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PRIORITY PROBLEMS and DATA NEEDS in COASTAL ZONE OCEANOGRAPHY

Earth Observation Satellite Planning

by

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and

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ABSTRACT

Coastal zone oceanographic problems and data needs have been defined for an oceanographic satellite. Problems are based on national and coastal zone priorities. Descriptions of the problems discuss the data needs and the expected utility of remote measurement. Data needs and resolution requirements are specified for surface and satellite measurement. Remote measurables are numerically ranked and evaluated. Coordination of the ERTS program with IDOE is discussed.

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The findings, recommendations, and opinions in this report are those of the authors. Distribution does not imply concurrence by NASA.

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CONCLUSIONS

I National environmental priorities in order are

1) air/water/soil quality and environmental balance
2) natural resources
3) extreme events
4) other aids to commerce and economic activity

II Coastal zone oceanographic priorities are

1) water pollution;
   estuarine and coastal ecosystems
2) fishery resources
3) water and mineral resources
4) extreme events
5) other aids to shipping and navigation

III Remote measurables in order of priority are

1) water surface temperature
2) water color
3) salinity
4) coastland vegetation and land use
5) others

Current and circulation data can be derived via several of the remote measurables.

RECOMMENDATIONS

I Coastal zone oceanography should be emphasized in the selection of experiments for an oceanographic satellite.

II Satellites for oceanography should be designed to remotely measure water surface temperature, water color, salinity, and coastland vegetation/land use.

Other remote measurables of importance are oil slicks, bathymetry, tides, shorelines and shore topography, sea state, sea level, and ice.

Current and circulation data can be derived via several of the remote measurables.

III The utility of a satellite-interrogation-buoy system for coastal zone oceanography should be investigated.

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SECTION I

INTRODUCTION

The National Aeronautics and Space Administration (NASA) Langley Research Center is participating in the early planning for Earth Observation Satellites (EOS), which will be designed for meteorology and oceanography. The Virginia Institute of Marine Science (VIMS) has assisted NASA Langley by performing this study of coastal zone oceanographic needs and data requirements. The study was conducted from the point of view of pressing national priorities in the coastal zone. It involved examination of oceanographic needs in coastal zone management and research, and definition of data requirements in the corresponding research, survey, and monitoring activities.

At national, state and local levels there is increasing awareness of the need for improved planning and management of the diminishing resources of the coastal zone. Emphasis on the coastal zone derives from the recent realization that most of the huge and growing population on "Spaceship Earth" is concentrating on the perimeter of the seas, with the result that coastal resources and environments are deteriorating. Special impetus has developed through studies of the Commission on Marine Science, Engineering and Resources (see Our Nation and the Sea, 1969), the National Council on Marine Resources and Engineering Development (see Marine Science Affairs, 1967-70), and several other studies sponsored by the federal government relating to estuarine and coastal waters and their resources. All conclude that the nation

has a high priority need for growth and development in coastal zone oceanographic research and management activity.

The achievement of this goal requires improvements on several levels of activity: a) new and improved organizational arrangements and management procedures, such as the recent establishment of a National Oceanic and Atmospheric Agency (NOAA); b) sufficient increase in research and engineering facilities to provide the necessary data analysis and advice; and c) substantial improvements in data-gathering methodology.

It is now widely recognized that satellite technology offers great potential for improving data-gathering methodology. Several studies have indicated the possible contributions of satellite-generated data to oceanographic research, planning, and management. We have examined the possibilities more carefully, first identifying coastal zone problems and needs in the light of national priorities, and then specifying data requirements within these problems and needs. On the basis of this study, it is possible for NASA Langley to begin feasibility studies and plan engineering and instrumentation for the EOS series.

Satellite systems for environmental monitoring may be viewed in a systems analysis context as in Figure 1 (for comparison, see Summers, 1969; Muir, 1970). The block diagram in Figure 1 illustrates both design and use of the satellite system. The design phase involves consideration of the items in boxes A through H, while use of the system involves activities in boxes I through N. These latter boxes constitute the satellite component of an environmental "nation-regulator" discussed in Section III.A.2.

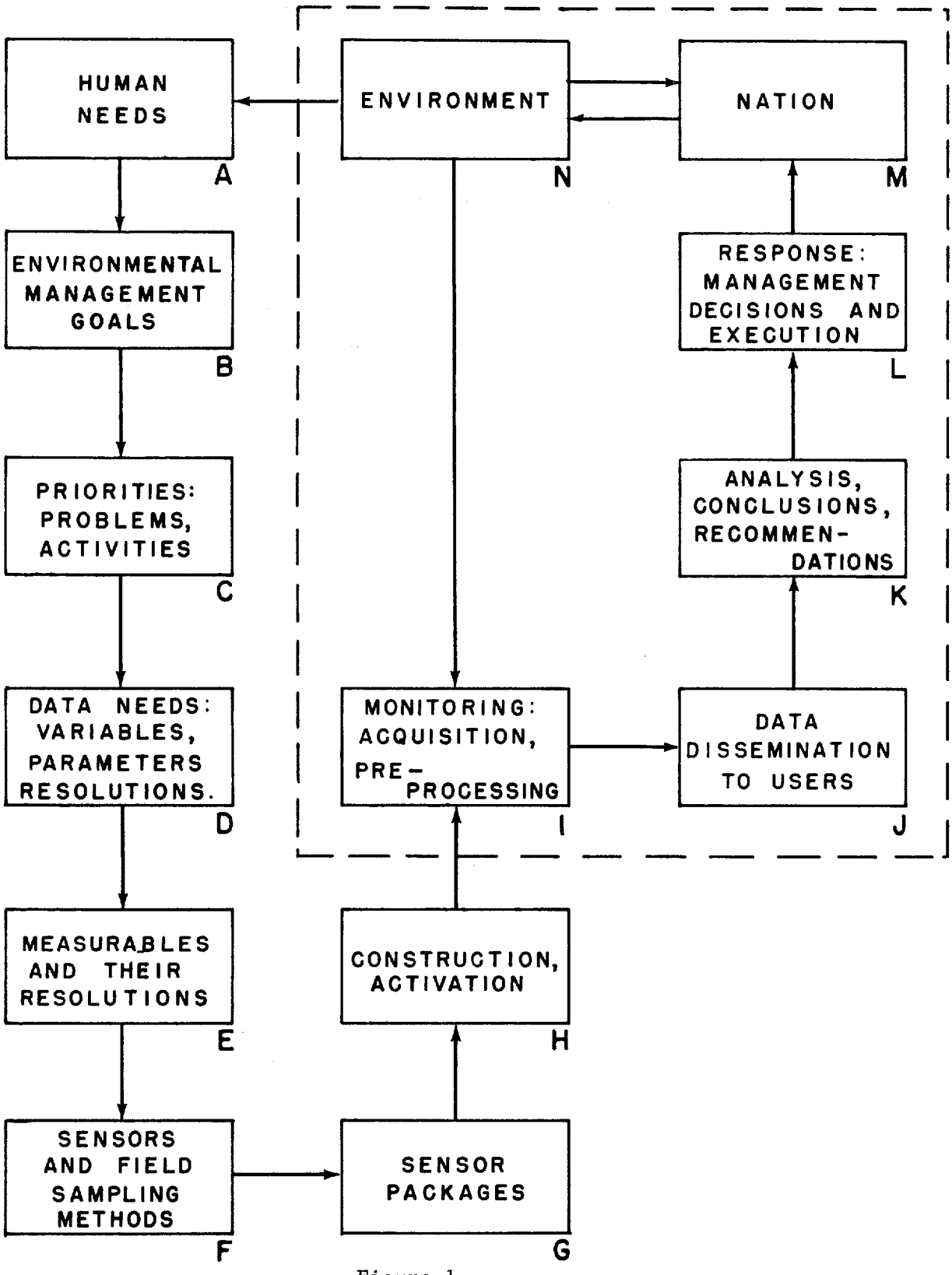

Figure 1

Design and use of satellite systems for environmental management. Design involves boxes A through H; use involves boxes I through N (enclosed by a dotted line), which constitute the environmental component of a "nation-regulator" discussed in Section III.A.1. and 2.

Occasional recourse to A through H is necessary to update the system.

Our study is concentrated on the satellite aspects of A through E, from human needs through coastal zone oceanographic remote measurables.[1] In Section III, we treat human needs (III.A.1), and management goals and priorities (III.A.2. through III.C.). In Sections IV, V, and VI, we treat coastal zone oceanographic problems, data needs, and measurables. Ways of coordinating the ERTS and EOS series with the International Decade of Ocean Exploration (IDOE) are discussed in Section VII.

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[1] "Remote measurable" replaces "remotely measurable variable" for brevity throughout the report.

SECTION II

COASTAL ZONE OCEANOGRAPHY

Coastal Zone Oceanography Distinguished From Deep Ocean Oceanography

The division of oceanography into coastal zone and deep ocean parts can be useful for a variety of purposes, including design of national and international law, management of natural resources, and organization of oceanographic research and engineering. Our definition of the coastal zone will be broad to avoid needless restrictions on the design of oceanographic satellites; however, it is recognized that precision might be necessary in other situations.

The coastal zone consists generally of land and waters extending inland to the limit of tidal action, and seaward to the junction of the continental shelf and slope. The coastal zone encompasses coastal plains, shoreline, bays, estuaries, inland seas such as the Great Lakes, and the continental shelf. Since the quality of coastal zone waters often depends on activity or processes in adjacent highlands, the coastal zone under some circumstances may be extended to these highlands. Where there is no continental shelf, it is necessary to specify a different seaward limit; this limit could be the seaward extent of river and bay discharges or any other land-derived influence. In addition, it is well to include in the coastal zone any industrial, commercial, or urban areas principally dependent on the seas or the large lakes. With these inclusions, the coastal zone becomes in a broad

sense the areas in which land masses and large water masses have a substantial interaction.[2]

Coastal zone oceanography is the biology, chemistry, engineering, geology, and physics of coastal zone waters, and their interrelations with other features of the environment.

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[2] For comparison, see the discussion of the coastal zone with tabulated statistics in Commission on Marine Science, Engineering and Resources, Science and Environment, Vol. 1, 1969, pp. III-7 to III-10.

SECTION III

NATIONAL PRIORITIES

A. National Priorities and the Role of Satellites

1. Overview

In the United States, widespread concern about national priorities is very recent, and has crystallized in response to developments in the last five years. The lack of concern in the past can be traced to the fact that during the first century of existence, our nation had abundant and unexploited natural resources, and could afford what Boulding has termed a "cowboy" philosophy with the economic ideology of laissez-faire. The public has only slowly realized that we all share a closed "spaceship" environment. This realization began to develop after the settlement of the continent was completed; it developed further because of the Great Depression and two World Wars; and to a large degree it culminated in the flights of Apollo to the moon.

Long ago, however, our nation recognized the material and cultural human needs -- food, shelter, good health, companionship, work and recreation, and underlying all, a harmony in the physical, mental, and spiritual aspects of life. Our nation, in particular, saw these needs in the light of individual liberty. In this context, it was stated ten years ago (Commission on National Goals, 1960) that "The paramount goal of the United States was set long ago. It is to guard the rights of the individual, to ensure his development, and to enhance his opportunity".

In a geographically large and populous nation, this goal requires benevolent leadership, social stability, defensive security, sufficient national resources, a moderate and predictable environment, well-developed science and technology (manifested in medical science, agriculture, manufacturing, transportation, and communications), and a healthy economy.

To these features should now be added the critical need of regulatory feedback. In cybernetic terms (see Ashby, 1956), our nation is a large dynamic system moving from "state" to "state", where each "state" consists of values of essential variables (such as per capita food production, or disease rate). Till now the states visited have constituted a set we may call "stable" or "desirable", but there is clear danger ahead. Major disturbances are threatening which may drive the system unstable. To maintain stability, a regulating mechanism is required. It must have two components: monitoring of disturbances and of essential system variables, and implementation of appropriately selected responses. Monitoring is thus a critical link in the regulatory process.

We lack adequate regulation against major physical disturbances which are threatening in the next 30 years. They are easily identified: nuclear war, famine, environmental and ecological imbalance, pollution, and over-population (Platt, 1969). Regulation against these threats will require a variety of mechanisms, each including monitoring and implementation components.

2. Environmental Monitoring and Survey with Satellites

Within the past ten years, a new monitoring technology has been made available, that of satellite remote sensing systems. The enormous potential of this technology derives from the convergence of four major technical and scientific advances (ESSA, 1968): First, a stupendous capability has been developed for orbiting manned and unmanned space platforms; second, the technology of remote sensing has undergone explosive development; third, computer technology has doubled and redoubled; and fourth, complex mathematical modeling has advanced to become a major analytical tool.

The interest in satellite remote sensing lies principally in its capability for wide-area environmental monitoring. Data on all but the smaller environmental features can be collected, including moderately-sized evidence of human activity. Data collection is rapid, uniform, and centralized. As a result, automatic data processing techniques can be applied to the data directly and quickly. Establishment of data receiving and handling centers is lagging the instrument technology, but planning for centers is underway. It is envisioned that data from satellites will eventually play a major monitoring role in all aspects of environmental science and management.

The monitoring in a "nation-regulator" must deal with both environmental data and other data not amenable to remote sensing (consider medical statistics, industrial production indices, and measures of educational quality). Therefore, establishing the desirability of a satellite system depends first on the relative

importance of environmental data, and secondarily on a cost/benefit analysis of the use of satellites for the environmental data.

We have not tried to quantify the importance of acquiring environmental data per se, in comparison to other national activities. Such analysis would take us too far afield. Nevertheless, we consider the importance of environmental data to be established beyond question. In terms of national priorities, environmental management and research rank at the top. Environmental balance and natural resources, the pre-requisites to human life, must be assured.

Moreover, natural resources are not static. Our resources as a whole include natural resources and also the knowledge and technology by which we utilize them. In response to new knowledge and new wants, our concept of natural resources is constantly changing (Zimmerman, 1951). As new knowledge is acquired, more and more of the natural environment becomes either natural resources or otherwise essential variables.

The consequence has been a continuing rise in concern about the environment. Projecting toward the future, we are certain that the need for environmental data will continue to grow, therefore, so will the need for earth monitoring and observation. It is especially important that because earth satellites will be a fresh source of new knowledge, they will constitute a positive feedback loop for insuring an increase in environmental concern. This insurance is very desirable.

3. High Priority Environmental Problems

Earth resources satellites have a potential application to three environmental priorities of pressing importance. In order of priority, they are:

a) air/water/soil quality and environmental balance,

b) natural resources (such as fish, crops, water and petroleum), and

c) extreme events (severe storms, earthquakes).

A fourth environmental category of almost equal importance is:

d) environmental data (other than the above) useful to commerce and economic activity.

4. Air/Water/Soil Quality and Environmental Balance

We are of one world. Man is integral with life, not separate. We share with other life the terrestrial biosphere.

These truths have all but been ignored.[3] The consequences, long ago obvious to some, are becoming painful. The tide is at the flood to propose a broad and highest level priority in environmental affairs: preservation of the earth as a nourishing habitat for life.

Air, water, and soil support the very activity of life itself. In a great cycle, air, water, and soil are then replenished and refreshed by life. Deterioration anywhere in the cycle causes small but measurable changes to reverberate throughout.

Although the components of the environment are often regarded in piecemeal fashion as only natural resources, they are

---

[3] In our culture.

emphasized here because of their importance in total environmental balance.

It has become of wide concern that the entire biosphere may be sufficiently upset by human activity that it will change markedly and suddenly (with respect to the human lifespan). In some quarters, there is concern that pollution may trigger irrevocable and fatal changes in the system.

In addition, pollution is a direct menace to human health. Indications that we are poisoning ourselves are legion (e.g. see Bové and Siebenberg, 1970; Hodgson, 1970; Air/Water Pollution Report, 1970; Lave and Seskin, 1970).

Wide-area monitoring of air/water/soil quality is in great need. Satellites offer the potential for rapid mapping, delineating large-scale effects, and discovering unknown correlations, such as between air/water quality and weather.

5. Natural Resources

Natural resources affect all of the national and basic human needs directly or indirectly. First we have direct need of food and shelter. Second, basic industry, the cornerstone of our industrial economy, depends on natural resources. Until the present time, plundering of resources could supply these needs. Now, in a world increasingly sensitive to long-term human needs and everywhere burdened by rapid population growth and rising expectations of living standards (and plummeting prospects, according to Ehrlich and Ehrlich, 1970), conservation and recycling of resources is an absolute necessity.

Two categories of natural resources are recognized: the renewable and the nonrenewable (Dasmann, 1968). Renewable resources are the biota of direct use to man, plus closely related soils and water. Note that "renewable" is a catch-all description since fast and slow growing biota are lumped together; it is important to recognize that replenishment of some "renewable" resources requires hundreds of years. We must also recognize that renewable resources constitute just a small part of the intricately-connected world-wide biotic system, which involves food webs, nutrient cycles, and geophysical relationships. Our modification of seemingly minor and local features of the biosphere may have far-reaching effects.

Nonrenewable resources include most minerals, fuels, and other geologic materials. Some are actually irreplaceable because they are destroyed by use, such as natural gas consumed in combustion. Others are dispersed by use, making re-use uneconomical.

Finally, special mention is given to water as a natural resource. Adequate water is essential to any industrial nation. Water supplies are required for urban residential use, industrial cooling, waste disposal, electric power generation, and irrigation (Dasmann, 1968). In the United States, the fresh water supply is about 1000 billion gallons daily. About half the supply is now "used", in one manner or another. Better regulation and new

technology must be pursued vigorously, or the demand will exceed supply within 30 years (Select Committee, 1961).[4]

6. Extreme Events

In the category of extreme events are included hurricanes, storms, forest fires, tornadoes, floods, earthquakes, tsunamis, and volcanic eruptions. These events cause enormous casualties, economic disruption, and extensive property destruction. They happen suddenly and with little warning.

In the five years 1965 through 1969, earthquakes worldwide killed 20,000 and caused property damage of $0.25 billion. Floods drowned 3,000 and caused property damage of $0.14 billion. Tropical storms killed 25,000 and left 7 million homeless. In the same period, in the United States, tornadoes killed 456, hurricanes killed 450, and hurricane damage was $0.35 billion annually. This five year period is typical. (These figures were collated from ESSA, 1969, and Kurtz, 1970).

If we consider the worst natural disasters of recent years, the impact of extreme events is even greater: the 1964 Alaska earthquake (roughly $.5 billion), the 1970 Peru earthquake (50,000 dead), and the 1970 East Pakistan typhoon (perhaps 500,000 dead). It is obvious why monitoring, assessment, and prediction of extreme events have long been of concern.

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[4] There is occasionally comment in the literature that such statements are unduly alarmist, and fail to grasp reality. Our opinion, after sober assessment, is to the contrary; in water supply and other aspects, an environmental crisis is well into development. To undo it will demand far more than present antipollution efforts.

The present monitoring and assessment methods are in need of improvement, since they do not allow rapid assessment nor synoptic wide-area measurement. Earth resources satellites clearly have the potential to dramatically upgrade the monitoring and assessment capability for extreme events.

Satellites could also assist in development of prediction capabilities for extreme events. Scientific understanding of extreme events is gradually, albeit slowly, increasing. It is foreseeable that prediction of earthquakes will become a reality within the next 25 years; many groups are actively seeking this capability (see Pakiser et al., 1969). Earth resources satellites can provide data which will be useful in such efforts.

Note particularly that extreme events are concentrated in the coastal zone. Volcanoes around the Pacific Ocean are so coastally concentrated that we have the phrase "ring of fire".

7. Other Aids to Commerce and Economic Activity

Some components of commerce and economic activity which can be aided by satellite data are not included in the above categories and are placed in a catch-all category of their own. Two components will be mentioned.

The first is measurement of economic activity. The measurement has always been difficult because of the necessity of assimilating vast amounts of data from individual sources. In the face of such problems, urban planners and economists have in the past chosen and measured a few indicators of these activities. In ecology, a similar practice is to look for "indicator organisms" in order to assess changes in the systems under study. The unique

potential of earth resources satellites is to allow new indicators to be chosen, and to be measured rapidly and uniformly. Of special importance are the accelerating changes in urban areas and in land use patterns resulting from population growth.

The second is the use of environmental data as routine aids to commerce and economic activity. Weather data and shoreline, bathymetric and sea state data are especially important to the maritime industry.

The importance of routine aids should not be overlooked. For example, shoals are a continuing hazard to the shipping industry. In 1962, 68 ships totaling 280,732 gross tons were completely lost to stranding. An additional 925 ships suffered partial losses by running aground. By 1975, potential worldwide losses of this type may be $.5 billion annually (IOC, 1964).

B. Importance of the Coastal Zone

1. Demography

People in the United States are concentrated in coastal areas. Eighty percent of the population lives in coastal states (NCMRED, 1970) and forty-five percent lives in coastal counties (CMSER, 1969a). Fourteen of the twenty-three cities of more than 500,000 people (i.e., roughly two-thirds of our largest cities) are within 30 miles of the coast (Kurtz, 1970). Concentration in coastal areas is not a new phenomenon, having been in progress for one hundred years, but it is now accelerating. Seven of the ten fastest growing urban areas are coastal (Kurtz, 1970), and the coastal population as a whole is growing twice as fast as the total U. S. population.

Thus, demography alone demands that we concentrate our attention on the coastal zone.

2. Unique Uses of the Coastal Zone

There are a multitude of uses of the coastal zone which are unique, i.e., offered by no other region (see NCMRED, 1968; Battelle Memorial Institute, 1966; Economic Associates, 1968).

a. Recreation and outdoor enjoyment

Abundant beaches, surf, shoreline parks, and fishing and boating are attractions to the recreation-oriented public. These attractions have resulted in intense competition for shoreline property and extremely high property values.

b. Defense and National Security

The junction of land and large water bodies forms a natural boundary for military defense.

c. Natural Resources

Fish and shellfish in large quantity are found mainly in coastal waters. Offshore petroleum, gas, and mineral deposits are of increasing importance. More than 1400 offshore oil wells will be drilled this year. Coastal water supplies in 1965 accounted for 20 percent of the total industrial use (CMSER, 1969).

d. Commerce

Our dependence on imports of various raw materials requires coastal shipping facilities. Water transportation is economically competitive. In 1965, coastal ports handled 78 percent of all United States foreign trade (FWPCA, 1969). In terms of waste disposal capacity, coastal waters must be considered an essential and unique resource.

3. Conflicts in Coastal Zone Uses

The multitude of unique uses of the coastal zone explains the coastal concentration of our population. Industries and cities will continue to congregate in the coastal zone to take advantage of these uses. Unfortunately, exploitation of some uses of the zone is destroying its potential for other uses.

Some activities will cause irreversible changes. Some uses may be completely incompatible. Finally, some uses, although compatible, may be ruinously competitive (Teeters, 1968).

Irreversible changes are bound to follow from the use of nondegradable pesticides, from the elimination of protective sand dunes and barrier islands, and from the filling and dredging of productive wetlands and marshes.

Hard choices must be made among incompatible and competitive uses. Increases in recreation, industry, waste disposal, and water supply needs must be carefully managed if we wish to maintain existing commercial fisheries.

In this situation, regulation and management of the coastal zone are obviously required. The diverse uses of the coastal zone must be maintained.

C. Environmental Priorities in the Coastal Zone

Three facts discussed above require that high priority be assigned to obtaining environmental data in the coastal zone:

1) the high-ranking national need for environmental data,
2) the national importance of the coastal zone, and
3) the fact that this importance derives specifically from the unique environmental features of the zone.

Into the priority-categories of environmental data presented in Section III.A., coastal zone data may be sorted. The result is an organized list of coastal zone environmental priorities (Table 1). High priority subdivisions are indicated by an asterisk.

Table 1 may be compared with lists of goals and programs developed by other study groups in recent years (see the Appendix for a review and comparison). These groups have not limited themselves to the coastal zone, nor to environmental data, but have considered both in the context of national priorities for marine affairs and oceanography as a whole.

These other studies share with this one the view that the nation has a high priority need for coastal zone environmental data.

Beyond this basic similarity, there are important differences. We highlight environmental and ecosystem balance. Other studies miss the unitary nature of environmental balance and emphasize only some of its parts such as pollution. We also attach special importance to extreme events, both prediction and assessment of effects. In other studies, extreme events are included in environmental prediction, and assessment is omitted.

TABLE 1

NATIONAL PRIORITIES FOR ENVIRONMENTAL DATA IN THE COASTAL ZONE

1)	<u>Air/Water/Soil Quality and Environmental Balance</u>	
	A) *Water Pollution:	toxic wastes, biocides, heavy metals, sewage, nutrients, oxygen-demanding wastes, radioactivity, oil, suspended sediment, thermal effluents.
	B) *Estuarine and Coastal Ecosystems:	primary producers, hydrography, chemical cycles, mathematical models.
	C) *Air Pollution:	------
	D) *Soil Conservation:	------
2)	<u>Natural Resources</u>	
	A) *Food:	fish, shellfish, coastal agriculture.
	B) *Water Supply:	municipal use, industrial cooling, waste disposal, irrigation, electric power.
	C) *Minerals:	oil, gas, sulfur, sand, gravel, dissolved minerals.
	D) Facilities for Recreation:	fishing, boating, swimming.
3)	<u>Extreme Events: Prediction, Warning, Survey, Assessment</u>	
	A) *Coastal storms, hurricanes, typhoons, floods, earthquakes, tsunamis, volcanic eruptions:	weather, sea state, surge, tides, littoral response, faults, land use changes, damage assessment.

* High priority subdivisions

TABLE 1 (Cont'd)

4) Other Environmental Aids to Commerce and Economic Activity

A)	*Shipping and Navigation:	shorelines, shoals, weather, sea state, currents, ice thickness and distribution.
B)	Ports, Facilities:	sand transport, sedimentology, channels.
C)	Urban Change:	land use patterns.

SECTION IV

PRIORITY PROBLEMS IN COASTAL ZONE OCEANOGRAPHY

The field of coastal zone oceanography encompasses nearly all of the items in Table 1. The broad interests of coastal zone oceanography derive from an emphasis on basic and applied research and engineering, and increasingly on environmental management. With this emphasis, it is timely to evaluate the potential of satellites for coastal zone oceanography, because the primary national benefit of earth resources satellites will be in environmental management.

Satellite systems cannot themselves obtain remote sensing data from sub-layers of the ocean. The three-dimensional structure of the ocean's parameters will have to be probed directly, by ships, submersibles, or buoys, with remote sensing data of the ocean surface serving as boundary values in volume forecasting and mapping. Inasmuch as oceanographic data from satellites will initially require careful calibration, it is wise to concentrate satellite surveys where surface studies are concentrated. Coastal zones, compared to the deep ocean, are the site of most oceanographic investigation; future needs demand that this emphasis continue. Under these conditions, we feel that oceanographic satellites should focus on coastal zone oceanography.

To ensure the maximum benefit from an oceanographic satellite, priorities for coastal zone oceanography have been selected from Table 1, and listed in Table 2. In the course of selection, some items have been re-expressed to emphasize the

TABLE 2

COASTAL ZONE OCEANOGRAPHIC

PRIORITIES FOR ENVIRONMENTAL DATA

	Rank*
1) Water Pollution and Ecosystem Balance	
A) Water Pollution	
toxic wastes, biocides and heavy metals	9
sewage, nutrients, oxygen-demanding wastes	9
radioactivity	9
oil	9
suspended sediment	8
thermal effluent	9
B) Estuarine and Coastal Ecosystems	
producers: wetlands, etc	9
phytoplankton	9
coastal vegetation	9
hydrography: dissolved oxygen	9
salinity	9
temperature (see above)	
currents, circulation	9
chemical cycles	8
mathematical models	9
2) Natural Resources	
A) Food	
fish	8
shellfish	7
B) Water Supply	5
C) Minerals	3
3) Extreme Events: Prediction, Survey, Assessment	
A) Coastal Storms, Earthquakes, Tsunamis	
sea state	4
surge, tides, sea level	4
littoral response, shoals, shorelines	4
4) Other Aids to Shipping, Navigation	
ice cover	2
shoals, shorelines, sea state, and currents (see all above)	

* Discussed in Section VI.A. High priorities are given high numbers.

viewpoint of oceanography. The lower priority items from Table 1 are omitted. We emphasize that in division (1), the entries are interrelated, and should be evaluated collectively.

The coastal zone oceanographic priorities in Table 2 indicate problem areas where efforts should be directed. More information is needed before the potential of satellites to contribute to these efforts can be evaluated. Problems itemized in the table must be reviewed in sufficient detail to ascertain whether associated remote sensing features are basic, important but not basic, or distantly related. In the first case, satellites will be of immense benefit (if the required instruments can be included in the payload) as they will provide primary data. Surface data will be required only for calibration purposes. In the second case, satellites will be able to provide important data in conjunction with a surface data acquisition program. For problems in the third category, satellites are of limited usefulness.

For the above evaluation, problem descriptions have been written for the items in Table 2. They are identified by titles corresponding to the major division and subdivision in the table. Some subject titles do not correspond directly to items in the table, a reflection of the fact that a table can misleadingly suggest divisions between subject areas.

A. Water Pollution and Water Quality

1. Determining Water Quality

At present, coastal water quality is largely unknown at any given time and location except near outfalls. Consequently,

laboratory experiments on parameters affecting marine organisms are difficult to design, and problems in biological resources cannot be anticipated. Detailed analyses are needed of the effects of pollutants on relations between organisms in coastal ecosystems; these analyses will require knowledge of trace concentrations of pollutants in coastal waters. Levels of pesticides, oil, and wastes in the marine environment need to be determined. That industries do not reveal the composition and concentration of their effluents is a key factor blocking rapid and efficient scientific effort on these problems.

2. New Measures of Water Quality

A gradually deteriorating aquatic environment may go unnoticed. Sophisticated techniques for determining subtle changes in water quality must be in regular use, so that changes can be discovered before deterioration becomes critical.

Studies are in progress on concentrations of dissolved and particulate organic matter. Radionuclides are being used as tracers for physical and biological studies. Similar parameters can be investigated.

Since living systems are usually very sensitive to changes in the environment, the use of organisms (bioassays) will provide the most sensitive method for determining many water quality changes. Criteria other than the traditional test of LD 50 (lethal dose to 50 percent) must be developed, because by the time organisms have died, environmental degradation is critically serious. Methods can be developed to employ the effects of pollutants on

sensitive metabolic responses and enzymatic reactions at the cellular and subcellular level.

Remote sensing of river and estuary effluents has a great potential. River and estuary effluents generally have visible and infrared region spectral signatures relative to the sea water into which they flow. These signatures result from suspended sediment, detritus, chemical wastes and temperature. Even without surface measurements, tracing the path of effluents will indicate dispersion paths. It appears that in areas where the variety of pollutants is large, surface measurements will generally be needed for quantitative determination of concentrations of pollutants and their spatial and temporal variations. Remote sensing will be of useful assistance in this case by delineating areas of overall degradation of water quality. In areas where the variety of pollutants is small, quantitative measurements may be possible without surface data. Several remote sensing techniques are being developed for quantitative measurement (Hemphill, 1968; Silvestro and Piech, 1969), and careful research into spectral signatures is underway for oil pollution (Horvath, et al., 1970). These developments look promising for quantitative remote sensing of water quality from both aircraft and satellites.

3. The Biological Effects of Water Pollution

The enormity of biological destruction caused by water pollution is already too overwhelming to fully appreciate. There is no point in listing examples -- there are too many (see Robert A. Taft San. Eng. Cntr., 1965). Our concern for the pollution

problem is sober and deep, compounded by the realization that its causes lie in our way of life and have a momentum which will be very difficult to stop.

In this section, we mention a few general considerations. In succeeding sections, particular problems are described.

Quite often a pollution problem is so complex that a given manifestation of it, such as a fish kill, requires diligent study to explain (e.g , see Hargis, 1965). This circumstance is testimony to how little we understand and to the need for persistent research.[5]

The ability of marine biological resources to withstand chronic pollution in the environment is largely unknown. Lethal concentrations of some substances are known, but extremely little information exists about synergistic effects or the effects of chronic exposure of marine organisms to sublethal quantities. Concentrations and effects is a major priority. An important method of study in this regard is the detailed comparison of species in areas of high versus low water quality.

Pollution studies should include:

a) survey of species health,

b) study of effects on reproduction, and stamina in all life stages,

c) tracing of effects through food webs, and

d) measuring levels of pathogens and parasites.

Remote sensing will not generally assist the study of biological effects of pollution in a direct manner. It will

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[5] We quickly add that much important research has already been done, and thorough searches of the literature are necessary to avoid duplication. Better-organized data flow from collection to management decision will hopefully reduce duplication.

assist indirectly via surveys of water quality and circulation patterns.

4. Toxic Wastes, Biocides and Heavy Metals

In tracing pollutants through food webs, biologists have shown that the effects of biocides are not limited to the target species. After passing through food webs, they eventually become a significant threat to human health. Accumulation of the chemically-stable chlorinated hydrocarbons such as DDT and dieldrin has already disrupted reproduction and caused death in coastal avian species (Woodwell et al., 1967) and inhibited photosynthesis in marine algae (Menzel, Anderson, and Randtke, 1970). The extremely low levels at which some biocides are harmful makes one expect that many more will be curtailed as soon as adequate testing has been done.

A new aspect of the DDT problem has lately become of concern. DDT is only slightly soluble in water, but it has high solubility in oils. There is now recognized the danger that DDT may be concentrated by oil slicks in coastal waters.

Hartung and Klinger (1970) have calculated the solubility ratio of DDT between oil and water, and have provided laboratory and field data which show that petroleum will concentrate DDT. Parker and Barsom (1970) have suggested that the world-wide dispersal of DDT may have been assisted by its interactions with surface oil films. Seba and Corcoran (1969) have sampled Biscayne Bay water and found high concentrations of pesticides in several permanent slicks.

Recently, a new class of toxic compounds has been recognized as a serious problem. The compounds are polychlorinated biphenyl compounds (PCBs), which are chemically inert, and have the characteristics which facilitate persistence in the environment and accumulation up the food chain. Studies to date show that PCBs are already in the world ecosystem in large amounts (Koeman et al., 1969; Jensen et al., 1969; Duke et al., 1970; Peakall and Lincer, 1970).

Even though the use of some chlorinated biocides in the United States is being decreased, continued vigilance is necessary. As new industries develop, new chemicals will threaten to become part of the waste stream (up to 400 chemicals per year, according to Science and Environment, 1969). Physical, chemical, and biological studies should be a matter of record before new products are approved for use.

Basic physical and chemical problems are numerous and of great significance. Determination of residence times is more important than formerly realized, since residence times are long, and sea water concentrations are rising at shocking rates. The chemical form (e.g., free or complexed, oxidation state) must be known for residence-time estimates to be valid. New problems of mercury contamination in the Great Lakes in regions free of recent mercury disposal suggest that bottom sediments may have stored and accumulated this heavy metal.

If new chemicals are approved for use, well-designed control measures should already be in operation. In some cases, the emphasis on control of one type of pollution has increased

another. For example, increasing numbers of municipalities use incinerators and dispose of incinerator wastes at sea. The result is a new source of marine pollution, excess quantities of various metals, which degrade the disposal area.

There is no way known by which the various toxic materials in coastal waters can be sensed remotely. Valuable assistance, however, will derive from remote sensing through its delineation of circulation patterns, temperature patterns, and oil slicks.

5. Sewage, Nutrients, Dissolved Oxygen, and Accelerated Eutrophication

Sewage consists of roughly 97 percent liquid and 3 percent sludge (Dalton et al., 1968). The liquid contains a large amount of potassium and the sludge contains large amounts of organic and inorganic nitrogen and phosphorus. Potassium, nitrogen, and phosphorous are the primary macronutrients for plants and algae, hence, the large volume disposal of sewage into water bodies allows a proliferation of photosynthetic growth (see Robert A. Taft San. Eng. Cntr., 1961). Bacterial growth is profuse, and oxygen rapidly disappears in the hypolimnetic water. Eventually the oxygen demands of wastes and decaying photosynthetic tissue all but eliminate higher animal life.

The enrichment of water by organic and inorganic materials and the ecological and morphological changes which follow are called eutrophication (see NAS, 1969a). Water bodies with low nutrient inputs generally experience eutrophication naturally over long periods of time; however, the natural process is no problem because it is so gradual. Sewage disposal, in contrast,

causes significant eutrophication at greatly increased rates; this artificially accelerated eutrophication is a serious disruption to existing uses of the affected water bodies.

Sewage disposal is primarily the concern of sanitary engineering, but the eutrophication which results is the concern of environmental science, especially coastal zone oceanography, since the bulk of sewage disposal occurs in waters of the coastal zone. A thorough review of eutrophication has been completed by Stewart and Rohlich (1967), where the primary research needs have been outlined. They include systematic surveillance of temperature, dissolved oxygen, and water transparency. Nutrient budgets should be studied, with special attention to limiting factors. Sediment cores can be studied to uncover water history via gross benthic changes. Bioassays should be used for determination of subtle water quality changes over short periods.

Two of the parameters recommended for surveillance can be monitored remotely, temperature and water transparency. Some work has indicated that ultraviolet absorbance may be a quantitative measure of sewage in marine areas (Ogura and Hanya, 1968; Tibby, in NCMRED, 1969). Absorbance at 220 nm is due to bromide (mainly) and to dissolved organics. Additional work is needed to identify the specific chemical species responsible for the absorption. The potential of remote sensing to detect variations in ultraviolet reflection as an indication of waste loading should be investigated.

Remote sensing can contribute significantly to disposal and eutrophication studies by the surveillance of temperature and

overall sewage content. Surface data will have to be obtained in order to make full use of the remote sensing data.

6. Radioactive Pollution

A continuing concern is the effects on marine organisms of radioactive materials from nuclear power plants, ships, and past weapons tests. A basic need is to know the radionuclides and their concentrations in coastal environments. These data must be on hand to facilitate study of uptake and concentration by pivotal food web organisms.

There does not seem to be any danger that a nuclear power plant could dangerously contaminate all the water in a moderately-sized estuary, because the volumes of water are too large. However, thousand-to million-fold concentrations of radionuclides could occur in the biota inhabiting the estuary. Also estuarine circulation could cause a dangerous concentration of radioactivity in specific areas. This potentiality can be investigated easily by dye studies with scale models. Since the validity of scale model studies depends on calibration against actual circulation patterns, the need is obvious for knowledge of estuarine circulation patterns in regions of potential nuclear power plant sites.

Remote sensing cannot assist study of radioactive pollution directly, but the remote sensing of coastal circulation will be of assistance in choosing locations for nuclear power plants and for surface monitoring of radioactivity.

7. Oil Films on Coastal Waters

Oil films are frequently found on coastal waters. Organisms in sea water are responsible for some films, and others are caused by spillage of petroleum products. The effect of these films has not been studied, despite the importance such films may have on biological processes and chemical reactions taking place at the air-sea interface. Although much work has been done on the gross biological effects of oil spills (see Radcliffe and Murphy, 1969), the cumulative effect of continual oil pollution in small amounts has remained unstudied. The nearest to a study of cumulative effects of oil pollution is that on Cook Inlet, Alaska (Kinney et al., 1969).

To assess the cumulative effect on the Chesapeake Bay, VIMS has begun a program of oil slick sampling and analysis. Slick compositions are studied by extensive laboratory chemical analysis which differentiates natural slicks and petroleum-derivative slicks (VIMS, 1970). In addition, plankton populations are being investigated in oil slick areas (Roy et al., 1970): results to date show that plankton counts in oil slick areas are 50 percent less than counts in non-slick areas.

These results indicate that oil slicks may be disastrously interfering with the surface phytoplankton populations. If true, this is a sober and serious matter, because phytoplankton are the primary trophic level of the oceanic food chain. These studies must be continued and enlarged.

An essential, complementary need is a determination of percentage areas of coastal waters covered by slicks of different

types, and investigation of the aereal dependence on season, weather, and human activity. In addition, experiments should be conducted to determine the effect of surface films on evaporation rate, wave generation, and oxygen exchange rate.

The importance of remote sensing in the monitoring of oil pollution is questionable. Briefly stated, oil releases thick enough and large enough to be detected from high altitude are infrequent and obvious at the surface, while the microlayer slicks with greater cumulative effect are harder to detect remotely, and too numerous to individually monitor from the surface.

In greater detail, the general problem is to ascertain the cumulative total environmental effect of oil releases. When massive releases occur, as from the Ocean Eagle, 1967, the Torrey Canyon, 1969, at Santa Barbara, 1969, and off Louisiana and Florida, 1970, they are obvious, and they attract great attention. Their effects are well-documented (see API-FWPCA Proceedings, 1969). The volume and area of massive spills can be estimated (albeit crudely) by observations from ship and spotting aircraft. Remote sensing of such oil masses has been demonstrated (Lowe and Hasell, 1969). Volume determination by photographic analysis has been initiated allowing delineation of oil spill areas at day or night (Estes and Golomb, 1970). Work is in progress on the problem of thickness determination and it appears that some thickness determination will be possible (see the review of oil remote sensing in VIMS, 1970).

It appears that for moderate to large oil releases, satellites could provide rapid detection, and quantitative data on area,

thickness, and volume. To take advantage of these capabilities, satellite sensors should be focused on harbors, shipping lanes, and offshore oil well regions.

The remote sensing of small volume releases of oil is less encouraging, despite their greater importance. The prevailing opinion is that our most pervasive oil pollution problem originates in the thousands of small spills each year in the national waters. This opinion is held strongly at VIMS, because our studies to date show the same decreased plankton counts for slicks of all thicknesses, even microlayer slicks (Dupuy, personal communication). Yet, because of small size and negligible effect on the spectral signature of water, the microlayer slicks appear to be detectable only at low altitude. From satellites, the only workable method might be the detection of visible region sun-glint patterns.

We recommend that study of satellite remote sensing of oil pollution determine the feasibility of detecting thin slicks via sun-glint patterns. If this method proves unfeasible, we feel satellite remote sensing will not greatly assist management of the problem of small oil slicks.

Remote sensing is of great assistance at the present time in research studies of oil slick motion, spreading, and longevity. Aerial photography is the only satisfactory method of determining oil slick areas and locations.

8. Silt and Other Suspended Solids

Besides sediments which result from waste disposal, there are sediments originating from natural and induced erosion of soils and geologic materials. Erosion sediments comprise the majority

by volume of water pollutants. From Grissinger and McDowell (1970) we summarize some statistics: 4 billion tons of sediment are produced annually in this country, 700 times that from sewage. One-third of the sediment is natural in origin. One-fifth is from bare soils during development and construction. One-half is from agriculture.

The physical effects of suspended and deposited sediments are well-known: Turbidity reduces photosynthetic activity by limiting light transmission through surface waters; sediments fill navigation channels and cover estuary bottoms, modifying and eliminating benthic populations; and suspended sediments modify erosivity of flowing water.

New research is elucidating the chemical effects of suspended and deposited sediments. Particles of sediment have active surfaces which facilitate nutrient and chemical exchange with water solutions. Sediments transport adsorbed and absorbed chemicals.

The visible region turbidity in coastal waters resulting from suspended sediments can be easily detected by remote sensing. In addition, accretion and erosion of coastal deltas, bars, and shoals from sediment deposition can be followed. Remote sensing should be developed into the major and primary method of detecting suspended sediments in surface waters. Careful research into spectral signatures will be required.

9. Temperature and Thermal Pollution

According to Holcomb (1970), power consumption in the United States has doubled every 10 years for the past 3 decades.

At this rate, the need for electrical energy will increase 8 times between 1970 and 2000 (while our population less than doubles). Thermal-electric power plants already use 70 percent of all water withdrawn for industrial cooling and condensing. By 1980, one-tenth of the fresh water runoff in the United States will be used for cooling and condensing (Parker and Krenkel, 1969, pp. 5, 282). By the end of the century, the figure will be one-third (Holcomb, 1970).

The expected heating of tremendous volumes of cooling water will aggravate existing biological problems. Evaporation rates increase, causing loss of fresh water and increased salinity in estuarine regions. Higher temperatures and temperature gradients alter species distributions. For example, localized "hot spots" act as dams to temperature-sensitive migrating fish.

Studies must be accelerated on the effects of thermal effluents on migration, survival and reproduction of estuarine and coastal organisms, and the damage to plankton populations in passage through cooling condensers (see Krenkel and Parker, 1969). Research is also needed on the transport and behavior of heat in water, on heat dissipation devices, on uses of waste heat, and on more efficient thermal-power production.

To satisfy these research needs, an essential task is extensive analysis of existing thermal pollution. This requires investigation of thermal patterns around discharges of power plants, and development of models whereby patterns around proposed plants may be predicted. Invaluable, essential, and unique assistance in these efforts is provided by thermal infrared imaging. Hopefully,

remote sensing satellites or high altitude aircraft can provide the desired spatial resolution.

Infrared delineation of surface temperature patterns is useful to more than just thermal pollution study. Isothermal charts are immensely useful in commercial fishing (see Problem C.3), and in the study of currents and circulation (see Problem B.9). Charts of ocean surface isotherms are essential for prediction of ocean thermal structure, a tool in development (James, 1966).

Aerial coverage of some coastal regions is currently obtained with an infrared radiometer and the thermal data published and disseminated to those interested (U. S. Coast Guard, Surface Isotherms). Occasional temperature anomalies appear in the infrared data. These are usually colder than surrounding water, and are assumed to indicate upwellings. Temperature anomalies could be located and reported by satellite; if rapid transportation to the site could be provided, then more could be learned about upwellings and their general importance to the ecology of coastal zones. At present they are known to bring up nutrients utilized by plankton. The plankton ultimately support fish populations.

B. Estuarine and Coastal Ecosystems

1. Estuaries

An estuary is most simply described as a partially enclosed body of brackish water lying between a land drainage area and an ocean. Much literature has been devoted to types and classifications (see Lauff, 1967, and Wohlschlag and Copeland, 1970). Our concern is for the environmental significance of estuaries, their ecosystems, and their fragility.

Estuarine ecosystems are governed primarily by the stresses of poikilohaline conditions; salinity and other parameters undergo periodic and seasonal changes. As a result, successful species are those with a tolerance to wide ranges of parameter values. Estuarine species diversity is inversely proportional to the degree of stress.

Estuaries are highlighted in this study because of their critical importance in the environmental balance of the coastal zone. Seven of the ten most valuable commercial fish species require estuarine habitats, and another eighty important species are estuarine dependent (CMSER, 1969). Consequently, half or more of the national fish catch depends on estuaries (FWPCA, 1968). Estuarine bioproductivity, measured simply in terms of annual dry weight yield of estuarine plants, far exceeds that of agricultural land and the deep ocean (Wass and Wright, 1969; CMSER, 1969).

Destruction of estuaries by pollution, "land development", and other activities, has severe consequences for fisheries, biodegradation of disposed wastes, recreation, and the industries dependent on these uses, in sum, for a multitude of coastal zone uses. In 1936, the shrimp harvest of the San Francisco Bay was over six million pounds; by 1966, with over 80 percent of the Bay marshes having been eliminated, the harvest was 10,000 pounds (CMSER, 1969). Present quantities of sewage and high BOD wastes overwhelm the ability of estuarine life to degrade them; the result is rapid biotic deterioration and increasing pollution, which leave the estuary unfit for recreation, and its water supplies unusable. Furthermore, the reduction in species diversity because

of pollution is often accompanied by proliferation of pest species such as venomous jellyfish, aquatic weeds, and alewives.

Many aspects of water quality important to estuaries have been described above under Water Pollution. The important biological and ecological aspects of estuaries are described below. Salient geomorphological and hydrographic aspects not previously covered are mentioned briefly.

2. Marine Ecology and Food Chains

Ecosystems in general consist of three categories of organisms: producers, consumers and reducers (see, e.g., McConnaughey, 1970).

The producers synthesize new organic matter from inorganic matter by photosynthesis. The producers include plants and algae (minute freely-floating algae being called phytoplankton). Remote sensing can be used to map communities of producers.

Consumers feed on organic matter and include all animal life. Some coastal zone consumers are observable remotely such as schools of fish, herds of mammals, and flocks of waterfowl. Because of low priority these applications of remote sensing are not discussed further.

Reducers consist of microorganisms not able to photosynthesize or ingest particulate organic matter. They reduce dead producers and consumers to nutrients. Reducers are not observable with remote sensing techniques.

Viewed simply, producers, consumers, and reducers in marine waters comprise a food chain or cycle consisting of three trophic levels between sunlight and edible resources, with a loss

of nearly 90 percent of available energy at each level. This picture has been found too simple for estuaries, and the practice is to speak of food webs with numerous levels and intricate food relationships.

Existing food web relations and dominant species within communities are poorly known in many coastal zone ecosystems. Community structure should be studied in a variety of habitats as a base line for future activities. We emphasize that community structure cannot be adequately described in a short period; natural short-term fluctuations need to be understood against a long-term baseline. Detailed food web studies should be conducted, especially on important filter feeders such as oysters, clams, and menhaden. A study of energy flow from estuarine and coastal marshes into adjacent open water communities is needed. Detrital flux and energy budget studies should be expanded. Food web studies, of necessity, span a multitude of species and habitats.

Some of the needed field studies in marine ecology can be assisted materially by remote sensing from aircraft or satellite. Important and representative examples involving producer systems have been selected for detailed consideration in following sections. The examples are wetlands, a class of basic estuarine producer systems, and phytoplankton, which constitute a basic producer system in both coastal and oceanic food chains. An important but little studied question is the relative productivity of phytoplankton versus wetlands.

We also consider coastal vegetation and land use because of their great impact on coastal zone waters. The discussion

is short because the subject is not really part of coastal zone oceanography.

3. Wetlands

Coastal wetlands are one of the most important components of coastal zone ecosystems. They are formed in low-lying temperate and tropical areas and are often associated with, but not confined to, estuaries. Wetlands generally include salt and freshwater marshes, tidal flats, swamps, and mangroves.

Vegetation consists of submergent and emergent vascular plants and various algal species, both epiphytic and benthic. The vegetation type in a particular area is dependent on tidal fluctuation, salinity, elevations, latitude, nutrients, and other factors. Although many of the plants in these areas are tolerant of wide ranges of natural ecological parameters, the requirements of most are sufficiently narrow that sharp zonation tends to occur. This sharp zonation is mainly the result of minute changes in elevation and salinity. The coastal zone wetlands are often said to be "brittle", that is, small environmental changes may lead to gross biological changes.

Wetlands have long been recognized as ranking high among primary producer systems. In the best grass marshes of Virginia the productivity approaches 10 tons per acre per year dry weight. The average for all wetlands is roughly 5 tons per acre in middle latitudes (Wass and Wright, 1969). Productivity of land areas, in comparison, is about 1.5 tons per acre (Vallentyne, 1965).

It has not always been clear, however, how this productivity is utilized by consumer species. It appears that the most

common pathway involves transport of plant material from the wetlands into coastal zone waters where it serves as an energy source. This energy source is particularly critical in middle-latitude estuaries and nearshore areas where turbidity is commonly so high as to limit phytoplankton photosynthesis.

The coastal wetlands are essential to the maintenance of stocks of many fish, shellfish, waterfowl, and furbearers of both sport and commerical importance. If wetlands are diminished, it is inevitable that the resources dependent on them will decrease. Such decreases are taking place, while, because of burgeoning population, the demand for the resources produced by the wetlands is increasing.

Wetland alteration comes about through dredging and filling, but also in significant amounts through erosion and salinity changes related to impoundments. By the time the damage is discovered, it has often proceeded to a stage that may be irreversible. Detection of such changes in their initial stages by the use of field methods is usually prohibitively expensive.

The overall importance of wetlands necessitates that we adopt a far-reaching but simple goal: preservation of wetlands. We should include frequently inundated marshes, submerged aquatic vegetation (especially eelgrass), protective shoreline, dune systems, plant species known for high cellulose productivity, and adequate water quality for maintenance of natural diversity.

Of late there has been considerable interest in wetlands by assorted state and federal agencies. This has led to a plethora of reports which, rather than representing new information, are

largely a compilation of existing data. Each agency tends to have a particular sphere of interest, leading to the over-emphasis of certain aspects and disregard of others.

The generation of such reports has also revealed management conflicts. It is difficult or impossible to simultaneously manage wetlands for fish, fowl, and fur. Further, without comprehensive wetlands data, no coherent management system can emerge. Although many wetlands would benefit from management, the best management for most would be to stop tampering with them until the effects of small alterations are understood.

The highest priority in coastal wetlands research and management is accurate mapping. Analysis of color infrared film now on hand should be carried out and calibrated with the aid of corollary ground truth.

The nature of most coastal wetlands is poorly known, even where mapped. The plant types, seasonality, and quantity of production have been studied in few areas, due to a lack of techniques and to the general inaccessibility of many wetlands. Some have never been accurately surveyed and the rate of alteration renders field surveys of many wetlands obsolete almost before completion. Because wetlands are often defined as the limit of mean high water, it is necessary to determine the extent and limits of flooding to describe coastal wetlands. Subsidence and variations in erosion and accretion because of upstream impoundments have probably changed many old boundaries.

High resolution aerial photography could be used to determine the extent of flooding and hence the boundaries of coastal

wetlands, particularly since most wetlands are within 10 feet of mean sea level. Photography is better than surface surveys in terms of both time and cost.

Some useful spectral signatures of coastal wetland vegetation are already known. Stroud and Cooper (1968), Pestrong (1969), and Wass and Wright (1969) have used aerial photographs to delineate species. Gross productivity estimates could be based on aerial photographs, since the productivity of a given wetland is a direct function of the types and relative abundance of the vegetation present.

Additional research into spectral signatures is needed. The contribution of organic material from wetlands to adjoining estuaries occurs mainly after vegetation dies and begins to decay. During this time, because of the breakdown of chlorophyll, carotenoids, and other pigments, there are changes in the spectral signatures of the vegetation. The rate of these changes and the time of inception in various wetlands could be remotely sensed and used to measure the relative and seasonal contributions of organic material from wetlands to estuaries.

Because of their locations, some wetlands contribute more nutrients and detritus to the overall ecosystem than others. It is necessary to identify for management purposes which wetlands are the most productive, and where the output is utilized. The distribution of organic material is dependent on the circulation patterns in the receiving body of water. Some of this organic material may be essential to communities tens or hundreds of miles from the original source. The water masses which transport this

organic material are turbid, and the turbidity may be remotely sensed.

Vegetational changes in coastal wetlands should be monitored on a regional basis by a central agency. Because of the rapid rate of increase in such alterations, surveillance must be carried out more frequently than can be done with the conventional use of field parties. A national program requires that mapping tasks and the detection of gross changes be accomplished by remote sensing. Field parties can then concentrate on detailed study of the most important wetlands, including assessment of the nature of change and its extent and significance.

In the initial portion of such projects, considerable surface truth will be needed to establish baselines. Field studies will be required for careful calibration of spectral signatures, both biological and physical, under a variety of environmental conditions.

Wetland loss and waterline erosion need to be followed more closely. It is apparent that a substantial amount of dredging and marsh filling occurs through a series of small alterations. For control of erosion, the use of plants should be expanded. Remote sensing is ideal for monitoring the resulting alterations. It is hoped that satellite remote sensing will have the spatial resolution needed for this monitoring.

Other studies of significance must be pursued which will not be amenable to remote sensing. Standing crop analyses ought to be done for major plant species and communities in every major marsh at appropriate times. Food analyses are in order for the

common crustaceans (mysids, amphipods, isopods) of the marsh guts and creeks, as well as in the adjacent rivers or bays. Highly successful trapping experiments in Virginia have indicated the abundance of amphipods in the marsh creeks. (In this case, the dominant species is one which was identified from Virginia only a year ago). Analysis of the feeding habits of these masticatory crustaceans will involve tedious laboratory work. Stomach analyses are needed of the principal prey fishes, particularly Fundulus, Gobiosoma, Notropis and Hybognathus species. Studies in progress on the food of Fundulus heteroclitus should add many times more information than is now available in the literature. None of the literature is quantitative. A closer study is needed of eelgrass resources and marsh fauna. Finally, study of benthic animal communities should be continued.

Detritus flow studies with special emphasis on the effect of elevation are also important. Remote portions of larger marshes in Virginia are lower than the portions bordering the rivers, as can be seen in the Poropotank (where the high marsh is mainly near the mouth) and in Terrapin and Cousiac marshes.

Esthetic evaluation of wetlands is needed. This evaluation is sometimes appreciated but otherwise it is little encouraged.

In summary, the needs of wetland research in the coastal zone are as follows:

a) accurate mapping of wetlands and adjacent submerged areas,

b) determination of vegetation types, distribution, and seasonal changes,

c) fate of organic material produced in wetlands,

d) productivity of wetlands, and

e) effects of natural and human alterations of wetlands.

Visible and infrared region remote sensing can contribute significantly to all of these research needs.

4. Mangroves

Mangroves are a special category of wetland ecosystems characterized by Rhizophora trees, with heavy brush and other plants and algae, in tidelands of tropical humid coastlines. Mangroves stabilize substrate, trap sediments, and add nutrients and in this way form and extend small island systems. Significant animal populations are directly and distantly supported by the organic material originating in these systems. The southern coast of Florida contains one of the largest mangroves in the world. Others are found in the West Indies, East Africa, West Africa, Pacific Islands (including Hawaii and the Malay Archipelago), Australia, and India (McConnaughey, 1970).

Until recently the Florida mangroves were relatively unstudied. New quantitative work (Heald, 1969, and Odum, 1970) shows that the annual productivity of mangroves from leaf fall alone exceeds three tons (dry weight) per acre. Enormous biotic populations are supported from the resulting detritus.

In the same fashion as for other wetlands, remote sensing can be used for rapid and wide-area survey of mangroves. Wide-area surveys will permit determination of their total contribution to coastal biota, a prerequisite to coastal zone resource management.

5. Phytoplankton Ecology

Phytoplankton are photosynthesizing microscopic algae, generally non-motile or capable of only feeble swimming. In all open waters, they are the first level in the aquatic food chain.

Being non-motile in a fluid environment, their ecology is controlled by fundamental environmental factors such as temperature, light, salinity, turbidity, and nutrients, and especially dependent on the single factor of currents. Of the other fundamental factors, only light is largely independent of currents.

Ketchum (1954), Sverdrup, Johnson and Flemming (1946), Gran and Braarud (1935), Redfield (1946), and others have shown that in areas where vertical currents occur (including coastal upwelling, divergencies, turbulence, convection currents and wake stream) compounds of nitrogen and phosphorous and elements such as silicon and iron are found in high concentrations. During active plankton multiplication and growth these nutrients are heavily utilized. Dead phytoplankton continually settle to the bottom as debris. The principal factors which cycle nutrients from decaying debris to the surface for new phytoplankton growth are vertical currents.

Dupuy (1968) has shown that a stable water mass is a necessary factor in allowing phytoplankton blooms to occur. Stable water masses are largely the result of lateral circulations; gyres and eddies are known to yield conditions where substantial blooms will occur. Winds produce turbulence and disrupt stable water masses, thereby inhibiting the production of blooms.

It is then of primary importance in understanding phytoplankton ecology to study both vertical and lateral currents. A comprehensive daily surveillance of the surface currents and major and minor circulation patterns should be undertaken to allow the biological oceanographer to estimate or predict areas where phytoplankton blooms may occur. As part of this surveillance, other contributing factors such as sea state and wind velocity should be measured.

Of prime importance to organic production by phytoplankton is the period and spectral intensity of available sky light and sun light. Visible light in the spectral range between 400 and 700 nm (in plants and algae) energizes the process of photosynthesis. Prakash and Medcof (1962), Prakash (1963), and Sparks et al. (1967) have shown that the total period of solar radiation controls the density of dinoflagellate blooms if other parameters are non-limiting. Therefore, intensity versus time for a given area must be known to allow prediction of phytoplankton blooms of any proportion.

Other factors influence phytoplankton growth, such as temperature and salinity. These influence stability of water masses, and also define seasonal cycles affecting what types of phytoplankton will be present.

The remaining consideration is the cyclic interplay between diatoms and dinoflagellates, the two major groups of phytoplankton.

Diatom blooms along northern temperate coastlines occur from March to September and October. They appear to be controlled by levels of inorganic phosphates, nitrates and silicates, which

are largely independent of the temperature (Dupuy, 1968). The short bursts of diatom blooms during July, August, and September thus may be the result of a small influx of nutrients.

Dinoflagellates, in contrast, require warm temperatures, grow at lower levels of nutrients, and are inhibited by a high density of diatoms. Needler (1949) suggested that spatial competition affects dinoflagellate growth and reproduction. There is some evidence that dinoflagellate growth is enhanced by the release of growth factors from diatoms. Dinoflagellates consequently appear from May to September during periods of high light intensity (no clouds), low nutrients, high temperatures, and following the decline of diatom populations.

In summary, the phytoplankton ecologist must have frequent measurements of:

a) currents and circulation patterns,

b) light intensity versus time,

c) sea state,

d) temperature,

e) nutrients,

f) salinity, and

g) definition of major population changes (whether diatoms or dinoflagellates are present).

Because the needed measurements above are primarily physical, remote sensing can contribute significantly. The utility of remote sensing for these measurements is discussed in other sections.

Remote sensing is also of great potential for detecting phytoplankton directly. There is little chance of species

identification by remote sensing (except if one species dominates a given area for part of the year), because of the great variety of phytoplankton species with their individual absorption spectra. However, phytoplankton can be detected as a group because some features of the absorption spectra are common to all species. Chlorophyll a, which has broad absorption bands with peaks in vivo at 430 and 680 nm, is a universal pigment in phytosynthesizing tissue, and thus is present in detectable quantity in all phytoplankton. Clarke, Ewing, and Lorenzen (1970) have demonstrated a high correlation between chlorophyll concentrations and remotely-sensed water color on the Georges Bank.

6. Coastland Vegetation and Land Use

This subject verges outside the domain of coastal zone oceanography, but is included because of its great importance for coastal water quality and primary bioproductivity. The relation of water quality and land use has been sketched by Bullard (1965).

A multitude of human activities on land are involved. Farming, grazing, lumbering, mining, road construction, and urban development are just a few. Notice that the first four and often the fifth involve exploitation of natural resources.

A variety of natural factors are involved, such as forest fires, rainfall, and snowfall. Climate and soil type determine the coastland vegetation and its successions.

The primary aquatic effect of coastland vegetation and land use is control of the load of suspended sediment. All other water pollutants are influenced as well. Depending on location,

aquatic nutrients and detritus deriving from vegetation/land-use may replace wetlands or phytoplankton as the first link in the aquatic food chain.

The coastal zone oceanographer desires reliable correlations between vegetation/land-use and coastal water parameters. The importance lies in monitoring and controlling water pollution, and in determining the relative importance of coastlands versus aquatic life in bioproduction. This knowledge is considered essential for effective environmental management in the coastal zone.

Remote sensing of vegetation/land-use is unmatched by any other data gathering method. The Departments of Agriculture, Interior, and Defense have long ago proven its unique advantages in providing rapid, wide-area, and reliable surveys. The principal remote method is aerial photography, but radar is rapidly becoming an accessory and complementary method with special advantages in crop identification (see Remote Sensing of Environment, 1962-1969; Johnson, 1969; NAS, 1970).

7. Hydrographic Surveys

Knowledge of the hydrographic features of bays and estuaries is required for managing bioresources and interpreting fluctuations in abundance of bioresources. Present surveillance of hydrographic conditions is occasional and piecemeal, in contrast to the need for continual records. The hydrographic surveys should include measurement of tides, currents, salinity, temperature, and dissolved oxygen.

Some of these items are covered separately in other sections. Here we mention aspects which deserve special attention in future surveys.

Estuaries having small volume and/or poor water exchange with the oceans can be readily altered by pollutants to the extent that they no longer serve as areas of primary production. Flushing times of estuaries must be determined and pollution limited so that our pollutants do not exceed the buffering capacity of the acid-base or redox equilibria in these waters, and that pollutants are sufficiently diluted to be harmless.

This problem must be studied in conjunction with tolerance and toxicity studies, and with dilution and circulation studies. By combining these types of studies, water quality standards can be established which will aid the long-term preservation of estuarine bioproductivity.

Greater understanding of tidal fluctuations is desired, to assist in analysis of estuarine flushing, salinity intrusion, and shoreline deformation. Geophysical studies, wind studies, bathymetric charting, and tidal recording are involved. Remote sensing can assist in obtaining synoptic wide-area tidal records, if data are obtained several times per day.

8. Salinity

Aquatic ecosystems in the natural state are constrained by four major parameters: salinity, temperature, nutrients, and dissolved oxygen. In the marine coastal zone, salinity assumes special importance -- a salinity gradient from fresh water to sea

water is confined to a narrow strip just a few miles (occasionally yards) in width. Topography, tides, and land drainage shape the oscillations of this gradient.

Ecosystem balance in estuaries is tied to existing salinity patterns. All species which manage to survive in the strenuous estuarine environment have adjusted to and depend on these patterns. Salinity plays a major role in determining species distribution (Water Resources Res. Inst., 1966; Lauff, 1967; FWPCA, 1968). Because of the importance of salinity, VIMS regularly monitors salinity in the lower Chesapeake Bay and its river tributaries. An oyster kill resulting from decreased salinity after Hurricane Camille was thoroughly documented (VIMS, 1969).

Small variations around existing means are tolerated, but major changes inevitably bring a redistribution of species. Field studies of the biological effects of salinity changes are often complicated by simultaneous changes in other parameters; laboratory study can help determine, in such cases, the controlling factor.

Salinity is also prominent in influencing transport, flushing, and mixing of coastal water bodies, because of the greater density of saline compared to fresh water. Aside from influences of tides, morphology, and the Coriolis force, river flow into the sea should progress as a layer of fresh water over more dense sea water below. With the simultaneous interaction of all influences, coastal water bodies assume a variety of circulation schemes (see the section, Physical Factors, in Lauff, 1967).

A thorough experimental and theoretical study is needed of saline intrusion into estuarine waters. It is important to

know the magnitude of drainage and river flow needed to maintain natural salinity levels from place to place in large estuaries (see MacIntyre and Ruzecki, 1968). Drought conditions in the past have allowed saline intrusions to jeopardize fresh water supplies and introduce marine predator and fouling organisms into areas normally protected by fresh water. Although laboratory flume studies have been made of the length of an arrested saline wedge in an estuary (Keulegan, 1966), the results are not applicable to real estuaries. The work was done with ideal boundaries, and the length of the salinity intrusion was expressed as a small multiple of the mean depth. In real estuaries, however, the characteristic length of the salinity intrusion may be as much as five orders of magnitude greater than the mean depth. Consequently, it is important to conduct salinity intrusion experiments using appropriate physical models of real estuaries.

For experimental studies, automatic salinity recording equipment is required. The needed density and frequency of data can not be obtained with the grab-sample techniques now in use. Remote sensing in this situation can be of tremendous benefit.

At present, however, the potential of remote sensing for mapping salinity has not been exploited. Development of techniques for salinity mapping should therefore be a <u>top priority</u> project for the remote sensing community. The reasons, summarized, are that salinity gradients are basic to estuarine ecosystems, and salinity gradients help drive major ocean currents and coastal circulation patterns (see Problem A.9).

Microwave radiometry is a feasible method for remote salinity detection. Computations of microwave brightness temperature of water versus its physical temperature at different wavelengths and salinities by Geyer (1968, reported in Edgerton and Trexler, 1969) indicate a small dependence on salinity for some wavelengths. This dependence has been utilized by Droppleman, Mennella, and Evans (1970) to detect salinity variations near the mouth of the Mississippi River. The conditions during the experiment were ideal, in that waters were calm and surface temperature variations were less than 1.0°C. A multiple-wavelength microwave technique should allow salinity determination in less ideal conditions: From thermal infrared data, temperature can be determined. From microwave data at a wavelength with no salinity dependence, it will be possible to obtain sea surface roughness using the temperature determinations. From microwave data at a second wavelength which has a salinity dependence, it should be possible to determine salinity. The choice of microwave wavelengths will be crucial, because the salinity dependencies are small.

Another possibility which should be investigated is radiophase conductivity mapping using surface wave signals from VLF radio stations. Barringer and McNeill (1969) reported the use of a prototype system for terrain conductivity mapping useful in geologic prospecting. It should be possible to apply the system to mapping of brackish waters where variations in salinity cause variations in conductivity.

9. Currents and Circulation

One of the greatest problems which confronts coastal zone oceanographers today is the lack of detailed knowledge concerning circulation in large lakes, bays, and on the continental shelf. Currents, circulations, and mixing are pivotal features of the physical, chemical, and geological properties of coastal water. The energies associated with mixing may actually drive motions of water masses. Solutions to a multitude of environmental problems depend on understanding these basic processes, because currents are a common factor in many problems: they determine rates of transport and patterns of concentration and dispersion for pollutants, fresh water, suspended sediments, and organic material, in transit through coastal waters to the sea. They affect distribution and survival of biological species.

Because the coastal current and circulation pattern is a significant factor in many and important coastal zone problems, the study of coastal circulation is an item of highest priority.

The more we know of estuarine hydraulics and coastal circulation the more favorable will be our position to deal with pollution problems. As population increases in the coastal zone, increased waste disposal will burden coastal waters. This disposal must not compromise bioproductivity or recreational activities on the shoreline. Oceanographers are frequently asked to advise on the best locations for subaqueous sewage outfalls. They are often unable to provide adequate advice because knowledge about circulation of the near-shore zone is insufficient. Exhaustive study of waste discharge plumes is required to determine

the rate of mixing and dilution of the waste. Study must take account of temperature, salinity and density, depth of entry, turbulence, tidal effects, and, most important, currents and circulation.

The study of currents in bays, river mouths, and along coastlines, particularly in rip currents, is important because it outlines areas of sediment deposition and erosion. The morphology of seaside marshes is influenced by near-shore circulation. Tidal discharge patterns should be obtained in inlet-marsh channel networks.

A special coastal zone area where circulation patterns should be studied is the mouths of large estuaries. It has been suggested that eddy systems exist on the sides of the mouths of estuaries; if this is so, these systems could very well determine the fate of populations of commercially important species. In the case of the Chesapeake Bay entrance, Harrison, Brehmer, and Stone (1964) demonstrated the existence of a non-tidal eddy south of Cape Henry during a period in August. Miller (1952) postulated an eddy near Cape Charles, and a westward flowing current toward the mouth of Chesapeake Bay from a distance of at least 30 nautical miles offshore. It is important to know if the suggested features actually exist; if so, they have significance for fisheries, distribution of sediments, and dispersion of wastes.

The importance of currents for fisheries is illustrated in the Chesapeake Bay, an important oyster-producing estuary. The most productive seed oyster area of the Bay is the lower James River whose productivity has been under investigation for some

time (see Hargis, 1968). It results from large regular sets, good survival (due to favorable salinities), and a subsurface upstream current carrying and retaining oyster larvae near good setting grounds. Thus, current is thought to be a determining factor in the abundance of seed oysters in the lower James River.

A second coastal area of interest is the oceanic island surrounded by deep water. In some open ocean regions, a deep thermocline and steady trade winds prevail. Such regions have been termed "oceanic deserts" because vertical mixing is strongly inhibited by the density structure, and surface waters have a poor supply of nutrients. When horizontal currents in such areas encounter islands, the resulting turbulence causes mixing and upwelling which bring nutrients to the surface. The areas consequently become "islands" of bioproductivity.

There have been many measurements of salinity, currents, and tides, and many studies of coastal circulation, such as Norcross, Massman, and Joseph (1962), Bumpus and Lauzier (1965), and Harrison, Norcross, Pore, and Stanley (1967). Our understanding of circulation as a whole, despite these efforts, still remains vague and imprecise. Where studied, circulation has usually been described in general terms and derived from gross spatial and temporal resolutions. A few exhaustive studies have been done for small areas, such as the analysis of lightship data by Mandelbaum (1955).

Coastal circulation studies should be detailed, with consideration of oceanographic, meteorological, and hydrologic factors. Emphasis must be placed on elucidating wind-driven currents. Daily

patterns should be determined within at least the first ten miles offshore. Long term programs (2 to 3 years) to obtain time-series data are needed with a higher spatial sampling density than on the deep ocean.

The potential gain from new effort at this time cannot be over-stated. With the use of computers, large amounts of data can be processed, and models can be refined to predict large-scale dynamics from a few input parameters such as wind, temperature, and estuarine inflow and discharge. The limiting factor is the lack of a synoptic, wide-area method of study.

Measurement and mapping of currents and circulation patterns has been tedious in the past, and all methods have been deficient in not providing synoptic wide-area data. Several new methods have recently become available. The tracking of oil slicks has potential because slicks form and move according to the direction of the surface flow. Another method of study is the use of natural and man-introduced radioactivity as an indicator of currents, circulation, and concentration areas.

Remote sensing in this situation is especially potent. It solves the problem of synopticity. Visible and infrared imagery constitute the best techniques for determining coastal zone circulation because of the existence of turbidity and temperature patterns. Remote sensing of salinity, as it is developed, will become another powerful method of coastal study. For precise measurement of currents, photogrammetry of ice and other floating objects with aerial and space photography has been demonstrated (Cameron, 1964; Ramey, 1968), but this method may be impractical

at satellite altitude. Overall, we believe that imaging remote sensing is capable and critically needed for the high priority problem of coastal currents and circulation.

10. Estuarine Chemical Cycles

An important complement to studies of estuarine pollution is the study of naturally-occurring estuarine chemical cycles. The chemical species of fresh water inflows are related to the soils and bedrock of the drainage basin. During summer seasons, estuarine stratification is accompanied by oxygen depletion and large natural changes in concentrations of nitrate, phosphate, and other nutrients. Research into such problems is needed for application to ecological studies. Remote sensing is not expected to be of major assistance. Some help will be obtained from the monitoring of water color, temperature, and salinity, but in general the needed information is chemically specific.

11. Mathematical Models and Computer Simulation

High priority goes to the development of computer-simulation models of major estuaries. It is of the utmost importance to form groups of coastal zone scientists given solely to developing the various models that are needed.

Estuarine models can be formulated which will predict water quality, spatial and temporal distribution of tides, wind-generated currents, changes in fresh water inflow, and responses to a multitude of other inputs. Such models can provide a quantitative framework for cost/benefit analyses and the maximization of beneficial uses of estuarine areas.

Models have been designed around specific aspects of the coastal zone, such as sedimentary processes, plankton ecology, and fisheries ecology. Recently, several groups have been active in developing hydrographic models for major rivers (Thomann, 1963; Hetling, 1969; Pence, Jeglic, and Thomann, 1969; Callaway, Byram, and Ditsworth, 1969; Camp, Dresser, and McKee (Consulting Engineers), 1969; Hacker, Billups, Wilkins, and Pike, 1970; Hargis, 1970). New emphasis, however, should be on unitary treatment of entire estuarine ecosystems, because the pressures on one aspect eventually have repercussions on others.

Remote sensing will be of value in modeling because remote data acquisition is synoptic and uniform in technique, accuracy, and format. This point should not be overlooked; it is of great importance. Modeling will require great volumes of data to reduce subjectivity in model design, and to allow correlations of statistical significance to emerge. The needed volumes of data will be unmanageable unless remote sensing can be exploited.

C. Fishery Resources

1. Summary of Problems

The major threats are pollution, destruction of estuarine nurseries and setting grounds, and inability to control disease and predatory organisms. Subsidiary problems include fishery statistics and abundances, and protection of public health. In the United States, although the populace is not starving for lack of fish, shortages in particular fisheries are increasingly severe. If estuaries become poor habitats for commerical species, the

general fishery may decline disastrously. Many of the threats to fishery resources have been considered above; in what follows we consider the resources themselves directly. Since fishery problems vary so much with area, we mention only general considerations.

2. Abundance of Commercial Species

Statistics of commercial fisheries of the coastal zone are needed for management and research, but are presently scarce and inaccurate. Remote sensing may assist in providing statistical data on vessel densities and frequencies.

Distribution of fish is not well known. Some are caught only when they appear in coastal waters. Thus, a major problem is the location of fish schools.

The delineation of temperature gradients and isotherms and the detection of fish oil slicks are of great assistance in locating fish schools. For example, sea surface temperature charts for the west coast issued monthly since 1960 by the Weather Bureau have been highly successful in assisting the tuna fishery (see NAS, 1969). Sea surface temperature measurement by satellite for location of fish schools should be emphasized.

We hasten to point out that additional aids to fishermen are not necessarily helpful to the long-range conservation of fishery resources. Over-exploitation and depletion of populations are well-known for many fishing industries, in particular the whaling industry (see Ehrlich and Ehrlich, 1970). Any improvement in fishing methods should be accompanied by tighter control of annual catch.

Estuarine conditions, especially temperature, critically influence anadromous fish populations. To manage and preserve stocks it is necessary to maintain water quality and existing water temperature patterns. Remote sensing of estuarine water quality and water temperature has a demonstrated potential to assist the management of fishery resources.

More must be known of fish behavior and physiology. The causes of population changes of commercially important fish and shellfish are still unknown. It is important to learn the relative importance of fishing, pollution, estuary destruction, natural environmental changes, and migration, in causing fluctuations.

The overall goal of a fishery resources program must be the maintenance of supply. The first priority should be to reduce pollution and preserve estuaries. Second priority should be placed on fishery statistics to permit determination of maximum yield consistent with ecological balance. Third priority should go to finding fish schools to support commercial fishing.

Remote sensing can contribute significantly to priorities one and three. It is a powerful method for monitoring water quality and water temperature, and for finding fish schools.

3. Health of Fish and Shellfish; Pathology and Parasitology

A major problem is determining the condition or "state of health" of commercial and/or important forage species. Presently we know only whether fish are present or absent, and the only indication of deterioration of a species condition may be mass mortality (i.e. a fish kill).

There is an enormous knowledge gap in the area of physiological parameters. Baseline values of many parameters are not known under either normal or stressed conditions, so we are unable to determine from measurement of these parameters if organisms are under stress. We do not know the relative importance of stresses such as parasitism, disease, or deteriorating water quality. Reliable indicators of stress must be discovered.

Disease problems today do not appear to be formidable. However, because estuaries are rapidly becoming unsuitable habitats for fish and shellfish, aquaculture may be extensively employed in the future, with crowding of organisms. Such crowding will result in epizootics. It is essential that basic information be gathered now concerning the biology of all fishery pathogens. Otherwise it will be difficult to control future outbreaks of disease.

These important subjects are outside the domain of remote sensing.

4. Public Health Protection

Studies on pathology of marine organisms should focus on protection of the public from poison, disease and infection. Studies also should continue on the concentration of pollutants by edible fish and shellfish. Petroleum products and other materials can make fish unpalatable and dangerous to public health. Investigations are needed to identify sources and determine toxicity levels.

Remote sensing cannot directly assist these important public health problems. Determination of circulation patterns and tracking of pollutants may be of some benefit.

D. Water Supply

1. Reduction of Fresh Water Inflow

Fresh-water inflow to coastal waters is being sharply reduced by storage, diversion, and irrigation, while the remaining water is being polluted (see Reid et al., 1966, and Black, 1966). More attention should be given to the effect of reducing water inflow on the fresh water supply in the coastal zone.

There should be immediate and complete control and management of dams, wells, and other water supply diversions, in order to conserve ground water, for ground water levels influence river flows more than commonly realized. It is estimated that 40 percent of the flow of the Delaware River comes from the ground rather than from direct precipitation runoff (Delaware River Basin Commission, 1969). With each new upriver diversion of water, the overall flow decreases and saline waters intrude further upstream. Ecosystems disintegrate which formerly were protected by fresh water. Major new diversions are nevertheless planned by the Delaware River Basin Commission to satisfy the growing regional population.

Studies are needed on the quality and quantity of water supply under a great variety of contingencies. Computer analysis would be most valuable in this regard. Selection of sites and appropriate times for water withdrawal could be based on tides, circulation, and salinity patterns. The potential utility of remote sensing of these parameters (discussed in earlier sections) is substantial.

2. Subsurface Fresh Water Supplies in Estuaries and Continental Shelf Floors

Fresh water resources beneath estuary and shelf floors are presently being tapped for municipal needs. Additional water resources will be required by enlarging cities and growth of marine-oriented industries.

To plan effective use of subsurface water resources we need to know the extent, capacity, and structure of bottom and sub-bottom ground water-bearing formations beneath estuaries and sounds. The salt-fresh water interface in the aquifers extending beneath coastal water bodies must be defined and monitored. Studies of the aquifers should be conducted in order to prevent the undesirable happenstance of a channel or other excavation breaching a shallow fresh water aquifer, permitting its contamination with salt water. Long Island is well-known for the infiltration of salty water into the aquifers underlying Brooklyn (Upson, 1966).

In general, the need is for geophysical study of structures beneath coastal waters. Geophysical data collected in such study will serve the needs of the immediate future and permit long-range evaluation. By taking into account the physical parameters of the subsurface environment it may eventually be possible to convert shallow sands with highly saline water to fresh water sands. Also, water containing bio-degradable wastes might be utilized to form a barrier or groundwater dam in areas where salt water intrusion is a problem or potential problem.

The potential of remote sensing in this problem is minimal. Remote sensing might be used to locate thermal contrasts due to fresh water discharge from submarine springs. If salinity could

be measured remotely, such discharges could be located by mapping salinity contours.

E. Mineral Resources

1. Continental Shelf Mineral Resources

The chief resource problem in geological oceanography deals with mineral resources on the floor of the continental shelf. Sand, gravel, oil, gas, and sulfur buried beneath offshore waters constitute large and economically important resources. The return from developing shelf resources would probably repay many times the effort invested in basic exploration.

We need to know the location of deposits, and their extent, thickness, structure, grade, and amount of overburden. Sediment distributions indicate where specific deposits are located. Sizable deposits should be examined in detail. From camera-grab samples, shallow coring, laboratory analyses and geophysical structure sections, a series of inventory charts can be prepared to evaluate the deposits.

Remote sensing may be able to assist mineral exploitation where remote bathymetry proves feasible, by providing maps of bottom topography. Remote surveys of local variations in the earth's magnetic and gravitational fields can also be of assistance, by suggesting where variations in the structure of the crust are located. Remote airborne surveys are currently conducted at sea by the U. S. Naval Oceanographic Office (ESSA, 1968).

2. Effects of Continental Shelf Dumping and Mining

As disposal sites on land become scarce, bay and shelf

floors are increasingly favored as dumping grounds. Before more dumping of industrial waste and sewage sludge is allowed, important questions must be answered concerning the ecological effects. For example, it now appears that the area receiving New York City dumping is biologically sterile (Segerberg, 1970). It is not known if wastes move about or remain stationary. Likewise, when gravel is mined, the movement of dredged material and the size of the area eventually affected are unknown.

These problems require that attention be given to an understanding of the natural distribution of sediments in relation to dispersive processes, waves and current action. The movement of waste material should, if possible, be tracked directly. Studies of natural bottom sediments are needed as a base for study of dump areas.

Remote sensing will be of assistance only by improving our knowledge of surface circulation patterns.

F. Extreme Events: Prediction, Survey, and Assessment

1. Coastal Storms, Hurricanes, Typhoons

The prediction of coastal storms, hurricanes, and typhoons is founded on meteorology and general oceanography. The oceanographic contribution is the study of processes of mass and energy exchange between air and sea. The field study of air-sea interaction is often conducted in the coastal zone, where storms are most important to man.

Because wind is the chief driving force for lake circulation, study of air-lake interaction is of special importance to research

of the Great Lakes area. A particular interest is the effect of the Great Lakes on lee side snow fall.

In these general oceanographic studies of air-water interaction, remote sensing can contribute fundamental data on sea state, foaming, and atmospheric water vapor. The theory of wave development by a surface wind field is well-developed; thus the remote sensing of sea state not only can provide for sea state forecasts, but also for description of surface wind fields (Moore and Pierson, 1967). Because radar can measure sea state, radar scatterometry of the sea is under vigorous development (see Remote Sensing of Environment, 1962-1969; Univ. Kansas Center for Research, 1970). It is being questioned, however, if radar will be useful at high wind speeds, where wind data are most needed.

The need exists not only for wind and storm data but also for sea state forecasts and prediction of storm tides and surges. The effects of surges should not be minimized: In April, 1969, 2800 sq. km of the coast of China was inundated up to 20 km inland to a depth of 1 m by a strong storm (Undersea Technology, 1969).

Air-sea studies should yield continual improvements in forecasts of such disasters. A major need in such studies is the acquisition of time-series data for winds, waves, tides, sea level, currents, and temperatures. Techniques are needed for obtaining the data over wide areas in synoptic fashion; the particular advantages of remote sensing would be in providing an opportunity to determine the scales over which air-sea processes are ergodic, and in the built-in smoothing of minor statistical fluctuations.

Tides can be determined by remote sensing, by means of stereo sequential aerial photographs of shorelines with black and white infrared film. Tide determination from satellite would appear to require data averaging techniques because of the problem of spatial resolution at orbital altitude.

The determination of sea level is at present a more difficult problem. First, the geoid at sea has yet to be defined precisely, and second, the remote measurement of small departures of the sea surface from the geoid will be difficult. The actual departures are in general 10-20 cm, with a maximum of 150 cm, and graded over long horizontal distances such as 100 km. If sea level data could be obtained, they would contribute greatly to the prediction and forecast of currents, tides, and storm surges.

Recent discussions of the sea level remote sensing problem indicate that it may be solvable (NAS, 1969). The key lies in the averaging of large numbers of radar or laser-radar determinations of satellite altitude. The satellite orbit must be known to great accuracy.

2. Tsunamis

Tsunamis, popularly known as tidal waves, are a rare type of sea waves generated by submarine earthquakes. They move at 300-500 nautical miles per hour, and travel thousands of miles. Tsunamis consist of a succession of slow waves several minutes to an hour apart. Their long period and their 0.3 m heights on the open ocean make them nearly imperceptible to the eye until they approach coastlines. In shallow water the waves develop in size

and routinely reach 3 m in height (USC & GS, 1952, and Spaeth and Berkman, 1965). Frequently the waves reach 15 m in height, and a height of 41 m has been recorded (Shepard, 1963). Tsunamis almost always occur in the Pacific Ocean. As a rough average they occur about once every four years.

Coastal damage from tsunamis can be severe. The tsunami of the Chilean earthquake of May 23, 1960 drowned 61 people in Hilo, Hawaii (Shepard, 1963). The tsunami of the Alaskan earthquake of March 27, 1964 caused damage of $11 million at Crescent City, California, and $78 million in Alaska itself (Wilson and Tørum, 1968). The tsunami damage in Alaska was in addition to the $300-400 million earthquake damage (Kurtz, 1970).

The immediate concern is a warning and prediction capability for the purpose of saving lives. A tsunami reporting network, called the Seismic Sea Wave Warning System, was organized by the U. S. Coast and Geodetic Survey in Hawaii in 1948 after the destructive tsunami of April 1, 1946.

Although effective in saving life, the network is not yet capable of accurately predicting wave heights and periods at locations of interest. Development of predictor equations will require data on tsunamis on the open ocean, and bathymetric, topographic, and tidal data in coastal areas.

Damage to buildings, port facilities, and boats from tsunamis can be minimized by construction design, because the mechanisms of tsunami damage are understood (Wilson and Tørum, 1968). What must be known is the expected structural load; therefore, more research is needed into tsunami water particle

velocities and pressure forces in coastal regions. The necessary data can be obtained from tidal current data and rapid and extensive assessment of property damage (before it has been repaired).

Tsunamis induce very high velocity currents which cause rapid erosion and channel scouring. Ship channels may be altered, sites of biological productivity destroyed, and land features heavily eroded. Large topographic and bathymetric surveys are needed quickly after a tsunami to assist in reopening ports and transportation networks.

A variety of the needed data can be obtained with remote sensing more easily than with surface methods. The potential remote sensing contribution is judged to be substantial.

3. Biological Effects of Extreme Events

The 1964 Alaskan earthquake caused drastic changes in stream bed elevations in Prince William Sound, particularly in the intertidal zone. The effect of these changes on the spawning of pink salmon is of major regional importance.

Assessment of the regional changes in biological populations after extreme events requires wide-area survey of the changes in bathymetry, currents, tides and tidal volumes, salinity, and water temperature. Remote sensing is the only methodology which can possibly accomplish such surveys. Census of populations and survey of bottom conditions will continue to require surface measurements.

Immediately following a storm, surveys should be performed to assess the degree of loss of coastal vegetation, because vegetation plays a major role in stabilizing shoreline and sediments.

On the east coast of the United States, the marshlands between the mainland and coastal barrier sustain extensive damage from storms. These areas should be included in the surveys. In addition, the new configuration of the shoreline and the elevation of beaches and backshore should be determined. This information would give a more realistic foundation to engineering design criteria for subsequent coastal defenses.

4. Shoreline Behavior

At the present there is rather incomplete knowledge of shoreline behavior. For example, in Virginia, compilations exist for some ocean shoreline (VIMS and U. S. Army Corps of Engineers) and for only the Rappahannock and Potomac rivers (Virginia Agricultural Experiment Station). However, there are no data for the bayside of the Eastern Shore or the remaining river systems.

Proper management of the shoreline requires a knowledge of the present shoreline response to extreme events and to long term processes. Thus, we need the historical trends for a given locality and reliable data on the physical processes which mold the shoreline. Data are needed on incident waves, winds, and currents, correlated with local shoreline change. A network of monitoring stations is needed, or a wide-area remote sensing system with accurate surface-truth.

a. Long Term Shoreline Processes and Responses

The first important task is to monitor the wave climate at the shoreline. The response of a coastal segment to wave energy is a function of wave direction relative to the shoreline at breaking, and the wave height and period. These variables determine

how much sand will move along the shoreline. Reliable estimates of expected transport are needed to determine the feasibility and maintenance costs of various coastal structures. At present the Coastal Engineering Research Center (CERC) of the U. S. Army Corps of Engineers maintains electronic wave sensors at widely spaced points along the United States coastline to monitor wave heights and periods (Darling and Drumm, 1967; Darling, 1968). CERC also has a visual observation program in cooperation with the U. S. Coast Guard lifesaving stations for observations of wave height, period and direction. There has been little success to date in monitoring the angle between breaking waves and the shoreline. All variables become difficult to monitor at the surface when sea surface motion is complex.

Satellite monitoring of shoreline wave climate would provide a major contribution to management and research. It would be desirable to monitor all three wave variables: direction, height, and period (or wavelength). In the absence of a capability for all three, then wave direction should receive highest priority. If the satellite could discriminate wave direction near the shoreline, the cost of installing additional surface sensors for wave heights and periods would be amply justified.

A subsidiary need is to know how waves transform in shoaling water. Sea state predictions made by the U. S. Navy and ESSA for operational needs are deep-sea forecasts. These forecasts should be extended to the shoreline. More research and observation is needed to properly handle the wave transformation processes. It is known that waves dissociate in passing over shoals, resulting

in a shift of the observed wave period (Byrne, 1969). Observations are needed of the sea-state spectra at various locations on the continental shelf to delineate the transformations which occur.

Several methods to obtain these data could be used: surface level wave recorders, airborne radar or laser wave gages, and satellite sensors. The first method is limited by the expense of installing and maintaining a high density of observation points. But its advantage is that the energy density is presented as a function of wave frequency. The U. S. Naval Oceanographic Office has used radar and laser sensors aboard low flying aircraft and reported some success (Ross, 1970; see also Kirk, 1970; Pierson, 1968; Moore and Pierson, 1967). Here the wave number spectrum is obtained and converted into a frequency spectrum. The successful combination of sensors will likely be low level aircraft flights utilizing radar or laser altimeters and arrays of surface gages. If satellites can provide the needed resolution, they can replace aircraft.

Sea state measurement is needed in both deep ocean and coastal zone oceanography. In the case of the deep ocean, the observations permit forecasting and description of the surface wind field. In the coastal zone, the observations are needed to extend operational forecasting to the shoreline.

The second important task in the study of long-term processes is to monitor coastline configuration in plan (cartography) and cross-section (topography). Prior to the 1930's reliance was placed on topographic and bathymetric surveys. From the thirties until the present aerial photography has fulfilled the need. With

improved coordination, aircraft photography will continue to be adequate to discern long term trends (i.e., sampling once every seven to ten years).

There are a number of transient shoreline features, however, which may be monitored most effectively by satellite. The nearshore zone and beach face is not a two-dimensional entity although this was the prevailing concept for many years. There are many periodic or quasi-periodic indentations which migrate along the coast, with wave lenths between tens of meters to kilometers. Their origin and behavior are poorly understood. Study has been hindered by the lack of inexpensive monitoring vehicles. One would like to determine the evolution and rates of migration of these features.

The practical value of monitoring these features is in determing change of sand volume on the beach. The change in sand volume is commonly obtained by repetitive elevation measurements across widely spaced transects. Obviously, this sampling method is inadequate as it does not consider the effects of migrating rhythms moving along the coast.

Another variable of interest in the plan view is beach width, which with elevation determines the amount of protection afforded backshore areas. Beach width varies seasonally in response to seasonal changes in wave climate.

Elevational changes in backshore dunes are of critical importance to management practices. This is particularly true for major portions of the east coast of the United States where the backshore dune acts as the last barrier to coastal flooding. In

many cases, dunes are stabilized by vegetation. Periodic topographic surveys could help determine what areas need restoration.

A third task is nearshore bathymetry. This has, historically, been one of the functions of the U. S. Coast and Geodetic Survey. Precision surveys were begun in about 1850. For any given reach of coastline, however, one is fortunate to find three surveys in the last 120 years. With such a large sampling interval only the most gross trends can be delineated, but we need information on seasonal and annual bathymetric variations. For most cases, it would suffice to chart the bottom to a depth of 15 meters. With this discrimination we could estimate the seasonal onshore-offshore cycling of sand as well as discern the evolution of hazardous shoals at the mouths of tidal inlets. Color photography from aircraft has demonstrated capabilities for depth discrimination when water clarity is high (Ross, 1968; Vary, 1969; Yost and Wenderoth, 1970). Airborne laser sensors are currently being evaluated for bathymetry (Hickman and Hogg, 1969).

Monitoring of tidal inlets should be included in this program as it is known there is strong interaction between the inlets and adjacent shoreline. The research should include in particular the study of storm induced changes of tidal inlets.

b. Short Term Shoreline Events

Effects of coastal storms are of the highest priority. Although of short duration, energy input is high, and the effects are severe. Damage results from any combination of high waves, strong winds, storm surge, and precipitation. Rapid assessment of storm damage by remote sensing is needed for delivery of

emergency aid and restoration of public services. Remote surveys also can indicate where to concentrate surface study aimed at understanding the dynamics of the land-sea interaction. The more important information needs are listed below.

1) Regional wave climate prior to, during and after a storm.

The density of CERC wave gages along the U. S. coastline is too low to establish gradients of storm activity. Consequently, knowledge of the length of shoreline affected by a given storm is vague. Coastal sea state data would indicate the length of affected shoreline, even with the spatial resolution now obtainable with radar scatterometers.

2) The extent of flooding due to storm surge.

Information on flooding has obvious importance in terms of warning and aid to the public, and it could serve to test mathematical models of storm surge. The value of models should not be underestimated since a verified model would permit prediction of flooding. The data needed are the extent of flooding, and sea level from shoreline to several miles at sea. Remote sensing of these data (see C.1) can be the major data-acquisition method. Because storm surges are much greater in magnitude than ordinary sea level fluctuations, surges will be much easier to measure remotely.

c. Priorities for Shore Study

The problems in order of their priority are measurement of:

a) sea state, especially wave direction at the shoreline,

b) sea level and flooding,

c) shore configuration in plan view (cartography),

d) shore configuation in cross-section (topography), and

e) near-shore bathymetry.

In conjunction with surface observations, satellite remote sensing can play a major role in satisfying these priorities.

G. Other Aids to Shipping and Navigation

1. Ice Thickness and Distribution

Voyages through the Northwest Passage by Humble's ice-breaking tanker Manhattan have raised the possibility that shipping through this ice-bound coastal region may become commercially important. Very little knowledge of regional sea ice conditions is now available. The task of acquiring this knowledge by surface studies would be enormous.

The shipping industry relies on the iceberg patrol of the International Ice Patrol Mission of the U. S. Coast Guard, and the continuing surveillance of glaciers in West Greenland. These glaciers are estimated to annually discharge 5400 icebergs. Ice cover is also of concern in northern rivers and on the Great Lakes, for which the U. S. Navy and the Canadian Department of Transportation carry out ice monitoring and forecasting programs. The savings from iceberg and ice-forecasting programs are thousands of dollars per ship-year.

Four methods of ice survey and study are used actively: field measurements such as coring, visual study from low flying aircraft, aerial photography, and satellite infrared imagery. For aerial reconnaissance alone the United States and Canada spend about $10 million annually. Microwave and radar techniques are being investigated.

The benefits of regular remote monitoring are already substantial, perhaps unique from the point of view of the relative inaccessibility of ice-bound regions. Remote monitoring using satellites began in 1962 with Project Tirec, a joint program of several agencies of the United States and Canada to test the ice-monitoring utility of Tiros photography. With expertise gained since 1962, the specifications for satellite ice monitoring are very well known. Remote sensing is a demonstrated and essential tool for monitoring ice cover.

2. Shoals and Shorelines

Safe navigation depends on accurate bathymetric and shoreline information. Hazards posed by shoals, derelicts, and reefs must be charted with up-to-date information.

The possibility of loss and damage continually threatens, even with charts now available. In 1962, 68 ships were lost to stranding, and another 925 ran aground (IOC, 1964). The losses are at least $100 million annually. The grounding off Great Britain of the Torrey Canyon occurred as the ship "cut the corner" around a coastal promontory (Smith, 1968), with tragic consequences for biota and public recreation.

Bathymetric data are needed most in the coastal zone where water is shallow. Periodic surveying is required, since littoral processes gradually result in large topographic changes. After extreme events, large bathymetric surveys should be mobilized rapidly.

Surveying activities of various United States agencies are already extensive and costly. Mapping, charting, and geodesy by

ESSA, NASA, the Bureau of Commercial Fisheries, the Coast Guard, the Corps of Engineers, and the Navy will consume 13 percent ($74 million) of the national marine sciences budget this year (NCMRED, 1970).

In equatorial latitudes, where sea water is relatively clear, bathymetric surveys will be possible from aircraft and satellite using laser ranging, or visible region multi-spectral photography carefully calibrated by water color measurement (see Ross, 1968; Vary, 1969; Hickman and Hogg, 1969; Yost and Wenderoth, 1970). Remote bathymetric surveys will remain limited to shallow clear-water areas; therefore, remote surveys must be viewed as complementary to surface surveys.

Shoreline surveys, however, can be done completely by remote sensing using black and white infrared photography.

Our overall evaluation is that remote sensing can play a major role in delineation of shoals and shorelines.

3. Currents and Sea State: Ship Routing

Information on currents is used in routing ships. Against ship speeds of 10 to 15 knots, an opposing current such as the Gulf Stream of 2 to 5 knots causes a significant loss of speed. Sea state and associated weather information is even more important for ship routing. High seas and bad weather not only compromise speed of travel but also make it dangerous.

Since 1957, the Military Sea Transportation Service of the U. S. Navy has operated a ship-routing program based on currents, sea state, and weather. Savings due to reduced travel time have

been $3000 per ship crossing the North Atlantic and North Pacific (NAS, 1969). The program undoubtedly reduces losses of ships and men, achieving inestimable savings. A numerical model is being developed for the ship-routing program to allow computer processing (NCMRED, 1970).

The need for remote sensing to delineate currents and sea state in the coastal zone has already been evaluated above in the light of other higher priority problems. Suffice here to say that new information from remote sensing would have economically important spin-off for the shipping industry.

SECTION V

DATA NEEDS

Types of data and their spatial, temporal, and spectral resolutions required for effective treatment of the problems of Section VI are specified below. The problems are divided into categories based on the utility expected of remote sensing. Resolutions for each problem are specified for both surface and remote measurements. For each datum type, we include (if appropriate):

$\underline{x}$:	Spatial resolution:	a) density of sample points expressed as number of km between points in a square lattice. If the resolution of each point must be sharper than the distance between points, a point resolution is given (in parentheses) as number of km per side of a resolution square.
$\underline{t}$:	Temporal resolution:	a) frequency of data collection.
		b) season of year most important.
		c) special events of importance.
$\underline{\lambda}$:	Spectral resolution:	a) general spectral region: visible including lidar (V), near infrared (nIR), thermal infrared (IR), microwave including radar (MW).

Special details such as biota of interest and temperature resolution are included under "other", or included beneath the resolutions as comments.

In general, spatial and temporal resolutions for coastal zone oceanography must be significantly sharper than for deep ocean oceanography, and the desired areas of coverage are more confined. A satellite capable of the needed resolutions for the coastal zone and providing continual coverage would swamp any data handling

system. Consequently, we recommend providing for data acquisition of selected areas by command: single sampling or a programmed sequence.

We envision that selected coastal areas would be the focus of satellite data acquisition for some segment of the year decided by the experimenter. The duration of this segment would initially be decided in conjunction with design of surface surveys and data handling capability. Surface surveys could become a smaller factor in the experiment duration once reliable surface calibrations of the satellite data had been obtained.

In a selected area, desired resolutions may sharpen by an order of magnitude as the site of data sampling moves landward from the continental shelf to a large estuary and then to the mouth of a tidal river. In such cases, separate resolutions are given for each type of sample site.

The world-wide locations of interest for coastal zone oceanography lie in the temperate and tropical zones, between about 65° North Latitude and 55° South Latitude. Only ice observations would be of interest outside this region.

A. Primary Use of Remote Sensing

Surface data for the following items serve mainly to calibrate satellite data.

1. Temperature and Thermal Effluents

	x		t	λ	Other
Satellite water temperature	5.0(1.0)km	shelf	daily	IR	0.5C°,
	1.0	bay	daily	"	range
	0.5-0.01	river	3 hr.	"	0-30°C.

	x		t	λ	Other
Surface water temperature	20.0 10.0 5.0(1.0)	shelf bay river	as needed for calibration; weekly at start.		0.1C°, surface to bottom at 3m interval.

2. Wetlands

	x		t	λ	Other
Satellite maps of areas and species zones	0.1-0.01km 0.01-0.003	areas zones	weekly "	V,nIR "	
detritus via water color	0.1		"	"	
currents and circulation (see A6)	0.1		"	"	
Surface map of species zones	transects		monthly		
water samples for detritus and nutrients	variable		weekly except during winter		

Comments: A multitude of surface data are required to complete a wetlands analysis, for example, local hydrographic and topographic data, total (weekly) light energy input, and animal food analyses.

3. Phytoplankton Ecology

	x		t	λ	Other
Satellite chlorophyll via water color	5.0-1.0km 1.0-0.02 0.5-0.02	shelf bay river	weekly (see comments) " "	V " "	0.1 mg/m^3., range 0.2-3.0 mg/m^3.
currents and circulation (see A6)	5.0 1.0 0.5	shelf bay river	weekly " "	(see A6)	
sea state (see A8)	10.0 5.0	shelf bay	daily "	MW "	
temperature (see A1)	5.0 1.0 0.5	shelf bay river	weekly " "	IR " "	1.0C° at surface

	x		t	λ	Other
salinity (see A5)	5.0	shelf	weekly	MW	2‰, range
	1.0	bay	"	"	0-33‰
	0.5	river	"	"	
Surface plankton counts from water samples	variable		weekly		
toxin concentrations	variable		weekly		
chlorophyll concentrations	20.0	shelf	weekly		See Above
	10.0	bay	"		
	1.0	river	"		

Comments: Surface studies must be detailed and it is difficult to specify a study design in advance of selecting a location. Total (weekly) light energy input is needed. Hydrographic data must be obtained at sites of water samples. Satellite data should be obtained weekly in spring and summer, biweekly in fall and winter until the plankton pattern is established. Chlorophyll a absorption peaks in vivo are at 430 and 680 nm.

4. Coastland Vegetation

	x		t	λ
Satellite vegetation/land-use	0.2km		monthly	V, nIR, MW
water color for all aspects of water quality	5.0	bay	monthly	V
	0.5	river	"	"
Surface water samples for water quality analysis, nutrients, detritus, and plankton	5.0	bay	monthly	V
	0.5	river	"	"

5. Salinity	x		t	λ	Other
Satellite salinity	5.0-1.0km	bay and bay entrance	24-3hr.	MW	2‰, range 0-33‰
	1.0-0.1	river and river mouth	"	"	"

	x		t	λ	Other
Surface salinity	5.0	river	3-1 hr.		0.5‰, surface to bottom at 3m interval.

Comments: Surveys should be modified (during and) after extreme events.

6. Currents, Circulation, Water Masses

There are a variety of indirect methods for remotely measuring currents and delineating circulation patterns. Each method has its particular data resolution requirements necessitated by the datum of interest. For example, ice flows are smaller than the circulation pattern which they follow, and consequently require greater spatial resolution to be of utility. The best indirect methods are indicated by an asterisk.

	x		t	λ	Other
General need current	5.0km 1.0 0.5-0.1	shelf bay river	daily, especially spring and autumn		magnitude: 0.5 m/sec, range 0.0-3.0 m/sec. direction: 5°. Surface to bottom at 3m interval.
Satellite ice (see A11)	0.01		1 hr.	V, IR, MW	
sea level (cont. shelf rather than near shore) (see A9)	10.0		24 hr	V, MW	5cm
sea state (convergence lines, etc.) (see A8)	0.1		3 hr	MW	wave ampl. 3m; wave length 30m.
tides (see A9)	1.0		3 hr	nIR	0.5m
*salinity (see A5)	1.0		3 hr	MW	2‰

	x		t	λ	Other
*water color	1.0		3 hr	V	4 visible bands
*temperature (see A1)	1.0		3 hr	IR	0.5C°
oil slicks (see B2)	0.02		1 hr	v, IR, MW	
Surface current	10.0km 5.0 1.0	shelf bay river	variable " "		current meter; surface to bottom at 3m interval.

Comments: The circulation pattern in different phases of the tidal cycle is desired in bays and river mouths. Surface data specifications presume adequate remote sensing data of one type or another.

7. Suspended Sediments

	x		t	λ	Other
Satellite suspended sediment via water color	5.0km 1.0 0.5	shelf bay river	daily " "	V	
sediment accretion and erosion via bathymetry (see A10)	1.0	where possible	monthly		depth to 15m with 0.3m accuracy.
Surface suspended sediment via water samples	20.0 10.0 5.0	shelf bay river	monthly " "		analysis of type and origin, correlation with water color.
sediment accretion and erosion via bathymetry (see A10)	0.5 0.5 0.1	shelf bay river	seasonally " "		depth with 0.3m accuracy.
sediment cores	variable		infrequent		

Comments: laboratory study needed of sediment chemistry. Surface surveys will provide primary data for accretion and erosion studies. Extra data needed after extreme events.

8. Sea State

Satellite	x		t	λ	Other
wave angle	10.0(5.0)km	shelf	daily	MW	3°
	5.0(0.5)	nearshore	"	"	"
	5.0-1.0	bay	"	"	"
wave amplitude	10.0(5.0)	shelf	daily	MW	0.3m
	10.0(0.5)	nearshore	"	"	"
	5.0-1.0	bay	"	"	"
wave period	10.0(5.0)	shelf	daily	MW	1 sec.
	10.0(0.5)	nearshore	"	"	"
Surface					
wave angle	20.0	shelf	monthly		3°
	10.0	nearshore	"		"
	5.0	bay	"		"
wave period	10.0	nearshore	monthly		1 sec.

9. Surge, Tides, Sea Level, Tsunamis

Satellite	x		t	λ	Other
surge	1.0km		6 hr at time of storms	V,MW	0.5m, range (variable) 0-6m
tides	1.0		3-1hr	nIR	0.2m, range (variable) 0-4m
sea level	10.0	cont. shelf	daily	V,MW	0.05m, range 0.15m
tsunamis	10.0	Pacific ocean	1 hr for 24 hr after earthquakes and volcanic eruptions	V,MW	0.2m on open ocean
tsunami currents (see A6)	0.1	nearshore	"	(see A6)	1.0m/sec, range 0-5m/sec.
floods	1.0(0.05)		6 hr at time of storms	nIR	

Comments: No special surface measurements beyond use of already-stationed tide gages is envisioned. The number of stations should be increased.

10. Littoral Response, Shoals, Shorelines

	x		t	λ	Other
Satellite					
sea state (see A8)	5.0(0.5)km	nearshore	daily	MW	
shore plan (cartographic) and cross-section (topographic) views	0.01km		monthly	V, nIR	0.5m vertical resolution
bathymetry	0.05	nearshore and near shipping lanes	seasonally and after extreme events	V	0.5m, range 0-15m
tides (see A9)	0.01		3 hr	nIR	0.2m, range (variable) 0-4m
Surface					
sea state (see A8)	5.0	nearshore	monthly		
shore plan and cross-section views	transects		monthly		0.5m vertical resolution
bathymetry	transects		seasonally, and after extreme events		0.5m, range 0-15m
tides (see A9)	1.0		monthly		0.2m

Comments: Plan and cross-section views would be useful even if the spatial resolution were degraded from 0.01 to 0.05km, and, in the direction of the shoreline, to 1.0 km. In particular for shore studies, bench marks in the field of view with precisely known coordinates are an important requirement.

11. Ice

	x	t	λ	Other
Satellite				
ice	0.05(0.01)km, 40° to 80° North Latitude	weekly	V, IR, MW	20cm thickness, range 0-1m, percent area covered.
Surface				
ice	variable	variable		cores

Comments: These data would provide for 5 day short-range forecasts of ice cover and icebergs.

B. Major Use of Remote Sensing

Surface and satellite data are complementary.

1. Sewage, Nutrients, Oxygen-Demanding Wastes

	x		t	λ	Other
Satellite					
water color	1.0km	bay	monthly	V	
	0.5	river	"	"	
water temperature	1.0	bay	monthly	IR	0.5C°, range 0-40°C.
	0.5	river	"	"	
Surface					
water samples for laboratory analysis	1.0	bay	monthly		
	0.5	river	"		

2. Oil Films on Coastal Waters

	x	t	λ	Other
Satellite				
oil films	0.1km	daily and after spills	V, nIR, IR, MW	area, thickness
Surface				
oil film samples for laboratory analysis	variable	variable		type, age, pesticide content.

3. Estuarine Chemical Cycles

	x	t	λ	Other
Satellite				
salinity (see A5)	1.0km	weekly	MW	2‰, range 0-33‰
temperature (see A1)	1.0	weekly	IR	0.5C°, range 0-30°C.
water color	1.0	weekly	V	
Surface water samples for laboratory analysis	5.0	weekly		

Comments: Summer is the season of interest in the temperate zone.

4. Coastal Fishery Resources

	x	t	λ	Other
Satellite				
fish schools	0.01km	daily	V, IR, MW	
fishing vessels	0.005	daily	V	transponder interrogation
water temperature (see A1)	0.05	daily	IR, MW	
chlorophyll via water color (see A3)	5.0	weekly	V	0.1 mg/m^3, range 0.2-3.0 mg/m^3.

Comments: Daily coverage is desired, with concentration in areas of known productivity: Georges Bank, Cape Hatteras, and Peru. Unfortunately, productive fishing banks have heavy cloud cover. Fish color varies with species, age, and behavior. No surface measurements beyond present levels is envisioned.

5. Water Supply

	x		t	λ	Other
Satellite surface supplies via river and reservoir water level	0.1km	river, reservoir	weekly	nIR	
salinity (see A5)	1.0-0.1	river	weekly	MW	2‰, range 0-33‰
tides (see A9)	1.0	bay, river	3 hr	nIR	0.2m, range (variable) 0-4m

Comments: Major portions of the data needs are supplied by geology, hydrology, and meterology.

C. Beneficial Use of Remote Sensing

Remote sensing data can supplement a program based primarily on surface data.

1. Toxic Wastes, Biocides, and Heavy Metals

	x	t	λ	Other
Satellite currents and circulation (see A6)	5.0km	monthly	(see A6)	
temperature (see A1)	5.0	monthly	IR	locate outfalls
Surface water samples for laboratory analysis.	1.0	weekly		
biotic samples for laboratory analysis.	1.0	weekly		

Comments: Surface samples should be obtained in industrialized areas. Special need for surface data after agricultural and aerial use of biocides.

2. Radioactivity

	x		t	λ
Satellite currents and circulation (see A6)	5.0km 1.0	bay river	monthly "	(see A6) "
Surface water samples for radionuclide analysis	0.5	nuclear power plants	monthly	

3. Mineral Resources

	x		t	λ	Other
Satellite currents and circulation (see A6)	1.0km	shelf, near deposits	monthly	(see A6)	
bathymetry (see in A10)	1.0	shelf, near deposits	yearly	V	where possible
gravimetric and magnetic data	___		___		

Comments: Geologic data for the continental shelf are the primary need.

D. Limited Use of Remote Sensing

Remote sensing is only of indirect and minimal use.

1. Dissolved Oxygen

	x	t	λ
Surface dissolved oxygen	5.0-1.0km polluted areas, estuaries	weekly	

Comment: Water color measured from satellite can indicate water quality. An inference about dissolved oxygen might be valid under special circumstances.

SECTION VI

REMOTE SENSING AND PRIORITY PROBLEMS: RANK ANALYSIS

A. Quantitative Ranking of Priority Problems

The quantitative ranking of priority problems in coastal zone oceanography is approached with caution, and with heavy emphasis on its limitations: ranking is subjective, and the transformation from opinion to numbers is ill-defined.

The utility of ranking is that it "forces the issue" and rapidly exposes defects in the list of problems and in the assigned rank values. Over time, modification and testing against the real environment can increase the reliability of the ranking and reduce its subjective content. The ranking then becomes useful in practical, organized problem solving and in mathematical modeling.

The ranking below has not had benefit of testing. To minimize misinterpretation, the ranking should always be considered in the context of the overall report.

Table 2, the list of coastal zone oceanographic problems on page 23, includes our assigned numerical ranking. Ranking was based on the integers 1 through 9 (in an arithmetic relationship), with multiple use of integers permitted. A high number indicates great importance. Integers were first assigned to main headings in Table 2 (such as 1) and 1A)), based on considerations of national needs from Section III.A., and of coastal zone needs from the rest of Section III. Entries under each heading were then ranked individually. Finally, the list of ranks as a whole was examined and rank values from different headings were compared by pairs for acceptability.

B. Remote Measurables

Remote sensing in oceanography has been actively examined and tested, and reports have appeared in a number of special publications and symposia: Ewing (1965), Zirkind (1965), Remote Sensing of Environment (1962-1969), Conrod (1967), Conrod, Boersma, and Kelly (1968), General Electric Company (1967), Spacecraft Oceanography Project (1968), ESSA (1968), NAS (1969b), Badgley, Miloy, and Childs (1970).

Because of the high level of effort, some oceanographic variables and parameters already have been demonstrated to be remotely measurable, such as sea surface temperature. For some variables in this category there remains the question of sufficient spectral, spatial, and temporal resolution. A few important variables are not remotely measurable at present, but there is reason to be optimistic that future technological development will make them measurable. In a third category are variables which are not likely to be remotely measurable, such as dissolved oxygen. The variables which fall into the first two categories will be termed "remote measurables" where this designation means "measurable from aircraft or satellite by means of the eye or instruments". A list of remote measurables for coastal zone oceanography is given in Table 3. Currents and circulation patterns are not included in Table 3 because their remote measurement is derived from the listed measurables.

Although coastal zone oceanography is broad in subject-matter, we have constrained it to exclude meteorological variables. This constraint is justified by the division between satellites for

TABLE 3

REMOTE MEASURABLES

FOR

COASTAL ZONE OCEANOGRAPHY

ice
sea level, altimetry
sea state
tides
salinity
water color, chlorophyll
water surface temperature
oil slicks
bathymetry
shorelines
shore topography
coastland vegetation, land use
benthic vegetation
fish schools
coastal mammals, birds
bioluminescence

oceanography and satellites for meteorology. However, meteorology and oceanography have such a fundamental interrelationship that making oceanographic and meteorological satellites complementary and mutually beneficial should be given the highest priority.

C. Relevance Matrix: Remote Measurables versus Data Needs

A relevance matrix (see Summers, 1969; Muir, 1970) for remote measurables versus priority data needs has been prepared (see Tables 2, 3, and 4). The rows are coastal zone oceanographic high priority data needs, and the columns are coastal zone oceanographic remote measurables[6]. The matrix entries are relevance or weighting factors (based on Section IV) which quantify the potential of measurement of each remote measurable to satisfy data needs. Consideration of required data resolutions compared to available remote sensing methods was deliberately put aside in the determination of weighting factors; it was assumed that the remote measurables could be measured with whatever resolutions are required. The matrix consequently owes nothing to remote sensing methods and instruments in use; on the contrary, it should be used as a guide for deciding what instruments are needed.

The meaning of the symbols in Table 4 is as follows: "X", the remote measurable and the datum need are identical; "3", the measurable is of primary importance; "2", the measurable is of secondary importance; "1", the measurable will be of help; and "blank", the measurable will be of relatively negligible help.

[6]Benthic vegetation, coastal mammals, and bioluminescence were omitted from the remote measurables in Table 4 by reason of low overall utility.

TABLE 4

RELEVANCE MATRIX:

REMOTE MEASURABLES VERSUS
DATA NEEDS

REMOTE MEASURABLES

DATA NEEDS

	ice	sea level	sea state	tide	salinity	w. color	temp.	oil	bathy.	shore	topo.	coast.	fish	SUMS
tox.						1	2	2	1			2		8
sew.						3	1	1	1			2		8
rad.					1	1	2					2		6
oil							3	X				2		9
sed.					2	3						3		8
ther.	2					2	X					2		10
wetl.					3	2	3		3	3	3	3		20
phyto.					2	3	3	3						11
coast.						2	1				2	X		9
oxy.						1	2							3
sal.				2	X							1		7
curr.	1	3	2	2	3	3	3	1	1	1				20
chem.					3	2	3							8
math.				3	3		3		3	3				15
fish					2	2	3	3					X	14
shell.					3	2	1		2					8
water					3	2		2				2		9
miner.	1							1	2					4
sea st.			X											4
surge		X		X										8
littl.			3	3		1	2		X	X	X	3		24
ice	X						3							7
SUMS	8	7	9	14	29	30	39	17	17	11	9	26	4	220

Several points about the matrix in Table 4 deserve attention. At this time, the matrix is not yet seasoned and cannot avoid being subjective. Consequently, we have without hesitation arranged it to please the eye and to imply which measurables are most important. The columns of remote measurables are arranged from left to right according to physical, chemical, geological, and biological oceanography. The data needs are interrelated; the interrelationships were considered in choosing weights.

D. Uncertainty Analysis

The ranking and the relevance matrix have been subjected to uncertainty analysis (also called information or communication theory). The methods of uncertainty analysis are outlined in Garner and McGill (1956), and Shannon and Weaver (1964); we relied on Ashby (1962, unpublished). The accepted measure U of "uncertainty" is the expression

$$U = -\sum_{i}^{n} (x_i/N) \log_2 (x_i/N)$$

where the x_i represent the countable occurrences (or items) in the i^{th} of n categories, and $N = \sum_{i}^{n} x_i$. The quantity x_i/N is often regarded as a probability.

Uncertainty analysis has been invoked in order to objectively resolve two problems. Problem (#1) is the quantitative effect of the weighting factors for remote measurables on the data-need rankings; the question here is whether the weights make some priority needs much more tractable than others. If an important need has no measurables at the present time, remote sensing or otherwise, its priority in the operational sense will decrease

(until new techniques surface or it can be rephrased to a tractable form).

Problem (#2) is selection of the most valuable remote measurables. These will determine the choice of sensors.

In the application at hand, U measures the "uncertainty" involved in, or the minimum bits of information needed for, determining in which data need a given unit-weight of rank may be found. Loosely speaking, high U means equally weighted problems, while low U means a few problems are heavily weighted, at the expense of others.

1. Results

For Table 2, n = 22, N = 161, and U = 4.37 bits. The 22 data needs if equally weighted would give nearly the same value, U = 4.46 bits; thus, the ranking is close to uniform. It has not singled out a small number of data needs for overwhelming emphasis.

Comparison may be made with a ranking based on sums of weights in each row of Table 4. Each "X" in Table 4 was replaced by "4" for calculations. Weights in the row for each of the 22 data needs were summed, and U for the 22 sums calculated to be U = 4.28 bits. Thus, if data needs were ranked not on intrinsic importance but on the utility of remote measurement, ranking would be slightly less uniform, that is, only slightly higher on some of the needs, in comparison to the actual ranking.

To answer problem #1, the question do the weights "modify" the data-need rankings, we combined weights with rank values by multiplying the weights in each row of Table 4 by the appropriate

rank value for the row (see Table 5). Each "X" in Table 4 was replaced by "4" for purposes of multiplication. In Table 5, entries in each row were summed, and U for the 22 sums calculated to be U = 4.19 bits. This result, compared to 4.37 bits on the rank values by themselves, indicates some change in overall ranking. Loosely speaking, the multiplication decreases the uniformity of ranking by 13 percent (since $2^{(4.37-4.19)} = 1.13$). Given the subjectivity of the rank values and weights, this change is significant but not major. Interesting details will be discussed in paragraph 2.

To answer problem #2, the selection of the most valuable remote measurables, sums S by columm were formed in Table 5. From the sums S, U = 3.35 bits. If the columns had been equally weighted, U would have been U = 3.70 bits, and we would be forced to choose among the measurables by arbitrary blind choice. Loosely speaking, the weighting has reduced our "blindness" by 27 percent (since $2^{(3.70-3.35)} = 1.27$), a significant amount. We feel that the test of time would modify S and U values by a small amount, but not enough to invalidate a choice of some measurables (and discard of the rest), on the basis of sums of weights, instead of by blind choice. Based on the column sums, the remote measurables are listed in order in Table 6 with their percentage scores.

2. Discussion

Although the weights of Table 4 do not cause a major shift in overall data-need rankings, a few individual data needs are affected enough to deserve comment. In Table 5, the row sums reveal which data needs might undergo a change in emphasis. The

TABLE 5

WEIGHTED RELEVANCE MATRIX:

REMOTE MEASURABLES VERSUS
DATA NEEDS

REMOTE MEASURABLES

DATA NEEDS	ice	sea level	sea state	tide	salinity	w. color	temp.	oil	bathy.	shore	topo.	coast.	fish	SUMS
tox.						9	18	18	9			18		72
sew.						27	9	9	9			18		72
rad.					9	9	18					18		54
oil							27	36				18		81
sed.					16	24						24		64
ther.	18					18	36					18		90
wetl.					27	18	27		27	27	27	27		180
phyto.					18	27	27	27						99
coast.						18	9				18	36		81
oxy.						9	18							27
sal.				18	36							9		63
curr.	9	27	18	18	27	27	27	9	9	9				180
chem.					24	16	24							64
math.				27	27		27		27	27				135
fish.					16	16	24	24					32	112
shell.					21	14	7		14					56
water					15	10		10				10		45
min.	3							3	6					12
sea st.			16											16
surge		16		16										32
littl.			12	12		4	8		16	16	16	12		96
ice	8						6							14
SUMS	38	43	46	91	236	246	312	136	117	79	61	208	32	1644

TABLE 6

REMOTE MEASURABLES

IN ORDER OF PRIORITY

	Item	Percent Score
1.	Water surface temperature	19.0
2.	Water color	15.0
3.	Salinity	14.4
4.	Coastland vegetation, land use	12.7
5.	Oil	8.3
6.	Bathymetry	7.1
7.	Tides	5.5
8.	Shorelines	4.8
9.	Shore topography	3.7
10.	Sea state	2.8
11.	Sea level, altimetry	2.6
12.	Ice	2.3
13.	Fish schools	1.9

remote measurables allow greatly increased emphases on wetlands and on currents and circulation. Moderate increase is allowed on mathematical models, and on littoral behavior. Severe reduction of emphasis is implied for dissolved oxygen, that is, it appears we shall be completely limited to surface measurement.

It may be asked whether selection of remote measurables based on high values of the column sums in Table 5 is wise, since a high sum means a large number of entries in a column, and numerous entries could mean that the measurable has a variety of interpretations. For example, the interpretation of water color in an area of moderate pollution may be ambiguous if several pollutants and microscopic organisms in the water have the same spectral signature. This potential problem deserves concern. It must be investigated in the context of remote sensing techniques and spectral signatures.

SECTION VII

EARTH OBSERVATION SATELLITES

AND THE

INTERNATIONAL DECADE OF OCEAN EXPLORATION

Providing information about the International Decade of Ocean Exploration (IDOE) likely to be useful to NASA is very difficult at the present time, especially with respect to the needs of coastal zone oceanography. A brief review of the recent history and present status of IDOE will demonstrate the basis for our hesitancy to provide positive recommendations.

The most useful overall statement on United States participation in IDOE is provided in the program recommendations submitted to the President by the National Council on Marine Resources and Engineering Development in September 1969 (NCMRED, 1969). This report (revised) was endorsed by the Committee for Policy Review.

The National Council identified seven long term goals deserving of highest priority for new funding during IDOE. These were as follows:

1) Environmental quality
2) Environmental forecasting
3) Seabed assessment
4) Fisheries exploration
5) Sensor development
6) Data sharing
7) Coastal charting

The selection of these priorities, especially numbers 1, 3, 4, and 7, implies strong emphasis on the coastal zone.

On October 19, 1969, the Office of the Vice President announced a five-point program to strengthen the national marine science activities (Office of the Vice President, 1969). This program included IDOE, and two proposals specifically related to the coastal zone: a new coastal zone management program, and the establishment of coastal marine laboratories.

Shortly thereafter the National Science Foundation was named to administer IDOE. On July 28, 1970, the National Science Foundation made the first formal NSF announcement on IDOE (NSF, 1970), containing IDOE goals and priorities as presently envisioned within NSF. This announcement indicated that available resources early in the decade would be concentrated on a limited number of themes: Environmental Quality, Environmental Forecasting and Seabed Assessment. The long range goals of IDOE as stated by NSF suggest that a clear distinction is being sought between coastal zone problems and open ocean problems, and that the proper emphasis of IDOE would be on the open ocean. Unofficial statements from NSF tend to confirm this inference.

A recent visit to the Office for the International Decade of Ocean Exploration within NSF headquarters failed to provide any clarification on this point except to confirm that estuarine problems would not be considered germaine to IDOE. Just where the dividing line may be is not clear. The National Science Foundation is in the final process of developing a much more detailed statement of guidelines; however, this statement is not yet

available and will only become available after the termination of this study. It appears, however, that most of the coastal zone as defined in this study may lie outside the interest of IDOE.

On the basis of present knowledge, it would appear that NASA could not rely entirely on IDOE for coordination with the ERTS and EOS programs, if ERTS and EOS come to emphasize the needs of coastal zone oceanography. Some coordination will nevertheless be needed between the ERTS and EOS programs and the national structure of coastal zone research and management activities. What structure will result from pending legislation on the coastal zone is far from clear at the present time. If a national coastal zone program does materialize, a prospect that appears likely, we do not know in what government agency it might reside.

All of the above-mentioned uncertainties make it difficult to suggest specific ways that the ERTS and EOS series might be coordinated with or through IDOE. IDOE undoubtedly would be a logical and perhaps the most logical point of coordination for open ocean uses of remote sensing; however, open ocean problems are outside the scope of the present study.

SECTION VIII

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SECTION IX

APPENDIX

STUDIES OF MARINE AFFAIRS PRIORITIES:

REVIEW AND COMPARISON

A. Review

After Sputnik, the first long range study of national goals in marine affairs was conducted by a Committee on Oceanography in the National Academy of Sciences (NASCO, 1959). The Committee recognized a need for general stimulation of oceanographic activities, because at this time, federal spending (including defense) for oceanography was only $ 21 million per year (NASCO, 1967). Recommendations for 1960 to 1970 were the following:

% Total Funds	Item
42	shipbuilding and ship operations,
15	technology,
14	shore-based research,
13	natural resources,
9	shore-based analysis of ocean survey data,
5	radioactivity in oceans, and
1	education and manpower.

The goals were not ranked in order of priority. Some idea of ranking is given by the recommended funding.

The NASCO report stimulated legislation and the formation of a Subcommittee on Oceanography within the President's Science Advisory Committee (PSAC). The subcommittee recommended formation of a permanent Interagency Committee on Oceanography (ICO) within

the President's Federal Council for Science and Technology, and recommended development by concerned federal agencies of a 10-year plan for oceanography.

The development of the 10-year plan was coordinated by the Interagency Committee on Oceanography, and a report was issued in 1963 (ICO, 1963). The plan stated a national goal in oceanography: "To comprehend the world ocean, its boundaries, its properties, and its processes, and to exploit this comprehension in the public interest, in enhancement of our security, our culture, international posture, and our economic growth".

ICO recommendations were the following:

% Total Funds	Item
23	basic science,
36	national defense,
19	management of food and mineral resources,
8	coastal water pollution and environmental alteration,
21	protecting life and property; insuring the safety of operations at sea, and
12	routine surveys and services of general utility.

Priorities were not ranked, but the Interagency Committee on Oceanography has consistently ordered the goals as in the above list (ICO, 1963, 1966).

A comprehensive summary of oceanographic developments and planning activities within the federal government up to this time was published by Coggeshall (1963).

Just two years later, the President's Science Advisory Committee formed a Panel on Oceanography which studied the national oceanography effort for a year (PSAC, 1966). The Panel recommended that the national goal for oceanography be: "Effective use of the sea by man for all purposes currently considered for the terrestrial environment: commerce, industry, recreation, and settlement, as well as for knowledge and understanding".

PSAC recommendations were:

% Total Funds	Item
56	national defense,
14	food resources,
10	environmental prediction and control,
9	navigation aids; port improvements,
6	pollution and environmental alteration,
5	mineral resources,
-	basic research,
-	undersea technology; oceanographic ships; and
-	education and manpower.

The Panel recommended funding levels for some but not all activities. No funding recommendation was made for defense; the percentage listed for defense is based on Navy oceanographic spending in fiscal year 1967.

A second NASCO report in 1967 assessed the developments since its first report in 1959, and made new recommendations (NASCO, 1967). Major recommendations were made for the management

of a national oceanic program. Minor recommendations were, without any discussion of funding or priorities:

a) marine resources,

b) radioactive wastes,

c) nearshore waste disposal,

d) oceanwide surveys,

e) ocean engineering,

f) long-range weather forecasting,

g) oceanographic ships,

h) deep manned submersibles,

i) buoys,

j) shore facilities,

k) new tools and instruments,

l) data handling, processing, and storage,

m) education and manpower, and

n) international cooperation.

A National Council on Marine Resources and Engineering Development, organized within the executive and reporting to the President, was established in 1966. In the first yearly National Council report (1967), the Council viewed national oceanographic goals and funding in terms of research, general services, and public needs:

% Total Funds	Item
16	basic and general research,
16	general purpose technology and services,
(8.5)	mapping and charting,

% Total Funds	Item
(4.6)	environmental prediction,
(2.3)	general purpose engineering,
(1.2)	education,
(0.3)	data center,
67	public needs,
(41)	national defense,
(11)	fisheries,
(6)	transportation,
(3)	recreation,
(2)	pollution abatement,
(2)	international collaboration,
(1)	mineral resources,
(1)	health,
(<1)	shore protection.

In subsequent reports (National Council, 1968, 1969), the goals were the same and the recommended funding was not substantially different. Recreation, pollution abatement, and shore protection were lumped as coastal zone development.

Recently, a significant study of national marine problems has been reported by the Commission on Marine Science, Engineering and Resources (1969). This Commission was established in 1966 by Act of Congress. Although members were appointed by the President, it had different responsibilities from the President's Council and was more independent. General priorities were identified as:

% Total Funds	Item
21	improving the national capability,
13	managing the coastal zone,
30	developing marine resources,
28	exploring, monitoring, predicting, and modifying the global environment; and
7	technical and supporting services.

The Commission adopted its own definitions and categorizations, and they differ from those the National Council used in Marine Science Affairs. Consequently, it is difficult to compare these priorities item by item in their present form with those in Marine Science Affairs (1967-1969).

However, the Commission reported that it gave less consideration to national security and transportation, and more to marine technical services, environmental monitoring and prediction, and coastal zone studies.

The most recent National Council report (1970) has acknowledged these differences and new emphases, and has given prominence to coastal zone management and research. Recommended funding levels have decreased for national security, fishery resources, and ocean exploration and mapping, while levels have increased for transportation, coastal zone development, research and general purpose engineering. Although pollution is not prominently identified, it is well-known to be receiving increased emphasis in other activities of the federal government.

Both Houses of Congress of the United States have emphasized this growing concern for the coastal zone in hearings and legislative committee actions in 1969 and 1970. Many coastal states themselves have increased their planning and management efforts, enacted new legislation and regulations relating to the coastal zone. Some have established specific coastal zone authorities. Governors of fifteen states formally organized a Coastal States Organization in June, 1970.

B. The Recognized Need for Coastal Zone Environmental Data

The above reports interpreted "oceanography" in the sense of all aspects and activities associated with the marine environment which have significant scientific and technological content. Priorities were based on items within the field of oceanography. Our approach is different in two respects. One, we consider oceanography in the more strict sense of marine science and engineering, and (to a degree) management. Two, our priorities are derived from all environmental data needs, not only those of oceanography. These differences arose quite naturally from our special interest in the potential of satellites for coastal zone oceanography.

Despite the differences, all studies share the view that the nation has a high priority need for coastal zone oceanographic data. Fully one-third of the items in the various lists of recommendations require acquisition of these data.

C. Order of Priorities

In light of the above review, the order of coastal zone environment data categories may be reappraised.

We place highest priority on the category of air/water/soil quality and environmental balance, with ecosystem balance the critical environmental factor. Other studies have missed this category as a whole, although parts such as pollution have received high rank. We view this omission seriously. The unitary nature of the category should be recognized and emphasized.

Environmental balance in the coastal environment is deteriorating and approaching a crisis rapidly. Waste disposal and environmental alteration constitute loads on the environment, and as the loading limit is approached, the rate of degradation is accelerating. Of all coastal zone problems, general environmental degradation will be the most expensive and the most difficult to repair.

Environmental quality is also the most severe problem in terms of the number of people affected and the degree of effect. Environmental deterioration is pervasive and non-discriminating. The number of people affected is large, because deterioration proceeds most rapidly where people are most numerous, i.e. in proportion to population and industrialization. It is obvious that the most densely populated areas are already the most severely affected. In terms of degree and numbers affected, Platt (1969) has ranked ecological balance as a top priority problem, which will reach crisis in five to twenty years, and which is exceeded in intensity only by the threat of world war involving

nuclear or radio-biological-chemical weapons.

Natural resources are given second highest priority. Other studies have accorded this category equivalent importance, although the recommended funding has been relatively variable.

At third priority we place the prediction, warning, and effects of extreme events. In other studies, extreme events are included in environmental prediction. We feel that the magnitude, the suddenness, and the pervasive character of extreme events and their effects deserve a special category. The emphasis, it is hoped, will stimulate increased attention and planning whereby the damage to human life and property will be minimized.

A major need in the case of extreme events is rapid distribution of aid and restoration of public services. Response, not prediction, is important after an entire area has been devastated. Rapid survey and assessment of the effects of extreme events does not receive proper emphasis when extreme events are included in environmental prediction.

Fourth priority is given to other environmental aids to commerce and economic activity, such as navigation aids which are not covered by categories of higher priority. Because it is a catch-all category, with items from various categories in other studies, comparison of its priority ranking between this and other studies is not meaningful. In our ranking the fourth place is justified because the major needs of commerce and economic activity are already included in the categories of higher priority.

A plainly visible difference between our priority list and others is our omission of a category for data needs of national defense. This category lies outside our domain.