

3. "Impact of Linear Elements (Roads, Pipelines, Embankments) in Coastal Wetlands," Sherwood M. Gagliano and Associates*

* Paper not available for publication

PROBLEMS IN THE ADOPTION OF NEW IDEAS AND PRACTICES

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Abstract

The Cooperative Extension Service has been described as that branch of the Land Grant University which extends the campus to the borders of the state. Historically, Extension has helped farmers, agribusiness groups, homemakers and youth through structured educational programs in agriculture, home economics, 4-H and community resource development.

A new Marine Advisory Program has been implemented through the Louisiana Sea Grant Program and Extension to reach producers and users of the marine environment, a new audience for Extension.

This paper describes the problems involved in dissemination of information from the researcher to the target audience. Additionally, the adoption practices by various groups in relation to the traditional Extension educational programs and the feedback mechanisms of the programs are discussed.

Almost every group is concerned with educating or influencing somebody. Industry, labor, churches and individuals use communication and education to present their points of view on particular subjects. For more than a century, land-grant institutions, through their Cooperative Extension Service, have had farmers as target audiences to increase farm production. Other highly successful programs have been directed toward homemakers, 4-H youth and adult leaders in communities.

People, although they may have been exposed to a new idea, generally are slow in adopting practices. For instance, at least 35 years have elapsed between the recommendation of correlating fertilization needs with soil tests and adoption of these practices. Even today, adoption is not complete.

The steps in the adoption process, according to Lionberger (1960), are (1) awareness, (2) information, (3) interest, (4) evaluation, (5) trial and (6) adoption. Even though people adopt a practice we have no guarantee they will continue to use it indefinitely. The key to continued use is how the integration of the practice fits into one's total ongoing operation.

Rogers (1958) noted that adoption of specific changes tends to conform to the normal bell shaped curve (Figure 1) and classified adopters as follows:

Innovators, representing 2 percent; early adopters, 13 percent; early majority, 34 percent; late majority, 34 percent; and laggards, 16 percent.

Research on practice adoption in agriculture generally indicates farmers most likely to adopt new practices are young, educated, have more than one agricultural interest or one large operation, are in management positions with supervision over workers and participate in other organizations and community development projects with many people contacts.

The Louisiana Cooperative Extension Service has targeted this early adopter and early majority group through its county agents with offices located in each parish seat (many offices are located in courthouses). The Extension Service reaches the general public at all levels, supplying information on such topics as house plants, gardens, community involvement, agricultural production of all farm commodities, marketing outlooks and homemaking tips. In addition, 4-H programs for youth aged 9 to 19 single out the Extension Service as an information source. Each generation builds an audience Extension can reach, and because of the local contact with parish residents and a reputation of giving people practical answers to their problems, the adoption of new ideas and practices becomes easier.

In a way, fishing may be termed a farming enterprise with harvesting equipment in a common pasture, the sea. A Marine Cooperative Extension Program was instituted in 1973, through funding from the Louisiana Sea Grant Program. Marine extension agents were to work within the existing framework of the Extension Service at the grass roots level in each coastal parish. Specialists located on the LSU campus would act as an information source between research and field agents. In 1973, one marine agent was hired for Lafourche Parish and eastern Terrebonne Parish.

The program was well received because Extension in general and county agents in coastal parishes in particular have wanted to provide educational assistance to fishermen in their parishes, but had no resource base to use in information dissemination.

In 1975, a marine biologist was added to the state staff and an additional field agent was assigned to St. Mary Parish and western

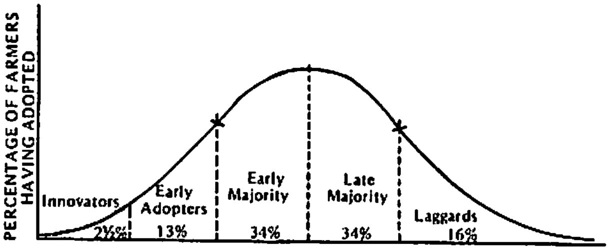

Figure 1. Adopter categorization on the basis of adoption frequency distribution (Rogers and Beal, 1958).

Terrebonne Parish. A seafood technologist was added to the program in 1976, and last month funds were secured from the Louisiana Legislature to implement the total program--four additional agents to serve across all of Louisiana's coastal parishes. Hopefully, by January 1977, the entire program will be functional with six marine extension agents, each of them serving two parishes along the coast and two marine specialists at the Extension state office on the Baton Rouge campus.

How do you initiate a program for fishermen? A first step is to identify the audience. The Extension Service has designed programs over the years for the farmer, but our audience is special. In some other areas of the country, fishermen are able to read research reports and adopt recommendations immediately without the aid of a "digester" to put the report in common language. In addition, other marine extension programs can plunge into such programs as tax seminars in which fishermen flood meeting halls with all their receipts and fill out tax returns with a minimum of effort.

In Louisiana, we knew we faced a different type fisherman, and a survey (Pesson, 1974) was conducted by French-speaking Extension personnel to profile our audience. Five hundred fishermen were interviewed. The results are shown in Table 1.

A summary of the findings show that coastal fishermen tend to be middle-aged, have a low level of education and live in a rural area. They have been fishing for a good while, the fishing business is self-owned and it is either a one-man operation or one crewman is employed. Self-reliance is a watchword, exemplified by the fact that many owe nothing on their boats, carry no insurance, mistrust cooperatives and do not name leaders among the fishermen.

Table 1. Results of 500 fishermen interviewed on various industry subjects.

SUBJECT	PERCENT	RESULT
Age	61 - over 40 39 - under 40	Middle aged
Education	52 - below 7th grade 27 - high school degree	Low level of education
Residence	61 - rural 39 - urban	Rural resident
Experience	47 - over 20 years 26 - 11 to 20 years 27 - 1 to 10 years	Many years in business
Ownership	88 - owners 9 - part owners 3 - managers	Owners of own business
Use of Navigational Equipment	35 - none 33 - charts 58 - compass 7 - radar 5 - loran	Use little navigational equipment
Insurance on Boat	65 - had none 35 - had insurance	Don't have insurance
Knowledge of Sea Grant	69 - none 27 - knew of 4 - unsure	No knowledge
General Opinion of Sea Grant	84 - undecided 15 - favored 1 - unfavorable	Undecided
Idea of Fisheries	40 - very much 12 - much 29 - some 19 - little or none	Liked idea
Cooperatives	43 - against 26 - yes 31 - undecided	Against

Table 1. - continued

SUBJECT	PERCENT	RESULT
Underwater Obstructions Problem	72 - yes 25 - no 3 - undecided	A problem
Knows County Agent	42 - yes 6 - undecided 52 - no	About half
Who County Agent Represents	70 - did not know 30 - knew	Do not know
Leadership	47 - no response 32 - area fishermen 12 - industry dealers 9 - professional	Don't know who to look to
Membership in Community Organizations	82 - 0 to 1 club 12 - 2 clubs 6 - 3 clubs or more	Low level
Use of New Ideas	89 - do not use 11 - try	Do not use
Aware of New Ideas Tried by Others	88 - not aware 12 - were aware	Not aware
Number of Crewmen on Boat	59 - none 23 - one 14 - two 4 - more than 2	Work alone
Feel Shrimp Crop Decreasing	46 - decreasing 39 - about same 10 - increasing 5 - no opinion	Mixed opinion

Most fishermen had not heard of the Sea Grant program and, consequently, were not able to express attitudes clearly toward it. They tended to feel that an extension agent in fisheries could be useful, but they were not necessarily clear about what he could do for them. Quite a few had contact with Extension Service, more often than not through their children as 4-H Club members, and knew of the county agent. The few new ideas which had been adopted were very diverse, and indicated that no concerted efforts had been made to introduce new ideas among the fishermen. Adoption behavior was normal, a "trickle-down process" (Rogers, 1971), with a few innovators, then early adopters, etc.

So the typical coastal fisherman, in many ways, seems much like the farmer of a generation or two ago: an older man, individualistic and self-reliant, in business for a long time, somewhat behind the larger society in education, with little trust in anyone. I hope you appreciate the substantial problems of reaching such an audience!

Hopefully, by slightly altering the traditional educational programs used in Extension, we can produce a positive program forcefully led, but locally acceptable. For instance, area agents have already established advisory committees in the three parishes in which agents are presently employed. The advisory committee, composed of representatives from all segments of the fishing industry, meets to discuss problems in its area, and how to solve or seek relief from those problems. A crabber at the close of a meeting said, "I can't believe that although we have our own problems, there are so many problems common to all of us."

We hope that through this grass roots organization of people-to-people communication at the user level, information will flow in an orderly two way fashion--from the researcher to the user with feedback from the user to the researcher.

An important question at this point is how the organization will function in relation to other agencies and programs in Louisiana. Other agencies, for instance, the National Marine Fisheries Service and the Louisiana Wild Life and Fisheries Commission, have primary responsibilities for research, establishing management guidelines, setting seasons and enforcement. Commission biologists have answered questions from the general public as an added service and, in many cases, on their own time. This marine extension program is not in competition with research programs, but complements them and uses the research results. We have had questions about why Louisiana Wild Life and Fisheries Commission biologists drag plankton nets to sample shrimp post-larvae. Shrimpers, although they had been trawling for more than 20 years, did not know shrimp spawn offshore, but reasoned they "had their babies" in the marsh because this is where they caught the migrating sub-adult shrimp.

Because of this problem, we initiated a 45 minute program to explain the life history of shrimp and review ongoing shrimp research. Over 3,000 coastal fishermen and high school students have viewed this presentation.

Every day, calls for information on specific subjects occupy much of the marine agents' schedules. Where do I get information on frog culture? What's the situation in Chesapeake Bay area on crab production? Where can I buy crawfish? What are the fishing regulations in Calcasieu Lake? What is the best type of trawl to use? How can I economically convert from Loran-A to Loran-C? How good is electro-trawling for shrimp? What can my seafood plant do to comply with EPA discharge requirements? Questions such as these are part of the everyday routine of the agent.

We will occupy our own niche, hopefully complementing and working with federal, state, and university personnel to disseminate information to user groups within the successfully existing framework of the Cooperative Extension Service.

The idea behind the program is summed up in an ancient Chinese proverb:

"If you give a man a fish,
he will have a single meal.
If you teach a man how to fish,
he will eat all his life."

Literature Cited

Lionberger, H. F. 1960. Adoption of new ideas and practices. Iowa State University Press, Ames, Iowa. 164 pp.

Pesson, L. L. 1974. The coastal fishermen of Louisiana: their characteristics, attitudes, practices and responsiveness to change. Louisiana Cooperative Extension Service, Baton Rouge, Louisiana. 60 pp.

Rogers, E. M. 1958. Categorizing the adopters of agricultural practices. Rural Sociology 23 (Dec): 345-354.

Rogers, E. M. and A. M. Beal. 1958. Reference group influence in the adoption of agricultural technology. Iowa State University Press, Ames, Iowa. P. 33.

Rogers, E. M. and Floyd Shoemaker. 1971. Communications of innovations: a cross-cultural approach. The Free Press, New York.

INFORMATION, CRITERIA, AND GUIDELINES TO IMPROVE COASTAL WETLAND MANAGEMENT

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Abstract

Among the major needs of regulatory agencies with responsibilities for coastal wetland management are: 1) information on the location, quantity and relative value of the various wetland resources, 2) techniques for evaluating the impact of alteration activity (dredging, spoil disposal, bulkheading, etc.) on these resources, and 3) a methodology for assessing development (alteration) activity within a coastal environmental system (e.g. Chesapeake Bay). With funds provided by the Research Applied to National Needs Program of the National Science Foundation, the Chesapeake Research Consortium has undertaken a multi-year study of the development activity problem in the Chesapeake Bay shore zone. (The Consortium is an incorporated association of the University of Maryland, the Johns Hopkins University, the Smithsonian Institution, and the Virginia Institute of Marine Sciences.) Sub-projects of this effort include: 1) use of Corps of Engineer permits to map patterns, trends and rates of development activity, and to identify key development issues, 2) development of a granted permit data bank that can be employed to monitor development activity in the bay, and 3) preparation of shoreline situation reports that contain baseline information on land use, morphological type, and erosion of the bay's shore zone. Both methodology and results of these three sub-projects will be reviewed.

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Paper not available for publication

ENVIRONMENTAL IMPLICATIONS OF MAN-MADE LINEAR ELEMENTS IN COASTAL WETLANDS

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Abstract

The impact assessment and environmental planning processes in coastal wetlands areas usually include consideration of man-made linear features such as railroads, highways, canals, levees, and utility lines. Such elements may segment ecological units, become barriers to natural movements of plants and animals, alter hydrologic regime, alter water quality, change land use, change aesthetic values, and become permanent landscape boundaries. Over the years planners and developers have evolved strategies for using such features to accelerate and enhance development. Likewise, in recent years environmental scientists and planners have devised strategies for minimizing detrimental environmental impacts of linear elements and for using them effectively in the geometry of multiuse management schemes. Conflicts often arise between the objectives of the former group and the latter group. Recognizing these different strategies and objectives aids in impact analysis and becomes an important tool in multi-use planning of coastal wetlands and other environmentally sensitive areas. Case studies will be considered to illustrate various impacts and strategies.

Paper not avaliable for publication