Oceanus

Fall 1975

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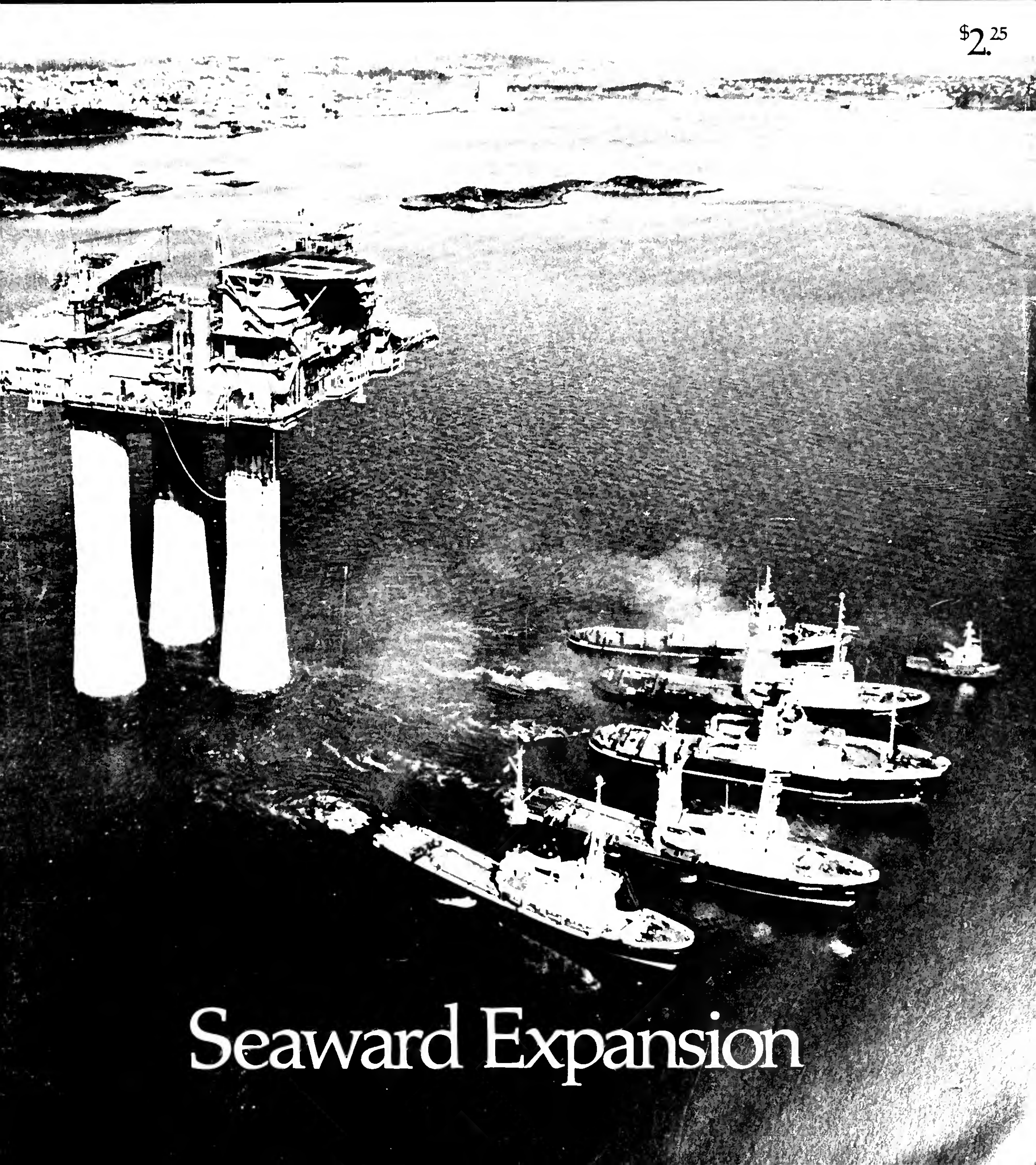

Seaward Expansion

Oceanus®

Fall 1975, Volume 19, Number 1

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Published quarterly by Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543. Application for second-class postage pending at Woods Hole, Massachusetts, and additional mailing offices. Copyright © 1975 by Woods Hole Oceanographic Institution.

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Subscription correspondence: All subscriptions and single-copy orders and change of address information should be addressed to *Oceanus*, 2401 Revere Beach Parkway, Everett, Massachusetts 02149. Checks should be made payable to Woods Hole Oceanographic Institution. Annual subscription, $8.00; single copy, $2.25; foreign subscription, $10.00. When sending change of address, please include mailing label.

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Cover: Beryl A, *the first concrete oil production deepwater platform (Condeep), leaves its fabrication site at Stavanger, Norway. After a five-day tow by five tugs with a combined strength of 68,000 horsepower, at an average headway of 2.1 knots, the 50-story-high platform was installed at Beryl Field in the North Sea.* Beryl A *is considered to be the largest single marine venture in history.* *See pages 25, 67, and 69.* *(Mobil Oil Corporation)*

The Importance of Ignorance

The move offshore is gaining momentum. No longer is it limited to the drain and fill operations that traditionally have claimed land from sea, though these proceed apace. Today, the stepping stones on the seaward path are the big rigs in the Gulf, the North Sea, wherever oil is proved or probable. Tomorrow, we are told, there will be artificial islands, floating platforms, and sea-bottom structures for resource exploitation, manufacturing, waste disposal, a whole system of activities. The day after that, we may see residential-commercial-industrial communities rising above the swells; the near ocean's most underrated resource may turn out to be space.

This issue is devoted to some of the more important technological, environmental, and social aspects of seaward expansion. It is clear from what the authors have to say that we have become sophisticated in the construction of offshore structures, more so perhaps than most of us realize. But as so often happens today, what technologists have learned to do many scientists are not sure should be done, at least not at flank speed. There is some friction between the confidence of those who are solving difficult problems of marine engineering and the caution of those who are engaged in the subtler business of measuring stress within the marine environment.

The case for confidence lends itself to public acceptance because it is linked to tangible achievement. The case for caution, with its implications of self-denial, is not apt to be so popular. It is nonetheless compelling. Consider petroleum, the motive force driving much of today's offshore activities. The substance is known to be harmful to marine and other environments under certain circumstances, but according to the organic geochemist Max Blumer of Woods Hole Oceanographic Institution, it is extraordinarily difficult to anticipate the full damage. Writing in the German journal *Angewandte Chemie*, Blumer explains that the biological effects of chemicals are immediately related to their fine structures in a way not yet generally understood despite intensive research. Therefore, all components of a natural organic mixture must be known before environmental chemists and biologists can effectively predict its impact. Yet, he adds, petroleum, like many other organic mixtures, is so incredibly complex that "even the best combinations of analytical techniques, providing the highest degree of resolution, have not yet separated any crude oil into individual components. . . . So far, each new analytical advance appears to have revealed a greater complexity of nature, and the explosion of knowledge has been paralleled by an equal explosion of ignorance."

It is easy, given the crisis mentality endemic to our society, to ignore the importance of ignorance, to hang our hopes on the technological fix and the scientific breakthrough. Certainly what we know can more effectively guide what we do; applied oceanography can be of great and growing service in this regard. But it appears equally certain that as we move out into the last remaining uninhabited provinces of the planet, we should proceed with the greatest restraint, with the greatest respect for what we do not know.

"We must remain cautious in adopting tolerance levels as long as our analyses are so incomplete," Blumer writes. And, he adds, "We now need to look for a transition to a more realistic study of nature that acknowledges the limitations of our present analytical powers and the gaps in our understanding." William H. MacLeish

Continental Shelves:

Their Nature and History

by Sir Edward Bullard

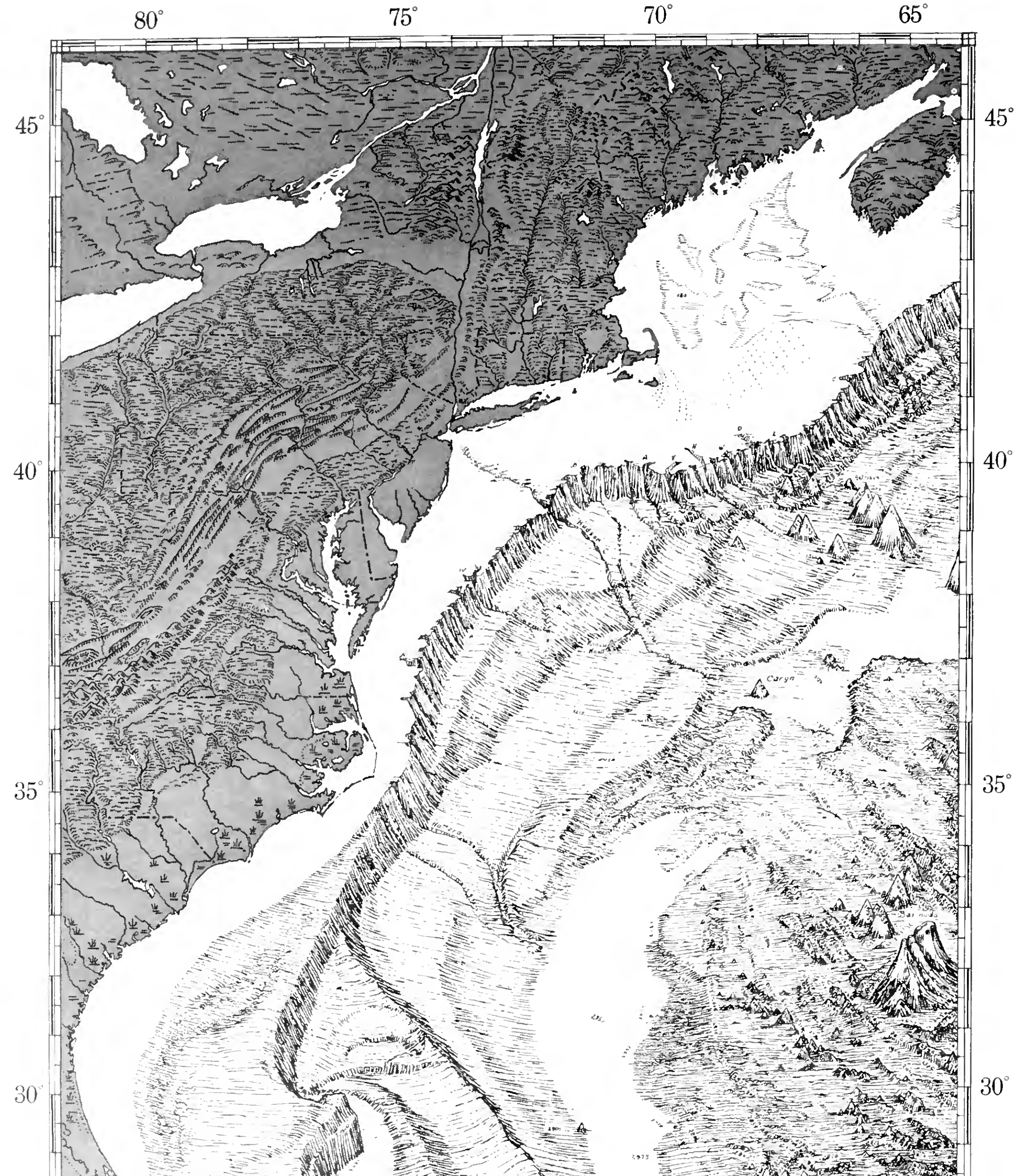
Coastlines are of two kinds. There are the peaceful ones, such as that on which Woods Hole is located, and there are the unstable coasts, such as that of Japan or the western side of South America, where great events are in progress. On or near unstable coasts there are earthquakes and volcanoes, evidence that the earth's crust is moving and changing. The stable kind of coast is called the "Atlantic" type, the other the "Pacific" type. "Atlantic" coasts are not confined to the shores of the Atlantic Ocean; they occur also on the east coast of Africa, on both sides of India, and all around Antarctica. Similarly "Pacific" coasts can occur outside the Pacific–for example, around the Carribbean and south of Indonesia.

That there are two kinds of coast is one of the primary facts of geography; the importance of the difference was stressed by the great nineteenth-century synthesizer of geology, Eduard Suess of Vienna, and by many people since. It has also been known for many hundreds of years that off an "Atlantic" coast the approach to land is heralded by "coming into soundings," that is, by finding that the sea floor can be reached by a lead on a sounding line. This warning was of great practical importance to the navigators of the seventeenth and eighteenth centuries, who had no reliable method of finding their longitude and were in constant danger of running ashore when the visibility was bad. The lead not only indicated the approach to shore but also brought up a small sample of mud, which stuck to a piece of tallow put into a hole in the lead. There are many tales of the skill of sea captains and fishermen in deducing their position from the appearance, taste, and smell of these samples.

Form

The continental shelf is the undersea platform that runs along the shores of "Atlantic" coastlines. It slopes gradually down from the beach to a depth that varies from place to place, but is usually between 100 and 200 meters; the slope then suddenly increases and the sea floor falls rapidly to depths of 4000 to 5000 meters. The width of the shelf varies greatly, 100 kilometers being typical. It is usually remarkably flat and level, a typical gradient being 2 in 1000 (0.1°)–a slope that a bicyclist would not notice. At the outer edge the shelf change in gradient is very sudden and is often apparent while a ship moves a distance equal to its own length. The average gradient of the slope beyond the shelf edge is not very steep (4° is typical). The whole "scenery" is different from that on the shelf; there are hillocks, precipices and gullies, and often great canyons comparable in width and depth to the Grand Canyon. At a depth of 2 or 3 kilometers the descent slackens, and at the foot of the slope there is a more gentle descent to the deep-ocean floor. This gentler slope is known as the continental rise.

It is natural to suppose that the shelf is, in some sense, a continuation of the continent. In fact it is clear that during the ice age, which ended about 10,000 years ago, so much water was locked up in ice sheets and glaciers that sea level was lowered by 100 meters or so and a large part of the shelf was dry land. Men hunted the reindeer and other arctic animals over what is now the floor of the shelf seas; in western Europe their stone tools and the engraved antlers of the animals they killed are still occasionally brought up in trawls. Although the shelf looks like a piece of continent that has been



The form of the sea floor off the U.S. east coast: the shallow, flat continental shelf; the sudden change of slope at the shelf edge; and the relatively sharp drop to the deep ocean. (From physiographic diagram of the North Atlantic Ocean, originally published by the Geological Society of America. Copyright © 1968 by Bruce C. Heezen and Marie Tharp. Courtesy of Lamont-Doherty Geological Observatory.)

drowned, this does not really say very much about it; it might be a rubbish tip built out over the ocean floor, or it might be a piece of continent that has been planed down below sea level by the waves or has subsided.

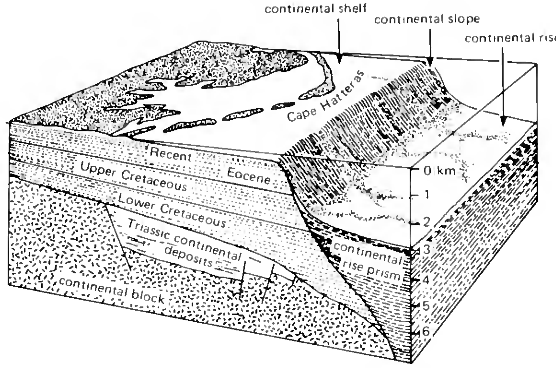
Structure

Serious study of what lay beneath the continental shelf only started in the mid-1930s. The first question was whether the shelf had only a veneer of recent sediments covering much older rocks or whether the old rocks sloped down to join the deep-sea floor and were covered by a great thickness of relatively recent and poorly consolidated sediment reaching almost to the surface of the sea. Drilling onshore in Virginia and elsewhere had suggested the latter, but only work at sea could show what was really there.

Such work was started by Maurice Ewing, then of Lehigh University, at the suggestion of R. M. Field of Princeton (perhaps the most original and certainly the most persuasive geologist of his day). Ewing took the seismic method of geophysical prospecting to sea. In 1935, using the ketch *Atlantis* from Woods Hole Oceanographic, he put instruments and explosives on the sea floor of the continental shelf and showed that there was a great thickness of sediments under the surface of the shelf. In some places the sediments reached thicknesses of as much as 7 kilometers and went below the level of the deep-ocean floor.

This was a great discovery in pure science, but it has also proved a discovery of tremendous practical importance. The continental shelf and slope have an area of over a third of the land area of the earth and are almost everywhere underlain by thick sediments. Since sedimentary basins on land are the places in which oil is found, it was reasonable to suppose that there would be great resources hidden beneath the shelves, and so it has proved. At first the immense technical problems of prospecting, drilling, and production made progress slow. Now, with decreasing yields from U.S. fields and mounting difficulties with foreign sources, the oil of the shelves looks more and more attractive.

Development of the technology for finding and raising oil from beneath the sea has turned the thoughts of many engineers to other possible resources, and it is to these and to their attendant difficulties, as well as to oil, that this issue of *Oceanus* is devoted. As a background to the engineering and political contributions, the rest of this paper will discuss the way in which the shelves have reached their present form. The shelf off New



Cross-section of the continental shelf off the eastern U.S., a typical "Atlantic" coast showing several kilometers of sediments. Vertical scale is exaggerated. (From "Geosynclines, mountains and continent-building" by R. S. Dietz. Copyright © 1972 by Scientific American, Inc. All rights reserved.)

England will be taken as an example, but much the same things could be said about the rest of the "Atlantic" coasts.

History

The continents are composed of rocks of all ages back to 3800 million years and have a long and complicated history. The oceans, on the other hand, contain only relatively young rocks; none, or almost none, are older than 160 million years, which is only 4 percent of the age of the oldest rocks on land. The history of the ocean floor is also much simpler than that of the continents and is probably better understood, though some land geologists might not agree. The difference in age between the continents and the ocean floor is only one of the differences between land and sea. The hard rocks are different, mostly granites on land and all basalts at sea; the mountains at sea are all either volcanoes or blocks of lava raised by faulting, while on land most rocks have been formed by the compression and folding of rocks originally near sea level; and, of course, the sea floor lies 5 kilometers below the continents.

The junction of these totally disparate kinds of geology lies somewhere beneath the shelf, slope, or rise; and its study is likely to be one of the most lively parts of oceanography, and, indeed, of earth science, during the next ten years. The edge of the shelf is a difficult area to investigate since the basement is covered not only by water but also by very thick sediments. The irregularity of the continental slope complicates the interpretation of every kind of measurement.

About 200 million years ago the Atlantic was closed and North America lay against western Europe and northwest Africa (earlier, 500 million years ago, there had been an older Atlantic, but that is another story). Forces whose nature is not entirely clear produced a crack that started off New England and ran the whole length of the Atlantic to the south, and right across the Arctic Ocean to the north. Naturally the crack was filled with lava as it formed. A similar process can be seen today in Africa where a crack, the Rift Valley, has spread from Abyssinia to Tanzania during the last 20 million years. The crack in the Atlantic was at first a valley with lakes and volcanoes on its floor, as is the Kenya rift today; as it widened and lengthened, the sea got in intermittently, evaporated, and deposited salt. A present-day analogy may be the Red Sea, which is connected to the ocean only by a shallow and narrow channel and which has several kilometers of salt beneath its floor—a sure sign of isolation in the past.

The Atlantic has been widening for 180 million years. New ocean floor is formed by the lavas coming out of the crack along the ridge axis, while the older ocean floor and the continents on both sides move away to make room for the new floor. The nature of the events occurring at the ridge has been beautifully illustrated by Project FAMOUS, particularly by the photographs taken from the submersible *Alvin* (*Oceanus,* Spring 1975). For a geological process the motion of separation is quite rapid. To make an ocean 5000 kilometers wide in 180 million years requires a motion of 3 centimeters per year; this agrees very well with the speeds estimated in other ways. In fact the formation of the Atlantic was not quite as simple as this; there were several false starts before the final line of break along the present mid-ocean ridge was established. One of these abortive splits was between Greenland and Labrador, another between Scotland and Rockall Bank; perhaps another is marked by a rift in the North Sea, which is completely filled with sediments and is closely followed by a line of major oil fields.

Clearly, if the Atlantic has been formed in this way, the eastern and western shores are the oldest parts, and at the extreme edge we may be able to find the old rift valley along which the supercontinent split. Drilling on the shelf off the east coast of Canada has shown just this. Under several kilometers of sediments lie old rocks similar to those found on land in the Maritimes and in Newfoundland. On the planed-down surface of these old rocks the first sediments were laid down on land in lakes and flood plains. Above this come the marine sediments. The basement is a good deal broken up and faulted, as is the floor of the Rift Valley in East Africa.

It is easy to imagine the outline of what happened, though not so easy to be sure of the details. The start was probably a doming of the continent in response to a "hot spot" produced by the generation of radioactive heat below the crust, though why it happened when and where it did is not known. The dome then split and formed a rift valley floored by continental rocks. Finally the rift valley itself split, lava came up from below the earth's crust, and the first strip of the floor of the new ocean was formed. As the splitting progressed, sediments from both sides of the valley were carried into it, gradually forming the great pile of sediments that we find today beneath the floor of the shelf, slope, and rise. It lies partly over the floor of the rift and partly over the outer parts of the floor of the widening ocean.

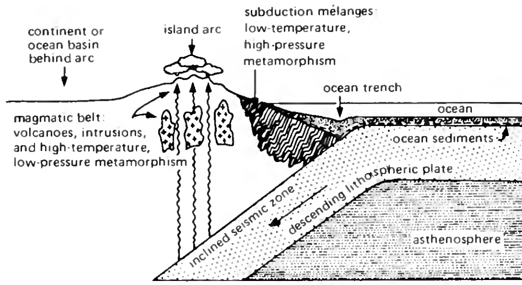
Certainly something of this sort happened, but there are doubtful points and difficulties. Why, for example, did the continental basement, on which the sediments rest, sink so far? There are several possible answers. The dome rose because the rock beneath it was hot; as it cooled over a hundred million years or so, the surface sank. The same thing has happened to the deep-ocean floor. The mid-ocean ridge is 3 or 4 kilometers shallower than the ocean on each side; below the ridge the rocks are hot, as is testified by the volcanoes. As the plates move away on each side, they cool and contract and the sea floor sinks. The sinking of the shelf will be encouraged by the weight of the sediments. The surface of the basement rocks beneath the sediments may also be lowered by stretching and faulting of the crust and by the erosion of material from the original dome. The relative importance of these factors is far from clear.

There is one glaring discrepancy between the shelf and a rift valley. All the existing rift valleys are much narrower than the depressed continental blocks under the shelves. For example, the Kenya rift is 30-50 kilometers wide, whereas the sunken continental basements off New England and Morocco are several hundred kilometers wide. Also there is no evidence in East Africa that there are any old rocks of the continental basement beneath the floor of the Kenya rift. There the split started with enormous outpourings of basalt, as it did at some places around the Atlantic, and no trace of the old rocks can be seen. In the Red Sea the oil wells have not reached the basement, and it is possible that old continental rocks are present beneath the much younger sediments; but it is not certain that they are, and there is some reason to doubt it. It may be that the process of foundering of the continental shelf involves long-continued faulting and sinking and that the width of the depressed block increases over a long period of time. This is a plausible notion, but unfortunately there is no example of an "Atlantic" coast on which active faulting is in progress on the landward side of the shelf. There are earthquakes in the eastern U.S. and western Europe, but they are infrequent, mostly small, and not distributed in a way that suggests continued foundering of the continental edge.

The "Pacific" Coasts

Since ocean floor is continuously and rather rapidly created, there must be a process for disposing of it. This occurs at the "Pacific" coasts. Here the plate formed at the mid-ocean ridge dives down beneath the continent, or sometimes beneath an island arc, and returns to the interior of the earth from whence it came. At the place where the plate subducts there is an ocean deep, and an inclined plane of earthquakes. Inland, over the place where the plate is sinking and has reached about 150 kilometers, there is a line of volcanoes fed by the melting and upward migration of the more easily fusible parts of the plate. This combination of descending plate, ocean deep, earthquakes, and volcanoes is very clear on the west coast of South America, in Japan, and in many other places. Here there is no depressed strip of continental rocks, and there are usually no great rivers to carry sediment from the land. Instead we find a narrow strip of tumbled and mixed up material scraped from the upper surface of the descending plate. Deep water lies quite close to shore, and there is no continental shelf of the type known around the Atlantic. If the plate descends beneath an island arc, there may be a trap for sediments on the landward side and great thicknesses may accumulate, as in the Sea of Japan and to the north of Indonesia.

The countries along the west coast of South America are unfortunately situated on a "Pacific" coast and have no real continental shelf. On the other hand, they have no island arc offshore and therefore no trap for sediments. This absence of a real shelf has had its repercussions at the conferences that have endeavored to negotiate treaties on the exploitation of the resources of the sea floor. As some compensation for having no shelf, the topography and the motions of the water off Peru have provided a gigantic upwelling not far from shore, which supports one of the world's greatest fisheries (*Oceanus,* Winter 1975). The upwelling has also produced immense deposits of phosphorite, a material of great value as a fertilizer.



Section across an island arc, a typical "Pacific" coast. The ocean floor descends under the arc, where its melting feeds the volcanoes of the islands. Vertical scale is exaggerated. (From Earth *by F. Press and R. Siever. W. H. Freeman and Company. Copyright © 1974. After W. R. Dickinson, "Plate tectonics in geologic history,"* Science, *vol. 174, p. 107. Copyright © 1971 by the American Association for the Advancement of Science.)*

Using the Shelves

The continental shelves of the world have an area equal to 18 percent of the exposed land area, and the slope and rise to a further 36 percent. It is not surprising that many nations should be looking to this considerable area for many things over which they are having difficulties on land. The biggest prize would be the finding of oil on the continental rise and the development of methods for extracting it. At present it is not known if oil occurs there. If it is there in the same proportion as on the shelf, then the immense volume of sediments under the rise would make it the greatest oil resource for the future and would change the relations and prospects of many countries.

Clearly there are almost endless possibilities of conflict between countries and between groups with different needs in the same country. It is to be hoped that the more or less amicable division of resources in the North Sea may be taken as an example elsewhere; however, it seems improbable that the biggest land grab in history will be conducted entirely peaceably.

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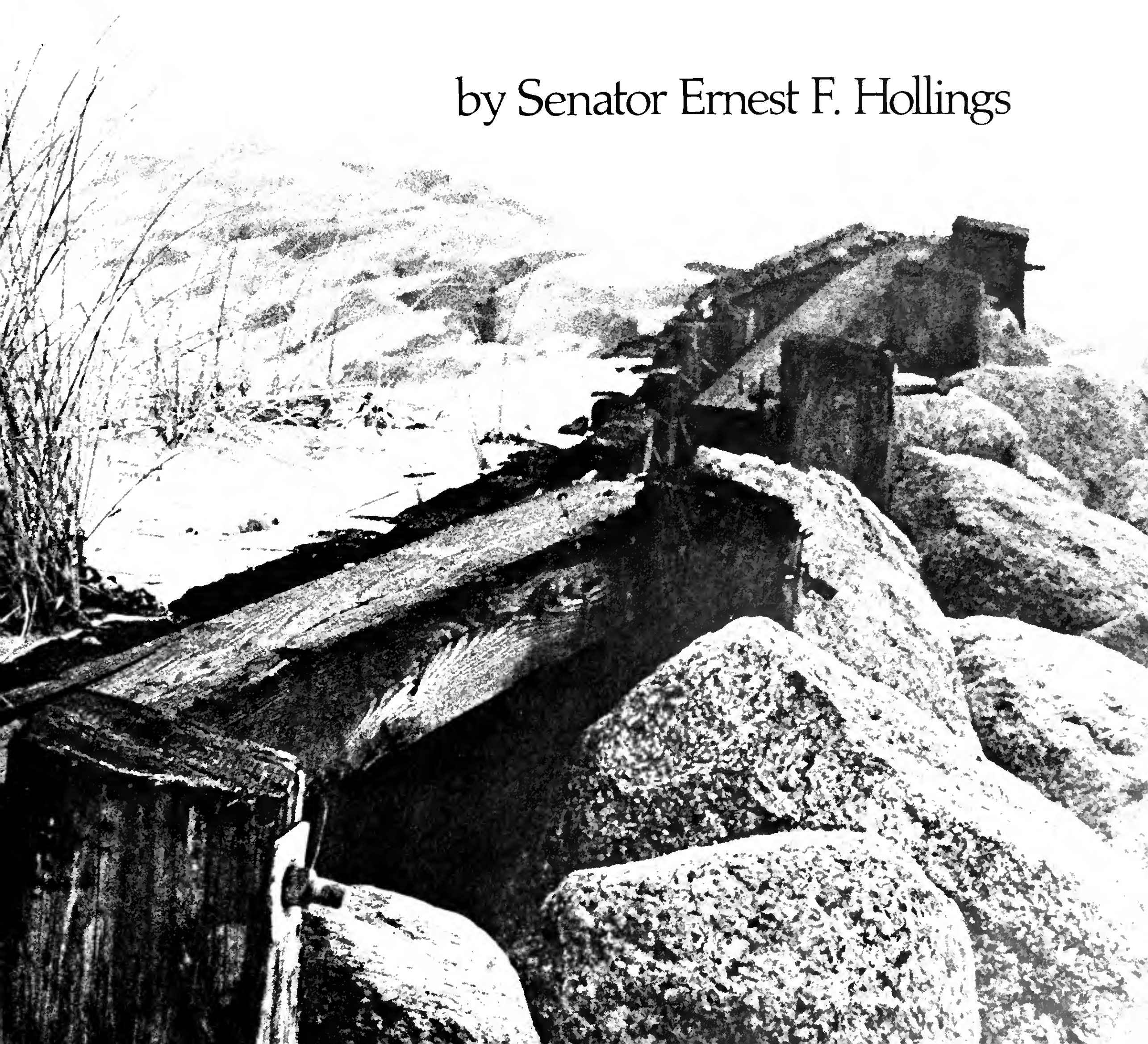
Photo by Keith von der Heydt.

National Ocean Policy: Priorities for the Future

by Senator Ernest F. Hollings



Off the coasts of the United States, on the continental seabed, lie approximately 853 million acres of the outer continental shelf (OCS). Beyond that, at depths in excess of 2500 meters, are vast areas of seabed that remain the common heritage of all nations. According to current estimates, the economic potential of offshore resources for the U.S. will reach $34 billion to $45 billion by the year 2000 (Table 1). These offshore areas are the last remaining frontiers; how they are managed can well determine the future of the U.S. This is not to imply that the ocean can satisfy the basic needs of society. There have been too many ridiculous claims to that effect. Nevertheless, it is vital that the federal and state governments adopt policies and develop institutions to properly manage the offshore resources and adjoining coastal zone.

The need for a national ocean policy to guide the use of offshore resources comes from another direction as well. While the progress made at the Third Law of the Sea Conference is disappointing, there will probably be an accord reached sometime in the future. If not, or if the recalcitrance of some nations persists, the U.S. Congress will move unilaterally toward an extension of the seaward boundaries to protect offshore resources. It was not until a similar move by President Truman in 1945, when, by presidential proclamation, he extended the national boundaries to include the 12-mile contiguous zone, that sufficient international attention was focused on the issue to permit an agreement at the 1958 Geneva Convention on the Outer Continental Shelf.

The extension of U.S. seaward boundaries, whether by treaty or statute, will in effect change the status of property in the affected areas from the Grotian concept of "common property" to that of property held in public trust. Implicit in this shift in legal status is an element of management control. Just as the OCS is subject to regulation and leasing by the federal government under the authority of the Outer Continental Shelf Lands Act of 1953, so must the extended area be brought under federal management. It may be in the national interest to permit foreign development of some of the marine resources within the U.S. economic zone; but foreign exploitation must be based on bilateral or limited multinational arrangements that are in concert with an overall scheme based on wise resource management. No longer can the U.S. afford to use its marine fisheries or seabed resources as items of international barter in the childlike games of foreign diplomacy. These resources must be managed on the basis of scientific principles and sound management criteria.

Space—land—is rapidly becoming one of the most valuable resources of all. This is particularly true for the coastal zone. Virtually all of the megalopoli projected for the next century are in the U.S. coastal states; even now, over 75 percent of the population lives on the East or West coast. The pressure from the interior of the country, where usable land is also at a premium, coupled with the development of offshore resources, particularly OCS oil and gas, have the coastal zone caught in-between.

Socioeconomic studies have shown that population and economic concentrations promote further growth; conventional wisdom indicates that the coastal region will continue to grow, both economically and demographically. But how much growth can the coastal zone endure without destroying estuarine productivity and changing the character of the coastline? It was in part to provide answers to this question that Congress passed the Coastal Zone Management Act, but that was in 1972 when the impact of the developing energy crisis on domestic energy production was not fully recognized.

In final analysis, the concentration of energy facilities in the coastal zone may turn out to be the greatest threat to its environment. Power generating stations are attracted to the region's population centers and to the ocean as a heat sink for thermal effluents. There are also proposals for offshore nuclear power plants, based on the assumption that remoteness will improve the safety factor. Deepwater ports, which are now regulated by the Deepwater Port Act, may proliferate as the U.S. becomes increasingly more dependent upon Mideast oil—as I am convinced it will. And the new impetus to accelerate the development of offshore oil and gas will create additional problems, including the support facilities—refineries, pipelines, service companies, and living space and services for personnel—that must be provided in the coastal zone (see page 23).

It is not only the physical presence of these facilities that coopts space needed for other uses and contributes further to air and water pollution but also the secondary growth that results from industrial activity. We have come to recognize that every area has a finite carrying capacity beyond which it deteriorates. Government policy at all levels—federal, regional, state, and local—must be sensitive to the developmental thresholds of the coastal region. In our zeal to develop the offshore resources, we run the risk of overlooking the onshore impacts. Now, more than any other time, we must plan the use of the marine and coastal resources in unity instead of striking out hellbent-for-leather, under the justification of "crisis," to do those things we should have done earlier and more reasonably.

There are at least six critical needs that must be met in developing a sound marine resource management program:

–Creation of a 200-mile economic zone,
–Reassessment and reorganization of federal ocean programs,
–Revision of the OCS Lands Act to reflect current national and regional values,
–Strengthening of the Coastal Zone Management Act to provide the coastal states with a greater capacity to deal with problems of energy facility siting,
–Establishment of a marine fisheries management system at the federal level, and
–Federal policy and licensing system for seabed mining.

Extended Economic Zone

As a matter of practical international politics, maritime nations want to preserve the freedom of the seas, while non-maritime countries favor restricted access to the ocean areas adjacent to their coasts. As a great maritime power, the U.S. has been a staunch advocate of freedom of the seas, at least so far as maritime trade and scientific research are concerned. After World War II, however, the country veered from the Grotian doctrine of *mare liberum* in its quest for the valuable resources underlying the OCS. According to Wolfgang Friedman of Columbia University, an authority on ocean law, it was the continental shelf doctrine as implemented by the first Truman Proclamation in 1945 that prompted the international movement toward the seaward expansion of sovereign

Table 1. Estimated and projected primary economic value of selected ocean resources to the U.S., by type of activity, 1972/73–2000, in terms of gross ocean-related outputs (in billions of 1973 dollars).

Activity	1972	1973	1985	2000
Mineral resources:				
Petroleum		2.40	9.60	10.50
Natural gas		0.80	5.80	8.30
Manganese nodules			0.13	0.28
Sulfur		0.04	0.04	0.04
Fresh water		0.01	0.02	0.04
Construction materials		0.01	0.01	0.03
Magnesium		0.14	0.21	0.31
Other			0.01	0.02
Total		3.40	15.82	19.52
Living resources:				
Food fish	0.74		0.95– 1.58	1.37– 4.01
Industrial fish	0.05		0.05– 0.08	0.05– 0.14
Botanical resources	*		*	*
Total	0.79		1.00– 1.66	1.42– 4.15
Nonextractive uses:				
Energy			0.58– 0.81	3.78– 6.03
Recreation	0.70–0.97		1.12– 1.50	1.64– 2.53
Transportation	2.57		4.40– 6.21	6.88–11.41
Communication	0.13		0.26– 0.36	0.44– 0.85
Receptacle for waste	†		†	†
Total	3.40–3.67		6.36– 8.88	12.74–20.82
Grand Total	7.59–7.86		23.18–26.36	33.68–44.49

Source: The economic value of the ocean resources to the United States, National Ocean Policy Study, Senate Committee on Commerce, 93rd Congress, 2nd Sess., 1974.

*Insignificant.

†Potentially significant, but unmeasurable.

Industry and recreation are among the activities that must compete for space in the coastal zone. (Tom Jones photo)

jurisdiction. Following the lead of the U.S., one nation after another made territorial claims beyond the traditional three-mile limit. The developing nations then had no significant interests in the distant-ocean resources because of their inability to exploit them, but they did have considerable interest in the ocean resources immediately adjacent to their coasts. Disputes developed—cod, tuna, and lobster wars—but the continental shelf extension soon became international custom. Multinational recognition of the continental shelf doctrine was formalized at the Geneva Convention in 1958, though seaward limits were not defined.

At the time of the convention, the extent of national jurisdiction was, for all practical purposes, limited by the technological capability to exploit the ocean space. The most optimistic futurist could not have foretold the rapid development of offshore technology that has taken place since that time. For example, the offshore industry is now capable of commercial operations on the sea floor at depths and under conditions once considered to be impossible; and foreign fishing fleets can perform sustained, intensive missions anywhere in the world. Russian, Japanese, and Korean trawlers and factory ships off U.S. coasts have had significant impact on domestic fisheries. The 12-mile contiguous fishery zone is meaningless as far as scientific fisheries management is concerned since it in no way corresponds to the range and habitat of many important species.

If the U.S. is to protect fisheries resources and utilize the seabed on the continental slope and beyond the continental shelf, then an extended economic zone is imperative. A 200-mile economic jurisdiction not only would provide the basis for developing resource management systems, but also would attract investment and industrial opportunity considered too speculative under the present common property system. The question now facing the nation is not whether to establish an extended economic zone but rather how to establish it. Everyone would prefer that the seaward boundaries be set by an international convention. But in the absence of accord the U.S. has only three alternatives: bilateral agreements, limited multilateral arrangements, or unilateral extension by legislation or executive proclamation.

Federal Ocean Programs

With the extension of seaward boundaries must come the organization of the federal establishment to meet the challenge of administering and enforcing resource management programs within the 200-mile zone. In 1969 the Stratton Commission foresaw the need for a strong civil agency within the federal government to administer national marine affairs. The President took an incremental step in this direction in 1970 with the creation of the National Oceanic and Atmospheric Administration (NOAA) by executive action. But NOAA, which is in the Department of Commerce, falls short of the agency proposed by the Stratton Commission.

Under the present federal organization, notwithstanding the central focus of NOAA, ocean-related programs are still dispersed among 21 organizations in 11 departments or agencies. For example, parts of the marine fisheries management program are in the Department of the Interior; Coast Guard, with its enforcement capability, in the Department of Transportation; responsibilities for certain navigational aids and marine safety functions in the Army Corps of Engineers; regulation of OCS oil and gas in the U.S. Geological Survey (USGS) of the Department of the Interior; ocean environmental regulation in the Environmental Protection Agency; and Maritime Administration in the Department of Commerce. In short, the federal government has failed to use oceans as an integrating theme. So long as marine programs are considered to be no more than addenda to other resource programs within the federal government, the U.S. will be unable to move toward a responsible ocean policy.

Unfortunately, the government reorganization schemes that have been proposed thus far would move in the opposite direction. Instead of organizing around ocean resources programs, it has been suggested that marine affairs become part of a Department of Energy and Natural Resources (DENR). Such an irrational move would condemn ocean programs to even lower visibility and almost ensure their subservience to energy and land-based resources. In fact, the creation of a department that would merge energy with any other resource—be it fresh water, land, environment, or oceans—would assuredly pale the importance of resource management in the pursuit of an expedient energy policy. This is the paramount danger in merging energy plans with other resource programs.

Those who opt for the creation of an all-encompassing DENR are also ignoring an important lesson in government organization that was ostensibly just learned. The now defunct Atomic Energy Commission (AEC) oversaw both development and regulation of atomic power. Realizing these responsibilities were at cross-purposes, the 93rd Congress dismantled AEC and divided these functions between two new agencies, the Energy Research and Development Administration, and the Nuclear Regulatory Commission. An energy and resources department would be AEC revisited. No single administrator is able objectively and efficiently to implement policies as divergent as are the goals of energy production, environmental quality, and natural resources management. A perfect example of this conflict is presently found in the administration of the OCS Lands Act for oil and gas development by the Department of the Interior. Interior is charged with the responsibility for both promoting the development of the OCS and regulating the industry in the development phase. Mission agencies are tools of the tasks they are assigned. In the case of Interior, the emphasis has always been the development or disposal of public lands, with regulation as a secondary function. OCS oil and gas development will result by far in a greater impact to the marine environment and the coastal zone than any other ocean-related use.

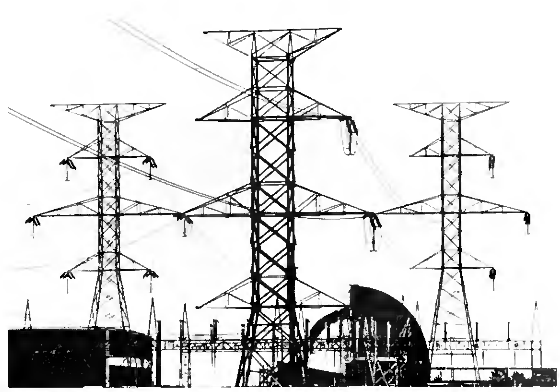
The Senate National Ocean Policy Study (NOPS), which was created by Senate resolution to study ocean problems and formulate legislative solutions, has begun analyzing the federal structure in light of the future needs for ocean program organization. The functional elements of marine activities are presently classified as data collection and monitoring, management, regulation, or research. There is little doubt that virtually all of these federal activities must be upgraded to meet the needs resulting from expanded national jurisdiction. Regulation, for all practical purposes, is part of management. Enforcement and implementation of a management policy is the key to successful resource management; therefore, an oceans agency must have the capability not only to implement policy but also to regulate and enforce it. Data and information are necessary components of resource management and must serve as the basis for policy decisions. Research is the foundation of future knowledge and must be matched to the needs of future ocean policy.

NOPS is considering a number of organizational alternatives, including a Department of Oceans and the Environment as a prototype for a cabinet-level office. Merging oceans and environmental programs into a single agency would permit mutual reinforcement among complementary programs. Above all, what is needed is a balanced approach to energy production and resource management, achieved by two departments of equal status: one to develop energy and resources, the other to protect the environment and manage the marine and coastal resources.

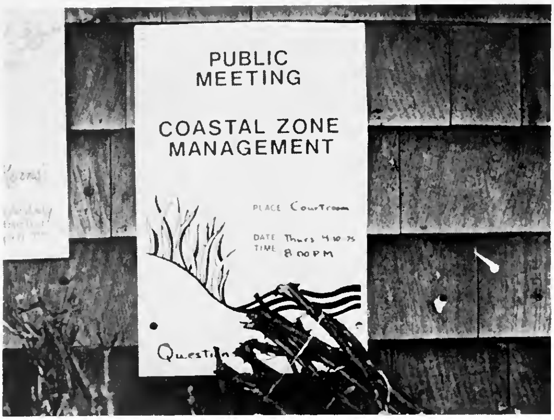
OCS Oil and Gas

Overshadowing all other ocean resources at the present time are OCS oil and gas. USGS, in recently revised figures, estimates that total domestic and undiscovered recoverable oil resources range between 61 billion and 149 billion barrels of oil. Approximately one-third to two-thirds of this total could be in the OCS. Although at the projected rate of current production this will last only 25 to 50 years, the federal government is relying on these tenuous resources as the foundation of a short-term energy policy. National energy plans are predicated on the assumption of full development of OCS oil and gas, yet little attention has been given to the effect that such development may have on the adjacent coastal zone and the marine resources and environment of the superjacent waters.

Present OCS policy is based on the development mentality of the 1950s, when oil was considered to be an endless resource. There were indications that we were nearing the end of the rope, but then, as now, those who proffered such



The greatest threat to the coastal environment may be the concentration of energy facilities, especially nuclear power stations. (Tom Jones photo)



The Coastal Zone Management Act provides for public participation in the development of coastal zone programs. Wise and equitable use of coastal and offshore resources depends on citizen involvement in the planning process. (Massachusetts Office of Coastal Zone Management)

foreboding were branded as doomsayers. The OCS Lands Act and its counterpart, the Submerged Lands Act of 1953, are not management in nature. Their original purposes were to partition resources for disposition by the states and the federal government at a time when the OCS was considered a source of wealth, not a means of existence.

There are five major issues concerning OCS oil and gas development:

- Sufficiency of resource information for government planning and valuation,
- Separation of exploration and development of OCS oil and gas,
- Federal-state roles in OCS leasing decisions,
- Equitable returns to government and industry for development of the OCS, and
- Compensation to the coastal states for adverse impacts from OCS development.

Sufficiency of resource information. Under the present leasing system the Department of the Interior purchases geophysical information from independent exploratory companies. Interior may also participate in "group shots," along with interested oil companies, to acquire additional information. Based on such data, the Bureau of Land Management (BLM), with the assistance of USGS, establishes a value for the resources. It is not until a lease is sold and the lessee actually drills exploratory wells that the presence and extent of the oil and gas can be verified. A study by the General Accounting Office showed a low correlation between the government estimates of the value of oil and gas on the lease tracts, and the prices bid by industry. BLM has improved the valuation system since the study, but there is apparently still room for improvement. The most caustic critics of Interior's resource valuation system claim that it is akin to "selling a pig in a poke." The consequence, they claim, is a reduced return to the government for the resources. There are indications, however, that inequities have run the other way as well; in some cases the government has received far in excess of the potential value of a lease.

There is another dimension to resource information: the need for it at the state and local levels for the planning and administration of coastal zone management programs authorized by the Coastal Zone Management Act. Only after oil is located and plans for production are developed is there sufficient information for meeting the impacts of OCS development. Steps must be taken to provide the best information possible so that coastal states can mitigate the impacts resulting from development of oil and gas off their coasts.

Some people have suggested that the federal government actively seek oil and gas on the OCS, including stratigraphic and exploratory drilling. I sponsored such a measure in the 94th Congress; but I am now convinced, based on additional study and information, that the delays necessary to implement a full exploratory program with the government would damage the economy and increase U.S. dependence on foreign resources.

Separation of exploration and development. Opponents of the current leasing system claim that once a lease is sold the sequence of events leads inextricably toward development without sufficient regard to the effects of production. The present system requires that the lessee file a development plan after exploration and prior to production. Until recently, the plan was almost pro forma and an environmental impact statement was not prepared, although on at least one occasion, in the Santa Ynez field off California, the Department of the Interior prepared an impact statement to accompany the development plan through the approval process.

There are two ways to separate development and exploration: government exploration through the exploratory drilling phase, and a process that calls for an independent decision and approval prior to development. I have already indicated that I believe the former to be inadvisable, given the current urgency of the energy problems. The latter, on the other hand, can be built into the administrative process so as to require the approval of a production plan between discovery and development. By expanding the requirements for a development plan and coupling it to a two-step environmental impact statement procedure—one before a lease, and an updated version prior to approval of the development plan—it is possible to separate the decisions sufficiently to safeguard against improvident development where development should not be allowed. Implicit in such a process is authority on the part of the Secretary of the Interior, embodied in the conditions of the lease, to modify, restrict, or prevent development that may result in undue damage to the marine environment of the coastal zone.

Federal-state roles in leasing. The decision of whether or not to lease on the OCS is wholly within the discretion of the federal government as provided through the OCS Lands Act. The states, however, have a legitimate and real interest in OCS decisions; they, not the federal government, must provide for the onshore impacts of offshore development. The 92nd Congress provided the states with an effective instrument to deal with problems in the coastal zone—the Coastal Zone Management Act. Unfortunately, the states' coastal zone programs, for the most part, will not be approved before 1976. In the meantime, plans and procedures to lease in the frontier areas continue.

Congress was sensitive to the problems of synchronizing federal decisions with the goals of the states. One provision of the Coastal Zone Management Act requires that federal actions affecting the coastal zone be consistent with the management programs of the coastal states once they are approved. The ringer is that the so-called federal consistency requirement does not go into effect until a state plan is approved. Somehow, in the OCS leasing process, a means must be found for considering state goals, policies, and laws prior to formal approval of coastal zone management programs.

While it is imperative that the states' policies and goals be considered in any OCS decision that would result in onshore impacts, it is not feasible to give the states veto power or an override in decisions of such high national priority. To a large extent, we must depend on the comity between national and state goals. Communication between federal agencies and the states is vital to achieving the national goals through the democratic process. These lines of communication must be further strengthened to meet the challenges of offshore development.

Equitable returns to government and industry. Although the OCS Lands Act authorizes two fundamental bidding systems for the sale of OCS oil and gas—bonus bid with fixed royalty or production, and royalty based solely on production—virtually all of the lease sales to date have been by bonus bid. Interior has experimented in a limited way with royalty bidding, largely at the urging of the House Appropriations Committee; but the results, according to Interior, are discouraging. A bonus bid is essentially a bulk sale; that is, the entire lot of oil or gas lying below a tract is sold, and a royalty of 16 2/3 percent of the production from the tract is levied. As a result of the sale, huge sums of money are transferred immediately to the federal treasury. This front-end investment, while it may or may not be a windfall for either the government or the lessee, strains the capital capacity of even the largest oil producers. For this reason oil companies have often formed joint ventures.

In many ways bonus bidding is nothing more than high-stake roulette. You win some, you lose some. Since there is no way of knowing whether oil or gas is present until exploratory drilling is done—and that takes place only after leasing—the bonus bid system has the potential for producing windfalls for either industry or government, depending on the amount of oil discovered, if there is oil at all. One effect of large front-end bonuses is to force development so that the lessee recovers his investment as quickly as possible. Another, according to opponents of bonus bidding, is the tendency of this system to color subsequent decisions of the Department of the Interior that must be made prior to development, and to prevent any cancellation or repurchase of the lease in the event of even the most serious environmental consequences.

An advantage of the bonus system is that it is easy to administer. Once a sale is consummated, the money is transferred and exploration and development begin at the initiative and pace determined by the lessee. The government's role is minimal beyond sale. I personally believe that the Department of the Interior has been unduly narrow in its interpretation of the bidding requirements of the OCS Lands Act. The language of the act should permit Interior to utilize combinations and variations of the bidding systems, the only limit being the imagination of those administering the program.

Amendments to the OCS Lands Act (S.521) now being considered by Congress would broaden the alternative bidding systems available to the Secretary of the Interior. One innovation, which I support, would authorize leasing larger areas including an entire oil-bearing, geologic structure. To avoid the pitfalls of the bonus system, multiple parties would bid for variable percentage shares of the lease. The high bidders (based on their proportional percentage shares) would form a blind venture. The federal government would retain a share of the net profits from the oil and gas production. Front-end bonus money would still be involved but would be used to underwrite up to 50 percent of the costs of exploration prior to production. The results of an assessment of this system made by the Office of Technology Assessment for NOPS were encouraging and demonstrated the possibility of this approach.

Such a system would tend to solve several of the problems mentioned earlier: While the lessee would still do the exploration, the government would have access to the data because there would no longer be a reason to maintain the strict confidentiality demanded by small-tract leasing under the bonus system; reservation of a net profit share to the federal government would be more equitable to all parties; and unitization of production from the structure would automatically be achieved. The key, however, is the willingness of the Secretary of the Interior to experiment with alternative bidding to arrive at the most equitable system.

Compensation to the coastal states. It has been shown that OCS oil and gas development has socioeconomic and environmental effects on the coastal zone. Associated with these onshore impacts are both benefits and costs. Since OCS decisions are solely the responsibility of the federal government, it is reasonable to assume that the coastal states are entitled to compensation for any net impacts of OCS activities. In some cases the states may need loans to get them through the initial period of development before tax revenues accrue from OCS activity, after which benefits may far outdistance costs. On the other hand, there may be instances where onshore impacts result in costs for a state over the entire productive life of a lease.

The question of compensation boils down to the question of how. There are those who favor a straight percentage (revenue share) of the proceeds of the sale of OCS leases with no strings attached. Others, myself among them, are convinced that impact money to the states must be tied to a demonstration of need, and then only to the extent of *net* impacts or costs to the states. Whatever the source and mode of distribution of impact funds—be they earmarked or appropriated, no-string or based on net adverse impacts—they should be contingent upon planning and management through the processes of the Coastal Zone Management Act. Only through that vehicle can the states meet the challenge of balancing the multifaceted goals of the state and the nation as they apply to the coastal zone.

Coastal Zone Management Act

There is now a need to amend the Coastal Zone Management Act so that the states can give more attention to the problems of energy facilities siting, not only to accommodate the impacts of offshore oil and gas development, but also for other energy activities, such as power generating stations and deepwater ports. Energy facilities planning, however, must be a part of the comprehensive coastal zone management program and not a separate, fragmented exercise in expediency. To accomplish a balanced expansion of the program, more money is needed. The federal government must also provide guidance and technical support through studies and analyses to aid the coastal states in meeting national requirements while preserving the character and quality of their coastal environment.

Such goals are exactly the focus of S.586, which was passed by the Senate July 16, 1975, and is currently awaiting action by the House of Representatives. The legislation would strengthen the federal consistency provision of the Coastal Zone Management Act as it affects OCS development; create a Coastal Energy Facility Impact Fund for planning energy facilities and for compensating states that suffer net adverse impacts; furnish 90 percent funding for interstate coordination; fund additional research and training activities conducted by the Office of Coastal Zone Management; and provide funds for public access to beaches and for the preservation of islands.

Marine Fisheries Management

Expanded jurisdiction in the form of a 200-mile exclusive fisheries zone would enable the federal government to assume an active role in U.S. fisheries management. Presently, the states control fisheries regulation within the 3-mile territorial sea. Within the contiguous zone, between 3 and 12 miles offshore, although the federal government has paramount jurisdiction to regulate fisheries, no federal regulatory legislation has been enacted. There are currently in effect 23 international treaties between the federal government and several foreign nations regulating marine fisheries.

It is the opinion of many that the international treaties have been unsuccessful in conserving fisheries, and as a result several important fish stocks are being harvested at less than their optimum yields. A classic example is the U.S. haddock fishery, which, despite attempts at regulation by the International Commission for the Northwest Atlantic Fisheries, has been so overfished by foreign and domestic fleets that the catch decreased from 134 million pounds in 1966 to 2.5 million pounds in 1972 (*Oceanus*, Winter 1975).

Regulation authority to 200 miles offshore would permit the federal government and the states to enter into agreements establishing institutional structures, perhaps in the form of regional compacts, for managing fisheries effectively on a broad regional scale. Because of the migratory nature of fishes, it is necessary to manage stocks to the extent of their ranges, which often cross several jurisdictional lines. Piecemeal regulation based on boundaries conforming to neither the range nor the habitat of fish stocks cannot effectually manage fisheries.

Increasing responsibility in fisheries management would necessitate restructuring the regulatory agencies involved. The State Department would have to renegotiate international fishing treaties based on 200-mile U.S. jurisdiction and, at the same time, consistent with traditional international law and principles of the Law of the Sea Conference (LOS). Such a task would not be easy, particularly since the U.S. desires to protect stocks of anadromous fishes, such as salmon, to the full extent of their ranges, which often include the high seas.

The role and the capabilities of NOAA's National Marine Fisheries Service must be expanded to meet the increased managerial responsibilities that would come with regulation of domestic fisheries to 200 miles, and also to meet the problems that would arise as a result of the impact of coastal state preference of international fisheries management.

A very important aspect of fisheries management under extended jurisdiction would be the necessity of compiling and analyzing sufficient data to be able to allocate fish stocks among the various domestic and foreign users. Concurrent with such compilation, analysis, and allocation must be the capability of constant reappraisal of management schemes and regulations, and reaction thereto in a timely manner, since stocks are dynamic and fluctuate widely over short periods of time.

Without adequate enforcement, fisheries management schemes are meaningless. Not only NOAA but other enforcement agencies, such as the Coast Guard, would have to be expanded to meet the increased demands of fisheries enforcement.

The 200-mile economic zone would have a great impact on present concepts of fisheries management. Current techniques—such as closed seasons, closed areas, and vessel and gear limitation—are being used to conserve fish stocks by making the fishery inefficient. The results are low profits and marginal operations for the fisheries, and high prices for the consumers. Also, because the common property aspects of fisheries allow all who wish to enter the industry to do so, including many part-time fishermen (64,000 of 144,000 coastal fishermen are part-timers), there is much overcapitalization in the industry.

Jurisdiction to 200 miles would permit the creation of management schemes, based on the accumulation and analysis of sufficient data, that would allocate fish stocks to domestic and foreign users permitted to participate in the fisheries. Licensing or limited access into fisheries would also result in the creation of some form of quasi-property rights, thereby encouraging rational development of fisheries resources, leading to increased efficiency and lower consumer prices.

Thus, in considering the various proposals for a 200-mile limit and for fisheries management legislation, Congress is being asked to decide whether it is desirable to manage and conserve coastal fisheries resources, whether it is desirable to provide for the continuation of the domestic coastal commercial and recreational fishing industries, and whether the conservation of coastal fisheries resources and the preservation of the domestic coastal fishing industries are wise socioeconomic investments.

Seabed Mining

Currently the U.S. is almost wholly dependent upon imports for manganese, cobalt, and nickel, which are vital to a number of industrial processes. Concern for balance of payment problems and the fear of extortion by foreign cartels controlling scarce materials have increased the interest in the ferromanganese nodules on the ocean floor. Manganese nodules in the Pacific Ocean alone may contain as much as 358 billion tons of manganese, 5.2 billion tons of cobalt, and 14.7 billion tons of nickel, as well as large quantities of other minor metals.

It is estimated that 4.6 million tons of ferromanganese nodules may be mined, processed, and marketed by U.S. firms by 1985. Based on these estimates and projected demand, the U.S. could produce nine to ten times its requirements for pure manganese metal and reduce cobalt and nickel imports by 70 percent and 20 percent, respectively. The projected market value of U.S. production of metals from manganese nodules by 1985 is estimated at $387 million.

The potential payoff is sufficiently high to attract the entrepreneur from both foreign and domestic mining interests. Because of the nature of the operations, the immense investment needed to recover and process nodules, and the uncertainty of the status of seabed minerals vis-à-vis international law, most companies are joining international consortia as a ploy to spread risks and reduce international conflicts.

Distribution of seabed minerals was one of the most highly contended issues at LOS, pitting developed against developing countries. Developing nations claim an inalienable right to share in the exploitation of the "common heritage" of the seabed, although they acknowledge their inability to mine it. Underlying their concern, however, is the fear that their market for manganese, cobalt, and nickel will be diluted, since 77 of the developing countries are major producers and exporters of these metals. As a means of distributing seabed wealth, the "Group of 77," which has now grown to 106 developing countries, supports a strong regulatory control by the United Nations together with an international mining organization to mine the ocean floor. Considering that so-called Third World countries now control the U.N. General Assembly, regulation of seabed mining would virtually be in the hands of the producers. This, in effect, would be the sanctioning of an international cartel under the auspices of the world union.

Primarily through the initiative of private capital, the U.S. has continued to develop the necessary technology to exploit the deep seabed. It is generally agreed that the U.S. is capable of launching commercial operations by 1980. One of the best publicized efforts, Summa Corporation's *Glomar Explorer* has proved to be an embarrassment because of its involvement in covert CIA activities in raising a sunken Soviet submarine from great depths in the Pacific Ocean. Although the operation may have prejudiced the U.S. position on freedom of research on the high seas at LOS, it effectively demonstrated the capacity to explore and mine the deep seabed.

The effects of extensive seabed mining and processing on the marine environment are unknown. Preliminary studies show little cause for concern. However, more extensive investigations must be conducted before the environmental impacts can be determined.

On the question of whether or not to proceed unilaterally with deep seabed mining, U.S. industry maintains that the federal government should guarantee its investment and protect its operations from interference in international waters. Others would establish a unilateral federal leasing-and-permit system for regulating mining operations. This would be like selling the Brooklyn Bridge, since

A 200-mile economic zone, with adequate enforcement, would enable management and conservation of U.S. coastal fisheries and preservation of domestic fishing industries. (Keith von der Heydt) the U.S. government does not own an alienable property right to the seabed beyond the continental shelf. As for guaranteeing business investment, profit is made on the assumption of risk; and those who stand to profit must include such risks in the cost of the product. What *is* needed is a system of federal licenses to regulate the domestic affairs of the industry and to establish rules protecting the marine environment.

Perspectives in Ocean Policy

The U.S. government has consciously promoted the development of private and public natural resources through public policies that have provided incentives for the extraction, harvesting, and conversion of raw materials to goods, based on the theory—one that is well founded in history—that wealth and economic power must ultimately originate from the earth's resources. But we are beginning to see that the cornucopian theories of John Locke and Adam Smith, at least as they apply to an individual nation such as the U.S., are riddled with assumptions about the infiniteness of exploitable resources. Although some political economists cling tenaciously to the familiar clichés, this lesson is being learned the hard way.

There is little doubt that we are entering the twilight of our productive years so far as extractable nonrenewable resources are concerned. We are rapidly slipping down the backside of the diminishing limb of resource production so graphically described by King Hubbert with his bell-shaped curves. Reluctantly we are being forced to play the politics of scarcity. Now, like many European and Asian countries, the U.S. must compete in the world market at inflationary prices to satisfy its insatiable demands.

The federal government once held two billion acres of public lands in trust for the people; but within 180 years, through deliberate public policy, it has disposed of one billion acres of the most productive public domain. Today there remains a scant 750 million acres, not including the OCS, and what remains has a low potential for meeting the nation's demands.

The challenge to researchers, ocean industries, and policy makers at the state and federal levels is awesome. Institutions must be restructured, policy must be formulated on the basis of sustained and scientific management of the resource rather than special interests, and far more knowledge must be gained in order to bring man's intellect and innovation to focus on the problems of the oceans.

Ernest F. Hollings, senator from South Carolina (Dem.), is chairman of the Senate Commerce Committee's National Ocean Policy Study. He is the acknowledged leader in Congress on ocean policy and has been instrumental in formulating legislation on offshore oil and gas development, coastal zone management, ocean dumping, protection of marine mammals, and other issues relating to man's use of the ocean and coastal resources.

Selected U.S. Laws Applying tc

Growth of commercial fishing and navigation—the historical uses of the oceans—has been joined by expansion of more recent activities such as minerals exploitation, dumping, and construction of offshore terminals and storage depots. Within the next decade there will be still newer developments—energy generation in offshore nuclear power plants and perhaps through more exotic means such as ocean thermal differences, tidal power, and wind power; offshore use of industrial-port islands; expanded mineral extraction; and aquaculture. Recreation and research are also likely to increase. One estimate is that the value to the U.S. of its ocean resources will quintuple, from $7.6 billion in 1972 to between $34 billion and $44 billion by the year 2000.

The activities mentioned above take place on a variety of structures, ranging from drilling ships to fixed platforms. They are variously called rigs, industrial vessels, platforms, and artificial islands and structures.

Growth of applicable regulatory law has paralleled seaward expansion. Some laws center on a specific use, for example, continental shelf resources or offshore deepwater terminals. Others apply to a variety of activities and regulate areas such as navigation, labor relations, safety of operations, and environmental protection. The present jurisdictional or effective regulatory reach of many laws extends beyond the nation's territorial seas. The subject is complicated by the fact that many of the structures are considered vessels for some, but not all, purposes, while other structures performing closely similar tasks are not considered vessels.

Listed below is a selection of U.S. federal laws pertaining to offshore structures and uses other than fishing. Some laws, such as the River and Harbor Act of 1899, are of long standing, although they continue to play an active role in the regulatory regime. Others, among them the Ports and Waterways Safety Act, the Ocean Dumping Act, and the Federal Water Pollution Control Amendments, were enacted in the early 1970s. Taken together, they provide extensive enabling authority to the agencies responsible for regulating the oceans. Further, much of the authority found in the more recent acts is still in the process of being implemented by new regulations. The laws presented here are discussed in the report *Federal Regulatory Aspects of Offshore Structures and Uses* by J. D. Nyhart of the Massachusetts Institute of Technology, scheduled for publication later this year under NOAA Sea Grant #04-158-1.

Title 14 USC Coast Guard

14 USC 81	Aids to Navigation Authorized
14 USC 83	Authorized Aids to Maritime Navigation
14 USC 84	Interference with Aids to Navigation
14 USC 85	Aids to Maritime Navigation on Fixed Structures
14 USC 86	Marking of Sunken Vessels and Other Obstructions
14 USC 88	Saving Life and Property
14 USC 89	Law Enforcement

Title 16 USC Conservation

16 USC 661–66c	Fish and Wildlife Coordination Act
16 USC 1431 et seq.	Marine Protection, Research and Sanctuaries Act: Title III
16 USC 1456 et seq.	Coastal Zone Management Act of 1972

Title 18 USC Crimes and Criminal Procedure

18 USC 2152	Fortifications, Harbor Defenses, or Defensive Sea Areas

Title 19 USC Customs Duties

19 USC 1434	Entry of American Vessels

Offshore Structures and Uses

Title 29 USC Labor

29 USC 655	Occupational Safety and Health Act of 1970

Title 33 USC Navigation and Navigable Waters

33 USC 151–232	Inland Rules of the Road
33 USC 401 et seq.	River and Harbor Act of 1899 (including Permit Requirements [§403] and Refuse Act [§407])
33 USC 471	Establishment of Anchorage Grounds and Regulations Generally
33 USC 472	Marking Anchorage Grounds
33 USC 901 et seq.	Longshoremen's and Harbor Workers' Compensation Act
33 USC 1001–15	Oil Pollution Act of 1961
33 USC 1051–94	International Regulations for Preventing Collisions at Sea (International Rules of the Road)
33 USC 1201–08	Vessel Bridge to Bridge Radiotelephone Act
33 USC 1221–27	Ports and Waterways Safety Act of 1972: Title I
33 USC 1251–1376	Federal Water Pollution Control Act
33 USC 1401–21	Marine Protection, Research, and Sanctuaries Act of 1972: Title I, Ocean Dumping Act
33 USC 1501 et seq.	Deepwater Port Act of 1974

Title 42 USC The Public Health and Welfare

42 USC 1857 et seq.	Clean Air Act
42 USC 4321 et seq.	National Environmental Policy Act

Title 43 USC Public Lands

43 USC 1301 et seq.	Submerged Lands Act
43 USC 1331 et seq.	Outer Continental Shelf Lands Act

Title 46 USC Shipping

46 USC 11 et seq. (and remainder of Ch. 2 as applicable)	Registry and Recording (including §71 et seq.: Inspection, Survey and Measurement)
46 USC 86 et seq.	Load Lines for Vessels Making Foreign Voyages
46 USC 88 et seq.	Load Lines for Vessels Engaged in Coastwise Voyages
46 USC 170	Regulation of Carriage of Explosives or Other Dangerous Articles in Vessels
46 USC 181 et seq.	Limitation of Liability Act
46 USC 221	Vessels of United States and Officers Defined; Officers to be Citizens
46 USC 222	Complement of Officers and Crew of Vessels
46 USC 223	Minimum Number of Officers
46 USC 224 (and remainder of Ch. 11 as applicable)	Licensing of Officers
46 USC 239(a) (b)	Investigation of Marine Casualties
46 USC 361–2, 367, 390b, 391 (b) (d) (e), 391a, 391b, 392(b), 393, 395(b) (c), 397, 399, 435, 441–45 (i.e., Ch. 14 as applicable)	Inspection of Steam Vessels (including Tank Vessel Act of 1936, as amended by Ports and Waterways Safety Act of 1972: Title II [§391a], and Seagoing Barge Act [§395])
46 USC 364	Vessels Navigating Coastwise and on Great Lakes
46 USC 688	Jones Act
46 USC 701	Various Offenses; Penalties
46 USC 713	Definitions, Schedules, and Tables
46 USC 761 et seq.	Death on High Seas Act
46 USC 1451 et seq.	Federal Boat Safety Act of 1971 (including §1461d, Negligent Use of Vessel)

Title 49 USC Transportation

49 USC 1651 et seq.	Department of Transportation Act, amending 18 USC 831–35, Transportation of Explosives Act
49 USC 1671 et seq.	Natural Gas Pipeline Safety Act of 1964

Title 50 USC War and National Defense; and Appendix

50 USC 191	Magnuson Act of 1950

—J. D. Nyhart, *associate professor of management, Sloan School of Management and Department of Ocean Engineering, Massachusetts Institute of Technology.*

Atlantic Offshore Oil:
The Need for Planning and Regulation

by James M. Friedman

Coastal wetland, York, Maine. (Tom Jones photo)

In March 1975 the U.S. Supreme Court decided the case of *United States* v. *Maine.* The Court ruled that the federal government, not the Atlantic coastal states, has jurisdiction over that portion of the continental shelf which lies more than three miles from shore. (In 1953 Congress had granted to the coastal states title to shelf resources within three miles of shore.) The case resulted from Maine's assertion that her jurisdiction extended two hundred miles to sea. One basis of the argument was a colonial charter that preceded the founding of the United States. Eleven other Atlantic states made similar claims and thus joined in the case.

An important consequence of the Supreme Court's decision is that Atlantic offshore oil development will be federally authorized and regulated. In April, several weeks after *Maine*, the Bureau of Land Management (BLM) of the U.S. Department of the Interior took the first step toward leasing the lands of the outer continental shelf (OCS) by issuing a call for nominations. (*Outer continental shelf* simply means that part of the shelf beyond state jurisdiction. The term, as used here, is of legal rather than geological significance.) When BLM issues a call for nominations, the oil companies respond by naming those offshore tracts believed suitable for commercial development.

The April call was for the section of the Mid-Atlantic known as the Baltimore Canyon. In June BLM issued a call for Georges Bank, off the New England coast. The Interior Department plans to lease the Baltimore Canyon area sometime in mid-1976, and Georges Bank later that year.

Not surprisingly, a number of the coastal states have expressed concern over the potential consequences of offshore oil development. Even if the actual drilling takes place one hundred to two hundred miles from shore, well within federal jurisdiction, the states will be vitally affected. Offshore oil exploration must be supported from onshore bases. And if oil is found, it must be brought ashore, stored, transported, and refined. Construction of port facilities, tank farms, and refineries can have substantial socioeconomic and environmental effects on a city, small town, or coastal area.

Certain coastal states are also worried that oil development may hurt commercial fishing. The Massachusetts fleet, which is concentrated in New Bedford and Gloucester, does most of its fishing on Georges Bank. Oil rigs, platforms, pipelines, and supply boat traffic are potential obstacles to trawling.

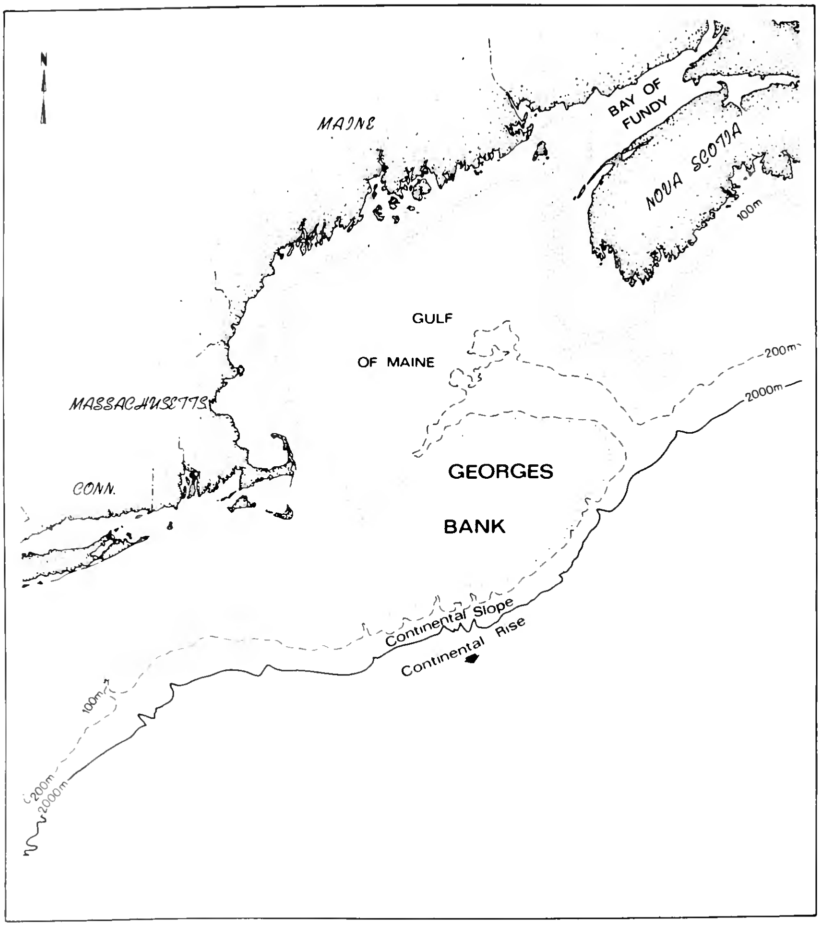
Another concern is pollution. Oil companies point out that offshore drilling results in less pollution than does transportation of oil by tanker. However, many state officials and environmentalists still fear the possibility of either a massive accident, such as a blowout, or the less spectacular but serious problem of chronic low-level pollution.

It is evident that offshore oil development is not without serious costs. The question is whether those costs can be minimized through proper planning and government regulation so that, on balance, development is worthwhile.

Onshore Impacts

Initially much of the debate about offshore oil focused on pollution. Those opposed to development argued that the environmental degradation from oil pollution is simply too high a price to pay. They could point to the infamous Santa Barbara blowout of 1969, which fouled the channel, blackened beaches, and killed an indeterminate amount of marine life.

Those who supported development asserted that offshore technology had continually improved, lessening the chance of another major blowout; and oil company officials stated that government



Georges Bank, a primary North Atlantic fishing ground, is scheduled to be leased for oil development in late 1975.

regulation had become tougher and more comprehensive since Santa Barbara. Proponents of drilling pointed out that, above all, we simply need the oil, and a certain amount of pollution must be accepted.

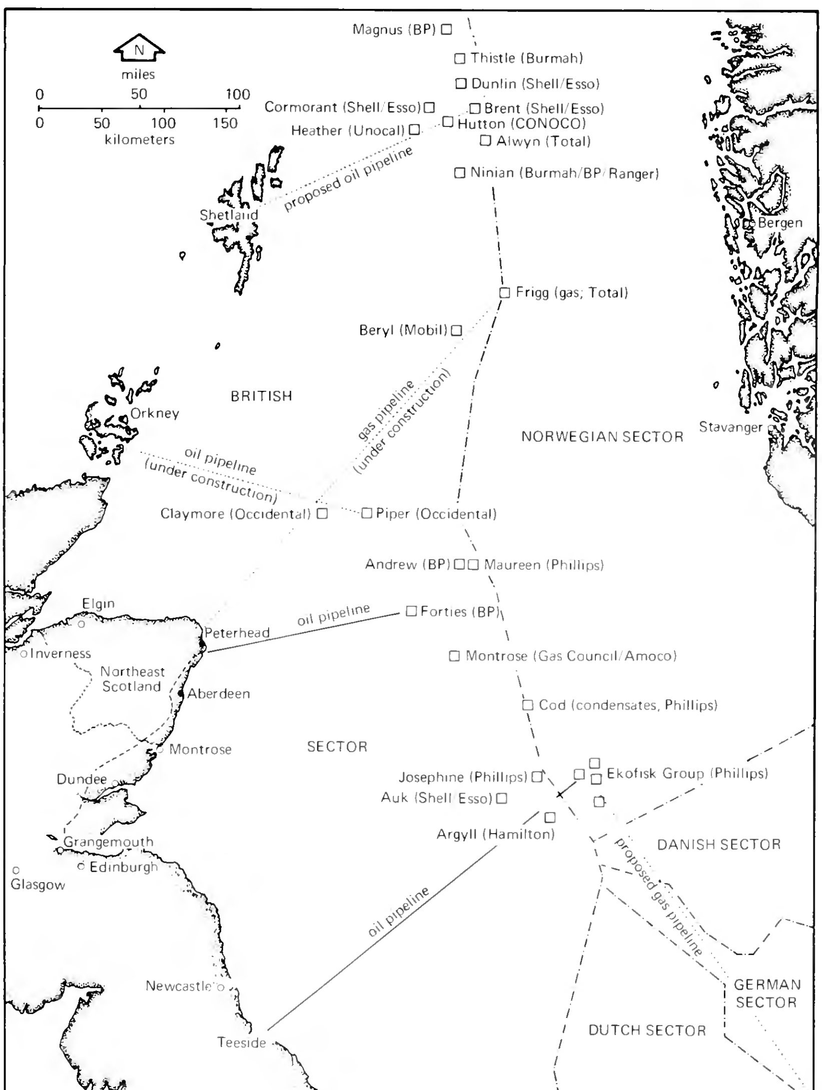
The various arguments presented by oil industry spokesmen, environmentalists, and those in-between have not resolved the pollution question. Most important, there is surprisingly little scientific data on the effects of oil in the marine environment, and most of what is known has been learned during the past five years. However, policy makers cannot assume that a lack of information means that the damage is minimal or acceptable. Caution is advised, particularly in siting for development a fishing ground, such as Georges Bank, that is an important source of protein for the world.

In recent months the focus of public discussion has shifted from pollution to onshore impacts, that is, anything that happens onshore as a result of oil development offshore. Onshore impacts can range from increased population and real estate costs in a coastal village to an oil refinery fifty miles inland. The emergence of onshore impacts as a subject for public debate is perhaps due to two separate events, the first of which was the decision by the Nixon Administration in 1974 to greatly accelerate and increase U.S. offshore oil production. The President's plan called for the leasing of ten million acres of the OCS in 1975, which would have doubled in one year the acreage leased over the last twenty years.

In fact, the ten-million-acre goal will not be met in 1975. It is doubtful whether the oil companies could have secured the equipment and capital necessary for such a sudden and massive development, even if the government had been able to properly lease and regulate that many acres. However, the accelerated program did result in the Interior Department's decision to hold lease sales in areas where no drilling had been done. These *frontier areas* included the continental shelves of the Atlantic and the Gulf of Alaska.

Local response in the frontier areas has varied. Offshore oil can mean a much needed boost to a local or regional economy. On the other hand, development can place serious strains on a social structure, or cause environmental damage. These conflicts were particularly felt by state officials in New England, where the economy has been hard hit in recent years. A refinery or port facility might be welcomed in parts of New England. But the region possesses traditional villages and a remarkable coastline. If these features were harmed by oil development, New England's sense of identity would be offended. Moreover, the vital tourist trade could be affected.

The second event to focus public attention on the topic of onshore impacts was the development of North Sea oil off the coasts of Scotland and Norway. During the past two years, several studies of Scotland have been published. The National Ocean Policy Study of the U.S. Senate Commerce Committee issued a report in October 1974; the Council on Environmental Quality sponsored similar research; and early in 1975 the Conservation Foundation published Pamela and Malcolm Baldwin's book, *Onshore Planning for Offshore Oil: Lessons from Scotland.* These studies, and others like them, give meaning to the



Oil and gas fields in the North Sea. (Northeast Scotland Development Authority) phrase *onshore impact.* The picture that emerges is worth noting in some detail.

The first phase of offshore oil development is exploration. After years of seismic study to locate geologically promising structures, oil companies and their contractors begin drilling with mobile rigs to determine whether there are commercial quantities of oil in a particular area. This activity is supported by onshore bases from which supplies are transported by boat to the rigs. The nearest harbor town therefore serves as a depot, with the possibility of increased congestion and competition for docking space.

During exploration there is usually little development onshore, aside from the supply bases. An exception occurs when drilling rigs are constructed in coastal communities adjacent to the offshore exploration. This did not happen in Scotland because most rigs were imported from the Gulf of Mexico, but Norway converted a depressed shipbuilding industry to rig construction.

If commercial amounts of oil are found to exist, development begins. It is at this point that onshore impacts are most intense. Logistical support must be provided for platform and pipeline construction. Tank farms and refineries must be sited and built. Contractors and service industries move into the towns that will serve as support bases for the offshore operations. All of this activity can put a severe strain on local planning. If the construction of oil-related facilities means new jobs and a general boost to the economy, it can also mean higher land prices, increased rents, and greater burdens on public services. A new refinery, for example, requires three to four million gallons of water per day. Onshore impacts are likely to be more severe in smaller towns or rural areas than in cities. But wherever coastal impacts are expected to occur, planning is a necessity.

Once the development phase has been completed and the oil fields are producing, employment opportunities usually decline. The Baldwins point out that while 2000 people are needed to build a refinery, it takes only 300 people to operate it. And, of course, many of these positions are not filled by local people. The threat of a boom-bust economy is a serious problem. To avoid such an occurrence Norway has established a national policy of gradual rather than rapid development of its North Sea oil.

While the North Sea experience is of obvious value in attempting to assess the effects of offshore development, it is especially relevant to New England. The North Sea and the North Atlantic around Georges Bank have similar climates and sea conditions. Both Scotland and New England support domestic fishing industries. And, perhaps most importantly, Scotland had no large domestic petroleum industry prior to the North Sea development; the industry had to come from outside the country. Similarly, New England has no major petroleum industry (there is currently no large refinery in the region); if Georges Bank is to be developed, the industry must come from outside the region. New England and Scotland are in contrast to the situation in the Gulf of Mexico, where nearly all U.S. offshore oil development has taken place. In the gulf the oil industry did not come from somewhere else; it merely moved offshore from the states of Louisiana and Texas.

In predicting the onshore impacts in New England, one can place too much reliance on the Scottish experience. Oil and gas development in the North Sea is one of the largest in the world, and geologists do not believe that Georges Bank will provide as rich a find. If there is less oil in Georges Bank than in the North Sea, onshore impacts will naturally be less in New England than they have been in Scotland.

To predict the degree and the locations of onshore impacts in New England is a hazardous task. The region's geography and the local political attitudes are likely to affect the course of development as much as does the amount of oil found offshore. The Narragansett Bay area, Cape Cod, and the offshore islands of Martha's Vineyard and Nantucket seem geographically well suited to support oil operations on Georges Bank. Of these, Narragansett Bay may be the most amenable: the waterway provides sufficiently deep approaches for supply boats, barges, and small tankers; and large parcels of land (former Navy bases) are open at Newport and Quonset Point. In contrast, Cape Cod and the Islands have smaller harbors and few large blocks of available land. Nevertheless, it cannot be concluded that Narragansett Bay will be the site of support facilities, because geography will not be the sole determinant of where onshore impacts will occur.

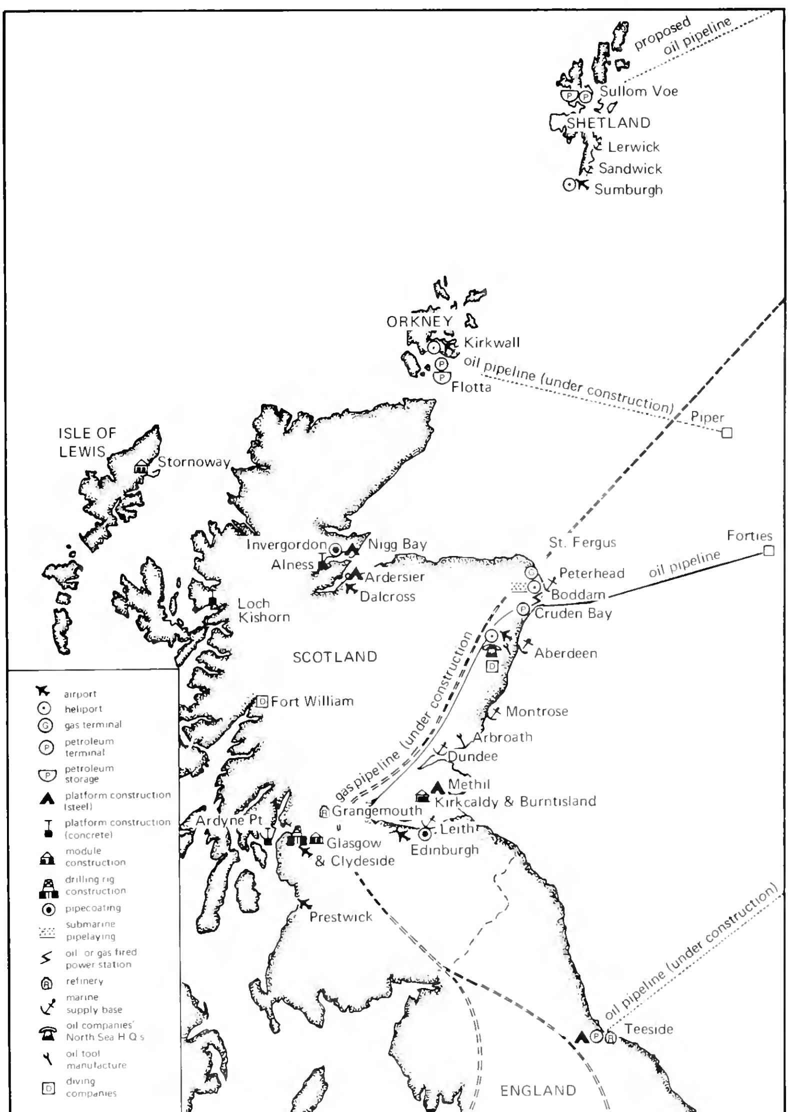
From a national perspective there is a tendency to assume that New Englanders are of one mind about oil development. However, even a brief examination of the various state governments suggests substantial differences in the way the New England states approach offshore oil. In Maine, for example, legislation in recent years has suggested that the state is determined to protect the beauty of its coastline and the vitality of its fisheries. The oil pollution control law states:

The legislature of Maine finds and declares that the highest and best uses of the seacoast of the state are as a source of public and private recreation and solace from the pressures of an industrialized society and as a source of public use and private commerce in fishing, lobstering, and gathering other marine life.

Although Maine's coastline is separated from Georges Bank by the Gulf of Maine, state officials are concerned about the ways in which offshore oil development will affect the state. If the ports are too far away from Georges Bank to serve as a supply base, there could be more proposals for siting refineries. This and other questions about offshore development will be addressed by a special OCS Advisory Committee recently appointed by the governor.

In New Hampshire, where the governor is a strong proponent of offshore oil development, state law provides that before a refinery can be built in a particular town, the town must approve the project by referendum. It is therefore difficult to predict the course of onshore development in New Hampshire.

Massachusetts towns also have substantial legal power and thus have much to say about onshore impacts. However, a bill is now before the state legislature to make refinery siting a state decision.



Onshore developments in Scotland. (Northeast Scotland Development Authority)

Aberdeen and Peterhead harbors host Britain's major supply bases for North Sea oil (see map, page 27). These bases provide berthage for supply vessels that carry equipment and provisions to offshore oil rigs and platforms, as well as warehouses, repair facilities, and office buildings. (Top) Peterhead Bay, with derrick barge, floating oil rig, and supply boats. (Center) Truckload of oil pipeline is delivered to a supply base in Peterhead. (Bottom) Supply boat All Tide *leaves Aberdeen Harbor. (Top photo: Charles Fraser; center and bottom photos: Richard Allen)*

In Rhode Island the state commission in charge of economic development has taken advertisements in oil industry trade journals announcing that the state would welcome the industry's use of the abandoned Navy bases. However, Rhode Island also has a coastal zone commission that must ultimately approve petroleum facilities on the shoreline.

In Connecticut the Coastal Area Management Office (CAM) in the Department of Environmental Protection is developing a coastal zone plan. Currently, primary responsibility for the siting of petroleum facilities remains with the towns. A CAM spokesman reported that it is too soon to predict whether the coastal zone plan will result in a stronger state role.

These differences in state attitudes and law are not academic distinctions. In assessing where an oil company may locate a refinery, tank farm, or supply base, the nature of state regulation is a prime variable. An oil company might choose one state over another simply because it sees less regulation and litigation there. Admittedly, geographical constraints remain.

Given the variety of impacts of offshore oil development, government regulation is increasing. And despite the complaints of some oil companies, this regulation seems necessary if there is to be proper onshore planning. However, state regulation is only part of the scheme; the federal government retains primary responsibility for offshore oil.

In recent months the federal administration of OCS development has been subject to serious criticism. State officials as well as congressional committees have charged that the Interior Department has done an inadequate job of planning and regulation. Understanding the current debate over offshore oil policy requires a basic knowledge of the legal-administrative structure for offshore development.

Federal-State Relations

In 1953 Congress enacted the Outer Continental Shelf Lands Act, establishing the basic administrative framework for offshore oil development. The act vested administrative authority in the Secretary of the Interior, who has delegated this authority to two agencies of the Interior Department: the Bureau of Land Management (BLM), which leases offshore tracts to the oil companies; and the U.S. Geological Survey (USGS), which regulates offshore operations after a lease is signed.

No doubt a basic purpose of the OCS Lands Act was to increase federal revenues from offshore oil production. This purpose was in keeping with BLM's traditional role of facilitating the exploitation of natural resources by private corporations. Since the passage of the act, American attitudes toward natural resources and the environment have changed. Although few people would deny U.S. need for oil, this need is no longer sufficient justification for the exploitation of natural resources without proper planning and regulation.

In the late 1960s and early 1970s, Congress enacted laws that expressed a new public awareness of the environmental costs of unplanned development and industrialization. There were anti-pollution laws, such as the Clean Air Act of 1970 and the Federal Water Pollution Control Act of 1972, and planning statutes, such as the National Environmental Policy Act of 1969 and the Coastal Zone Management Act of 1972.

This legislation was designed to regulate not only the public but also the government. The National Environmental Policy Act, for example, requires that all federal agencies file an environmental impact statement before taking any action that will significantly affect the environment. The statement must include: an assessment of adverse environmental effects of the proposed action; alternatives to the proposed action; a statement of the relationship between the proposed short-term use of the environment and the long-term effects on the environment; and a statement of any irreversible commitment of national resources resulting from the proposed action. The purpose of these bulky requirements is to make the government more sensitive to the environmental consequences of its policies.

In October 1974 BLM issued a draft environmental impact statement for the accelerated offshore leasing program. Pursuant to the requirements of the National Environmental Policy Act, there were public hearings on the draft statement. The East Coast meeting was held at Trenton, New Jersey, in February 1975; and while the ostensible purpose was to gather public comment on the impact statement, discussion went considerably further. Oil company representatives accused the coastal states, particularly those in New England, of delaying offshore development (*U.S.* v. *Maine* had already set back the leasing schedule). Industry spokesmen also suggested that the New England states were being selfish, that they were placing their environmental concerns above the national need for energy.

In responding to these accusations, coastal state officials and others criticized the impact statement as being superficial, without useful scientific data or analysis. (Anyone who has waded into the statement's sluggish prose would find it hard to disagree with this charge.) Witnesses from the coastal states asserted that BLM was little concerned with proper planning and was ignoring the states in developing its program. Finally, local officials and members of citizens groups from the Northeast maintained that they were not being selfish in opposing BLM's methods of doing business. Their argument was not with oil development per se, but with a poorly planned and administered offshore program that was not part of a well-thought-out national energy policy.

Regardless of how one views the various criticisms, the point is that BLM and the coastal states are not working together in planning for Atlantic offshore oil development. Since many of the impacts will fall within state jurisdictions, even though the drilling will take place on the federal OCS, a lack of state-federal coordination could cripple oil development and result in unnecessary environmental and socioeconomic damage.

There is nothing in the OCS Lands Act that requires the Interior Department to work closely with the coastal states in planning the offshore leasing program. However, the Coastal Zone Management Act emphasizes a strong state role in planning for all matters affecting coastal areas and mandates federal-state cooperation. It states that "the key to more effective protection and use of the land and water resources of the coastal zone is to encourage the states to exercise their full authority over the land and waters in the coastal zone." As an incentive, the Office of Coastal Zone Management, which administers the program, makes federal funds available to any state that will develop a comprehensive plan for its coastal zone. To prepare such a plan, or management program, a state must carry out baseline studies of its coastal resources, designate areas of particular fragility or concern, define permissible land and water uses, and develop the political structures necessary to implement its program.

Clearly, the Interior Department cannot properly plan for offshore development unless it consults with the coastal states. A state might allow a tank farm at one place on its shoreline, but not at another. The Interior Department should have such information before granting a federal right-of-way permit for a pipeline. Similarly, the states, in making their planning decisions, should be aware of the special problems of the offshore developer and the Interior Department. Perhaps a pipeline can be routed ashore only at several points because of the bottom sediments of a particular portion of the continental shelf.

Oil rigs under construction, Bergen, Norway. (Richard Allen)

Section 307 of the Coastal Zone Management Act requires that no federal license or permit be granted for any activity affecting a state's coastal zone unless the state has certified that the activity is consistent with its management program. Thus the act seems to require that federal agencies recognize state planning needs. At the present time, however, Section 307 is not in force because no coastal state has yet implemented its final plan. The work of gathering and analyzing substantial scientific and socioeconomic data has taken longer than the developmental period envisioned in the act. Also, the Nixon Administration delayed the states at the outset by impounding coastal zone funds.

When a state has completed its management plan, the program must be approved by the Secretary of Commerce if the state is to maintain its federal funding. The secretary grants or withholds approval on the basis of criteria presented in the statute, one of which is that the state's plan must provide for "adequate consideration of the national interest involved in the siting of facilities necessary to meet requirements which are other than local in nature." The secretary could use this clause to invalidate a program that makes no provisions for energy-related facilities.

Although there is room for federal and state officials to argue about what cooperation means and who must compromise, the Coastal Zone Management Act is a significant addition to the administrative legal-framework for offshore oil development. It provides a concrete mechanism in Section 307 for coordinating federal and state programs, and it recognizes that the protection of coastal resources, such as wetlands and estuaries, is best achieved through strong local and state participation.

In sum, current planning for offshore oil development is hampered by poor federal-state relations. BLM has relied too heavily on oil company opinion and expertise—a practice that has made many of the coastal states suspicious of the agency. Opening the planning process to the states and the public would not only lessen suspicion of BLM but also make the agency a better manager.

The primary responsibility for regulating offshore oil operations rests with the USGS Conservation Division, although other federal agencies such as the Army Corps of Engineers and the Coast Guard are peripherally involved. USGS issues a variety of regulations called OCS Orders, which cover, among other things, safety (well easings and blowout preventers), plugging and abandonment of wells, pollution control, and drilling procedures. The quality of offshore drilling operations is therefore greatly dependent upon how well USGS does its job.

In recent years USGS, like BLM, has been severely criticized. On October 1, 1974, the House Committee on Government Operations issued a report, based on a Government Accounting Office study, concluding that USGS inspection procedures were inadequate. According to the GAO, only half of the fifty wells started in fiscal year 1972 were inspected for compliance with pollution and safety regulations during drilling operations. The House report cited additional statistical evidence of lax enforcement.

Other congressional committees, including the House Small Business Committee, have found fault with USGS. At the heart of much of this criticism is a belief that the agency has been "captured" by the oil industry it regulates. Of course, this idea is not new; federal agencies are often charged with representing the interests of the industries they regulate rather than of the public. However, the Interior Department seems particularly prone to this argument.

Another reason for criticism of USGS is that the agency considers information on seismic work and exploratory drilling to be "proprietary." The oil companies argue that since they lease an offshore tract before doing any exploratory drilling, they are entitled to keep the USGS data secret. Otherwise, competing firms will use the information to assess the value of adjacent tracts that have not been leased. While the argument makes good sense to the companies, it also makes planning extremely difficult. Without information on the potential size of an offshore field, coastal zone commissions cannot adequately prepare for onshore development.

In recent months both BLM and USGS have made some attempts to involve more people in planning and regulation. USGS representatives met with New England fishermen to discuss how oil and fishing operations could be made more compatible. BLM has stated that it will listen to discussion on which offshore tracts should not be nominated because of environmental hazards or conflicts with other industries, such as commercial fishing. Of course, BLM has made it clear that it will not be bound by such "negative nominations."

While these attempts to involve more people in the formulation of offshore policy are to be commended, they emphasize how isolated the Interior Department has been. USGS still does not hold public hearings in preparing its regulations. And BLM still acts more like a private real estate agent than as manager of the public's natural resources.

The purpose of planning is not to hinder development of natural resources but to minimize environmental and socioeconomic damage. The federal agency in charge of offshore oil development should be suspicious of neither planning nor the public.

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Marine Sand and Gravel Mining

by Michael J. Cruickshank and Harold D. Hess

The 30,000-ton "hydro-barge" Ezra Sensibar, *an ocean-going suction hopper dredge designed for sand and gravel mining. It is self-loading and self-unloading, carries a crew of eleven, and can dig in water depths to about 30 meters. (Construction Aggregates Corp., Chicago)*

Sands and gravels account for the greatest volume of non-energy minerals mined annually in the United States. Production from all sources in 1974 amounted to about 904 million tons valued at $1.6 billion, involving about 5600 commercial operations. Based on Bureau of Mines statistics, tonnages produced in the U.S. represent about 13–14 percent of world production.

The major use of sand and gravel is in the construction industry, which utilizes about 95 percent of the supply: highway construction and maintenance, including concrete and asphalt paving mixes for bridges, tunnels, and road bases, account for 56 percent of the total; building construction and maintenance, including urban renewal and metropolitan transit systems, 39 percent. The remaining 5 percent is used for abrasive products, foundry and glass sand, railroad ballast, and miscellaneous industrial items.

Because sand and gravel is a low-cost, high-bulk commodity, making the price very sensitive to transportation costs, markets have traditionally been established before a local source of raw materials has been sought. Under this system cost to the consumer has remained fairly stable over the years. Now, however, prices are beginning to rise as a result of the increased costs of labor, land, and reclamation, in addition to the need to produce from lower-quality or more-distant deposits as the better ones become depleted or are enveloped by urban expansion.

The influence of these variables is demonstrated further by the range of prices charged at different locales. According to the Bureau of Mines, representative carload prices of sand in 19 cities in 1972 ranged from $1.05 per ton in Detroit to $5.40 per ton in Pittsburgh, with an average of $3.14 per ton. The cost of 3/4-to-1-inch gravels ranged from $1.60 per ton in Birmingham to $7.00 per ton in New Orleans, with an average of $2.80 per ton. The average price F.O.B. plant for all U.S. sand and gravel production combined was $1.31 per ton (Pajalich, 1973). These variations largely reflect transportation costs, which in most cases limit the distance the commodity can be carried to a market and still be economical. In California, for example, this distance is roughly 65-80 kilometers, and in Oregon less than 32 kilometers. As a general rule, the prices of sand and gravel double for each 32–40 kilometers by truck.

Compared with other forms of land-based mining, sand and gravel mining represents close to 10 percent of the value of all U.S. minerals production, excluding energy minerals. During the 20-year period 1952-72, production of sand and gravel increased at a rate of almost 5.5 percent per year and is expected to grow at the average rate of about 3.9 to 4.7 percent per year through the year 2000 (USBM, 1970). This reflects an annual demand by the end of the century of between three and four times the present production. We must therefore find new sources that are economically competitive to mine and transport, and whose utilization has minimal impact on the environment.

An alternative source that is beginning to receive serious attention in the U.S. is the submerged lands of the continental margin, including the coastal zone and the outer continental shelf. Obviously, with the joint requirements for markets and competitive prices, coastal or near-shore deposits will not be the answer to shortages in mid-continent. However, the location of large urban centers near the coasts and the anticipated increase of future construction needs in the coastal zone make the possibilities for an enlarged marine sand and gravel industry not only attractive but also compelling. At the present time in the U.S., operations are extremely limited and restricted to a few locations, such as coastal estuaries and inland waters. Although industry interest in many offshore areas has been high, public protest has led to dredging moratoria in most coastal states. In many cases the restraint results from a lack of information on environmental effects, for neither the nature of the resources nor the magnitude of the impacts has yet been determined. Nevertheless, some understanding of these areas can be reached in the light of U.S. and foreign activities.

The marine sand and gravel industry of the United Kingdom, for example, is the largest and most advanced marine mining activity in the world today. It supplies about 20 million tons per year of concrete aggregate for construction purposes in the U.K. and on the European continent. In addition to U.K. operations, Denmark dredges approximately 1 million tons of sand per year from the Baltic Sea for building purposes in Scandinavia. The Dutch recover about 10 million tons of sand per year for land reclamation from North Sea sources far off the Netherlands coast (Hess, 1971). Japan also has an active sand and gravel industry offshore, supplying about 19 percent of the country's needs, though mostly from sheltered waters. In France, government-sponsored exploration has been completed with a view to utilizing offshore reserves in the English Channel and in the Bay of Biscay.

Costs

Reported costs from Europe and the U.S. indicate that marine aggregates would be competitive with those from land. Table 1, based on U.K. dredge operations in 1970, shows capital costs of between 80¢ and $2.68 per ton of annual production capacity and operating costs, including capital pay back of between 35¢ and 49¢ per ton. By comparison, product value for inland sand and gravel delivered to the Los Angeles Harbor area in 1968 was $2.69 per ton and is expected to exceed $6.00 per ton by 1980.

Sand and Gravel Resources

Apparent resources of sand and gravel have been tentatively estimated for the U.S. and the world, both onshore and offshore, and compared with projected demands (Table 2). According to these estimates, economic land sources of sand and gravel for the U.S. and the world would be depleted by the year 2000, if the present rate of increase of usage is maintained. Additional marine resources of sand and gravel on the continental margins are indicated, which would increase the resource base by a factor of 25 for the U.S. and 93 for the world. As yet, there is no way to substantiate these very impressive numbers because the resources have been mapped in only a few areas, such as the northeastern U.S. (Figure 1) and parts of Europe (Figures 2 and 3); and even there, the depths of the deposits have not been adequately mapped. However, it appears from these beginnings that there are significant deposits of commercially usable materials off most coastlines throughout the world.

Sand and gravel is certainly the most prolific of the industrial mineral deposits on the U.S. continental margin. Its occurrence has been recorded in most areas of medium- to high-energy environments, and for the East Coast it is well described in the literature (e.g., Campbell et al., 1970). Estimates of sand and gravel resources, based on sampling and seismic profiling, have been made for selected areas of the U.S. continental margin (Table 3). Nearly 500 billion tons have been indicated for the Atlantic Coast alone, with a ratio of about 15 to 1, sand to gravel. These figures have been projected to include all U.S. coastal regions

Table 1. Examples of capital investment and 1970 operating costs for five marine sand and gravel mining operations in the North Sea.

Example	Cargo (tons)	Capital cost ($)	Round trip (miles)	Annual production (tons)	Annual operation cost ($)	Cost per ton ($)
A	300	75,000	20	90,000	44,000	0.49[a]
B	500	200,000	8	191,800	78,500	0.41[b]
C	850	600,000	20	282,565	125,000	0.45[c]
D	1200	600,000	30	300,000	105,000	0.35[d]
E	2000	1,075,000	140	400,000	196,000	0.49[e]

Source: Hess, 1971.

[a]Converted (1948) [b]Conversion (1966) [c]New build (1966) (Scraper discharge)
[d]New build (1967) [e]New build (1967) (Scraper discharge)

Table 2. Apparent resources of marine sand and gravel compared with apparent land resources and cumulative demands to the year 2000. The units represent gross market values in 1972 dollars and do not indicate economic reserves.

	$ Billions (1972)	
	U.S.	World
Present annual demand[a]	1.02	7.45
Cumulative demand to A.D. 2000[a]	76.7	535.0
Apparent land resources [a]	67	333
Apparent marine resources	1690[b]	31,000[c]

[a]U.S. Bureau of Mines, 1970.
[b]Cruickshank, 1974a.
[c]Cruickshank, 1974b.

(Table 4), taking into account the differing characteristics of the margins, and indicate apparent resources of up to 1400 billion tons. These estimates are gross and do not take into account the economic factors associated with the supply of materials to the market. For example, deposits are at varying distances from urban centers and in areas of very different environmental conditions. Such factors are the basis of benefit/cost studies, required to determine the minability of a deposit, that include characterization and economic evaluation of the deposit, determination of mining methods and costs, and analysis of environmental impacts and costs (Cruickshank, 1974b).

Nature and Occurrence

Marine sands and gravels resemble those from land in most characteristics. Their petrologic nature depends on their source, from which they may have been transported by glacial or river action, currents, winds, or wave action along coastlines. The calcareous sands made up of shell material from marine organisms are generally used as a source of lime rather than for construction purposes. Common impurities in marine deposits vary with their location and may include salt and shells, and in certain coastal areas such organic materials as sewage, dead fish, seaweed, coal, and tarballs. Washing removes the salt; the other impurities, though not a major problem, can be eliminated by a variety of methods.

Sand covers most of the U.S. Atlantic and Pacific continental shelves, except in the northern latitudes around the Gulf of Maine-Georges Bank area and parts of the far northern Washington continental margins, where reworked Pleistocene gravels of continental origin are also abundant. The largest gravel deposits along the Atlantic Coast occur off Nova Scotia and Massachusetts, the latter near Nantucket Shoals on federal land (Figure 1); and along the Pacific Coast, seaward of Cape Flattery and southward to the Hoh River area. Gravels in these northern latitudes are of superior quality for the construction industry because they are continental gravels of granitic and metamorphic origin that were introduced by Pleistocene glaciers invading these areas from the north. Gravel deposits also occur in the southern latitudes, but they are generally not as widespread and are commonly more intermixed with sand. Mixed sand and gravel deposits, showing little evidence of segregation, are most common off U.S. coasts, particularly in the southernmost latitudes.

Mining Methods

Sand and gravel has been traditionally mined underwater by two basic methods, one of which employs a stationary, or anchored, dredge that digs a pit; and the other of which utilizes a transient dredge that skims off the top layer of material as the vessel moves along. The choice of method depends on such variables as extent, thickness, and composition of the deposit; sand-to-gravel ratio; type and depth of overburden,* if any; location with respect to shore facilities; and prevailing weather and sea conditions.

Dredges most commonly used in sand and gravel operations are straight suction hopper or clamshell dredges in the stationary mode, and trailing suction hopper dredges in the transient mode (Figures 4-6). Submerged booster jets may increase the depth capability of the suction dredges in depths below 30 meters. Other types of dredges that may be used in special circumstances are the dipper, dragline, bucket ladder (Figure 7), and cutterhead suction. For the most part these work in a semi-fixed position where they can cut into a bank while moving progressively forward by means of anchor lines or walking spuds. Dredged materials are normally fed into a pipeline or a hopper barge moored alongside.

The need for sand and gravel for marine-related construction has resulted in occasional contract-type operations to supply the material from marine sources, and this type of demand is likely to increase as the coastal zone becomes more important to industrial development interests and public land management agencies. There are many instances of beach replenishment for recreation and to combat erosion; of the construction of artificial islands for land extension, utilities, mine shaft sites, and other industrial purposes; of the construction of

*Unwanted material overlying the deposit; usually muds, silts, or clays.

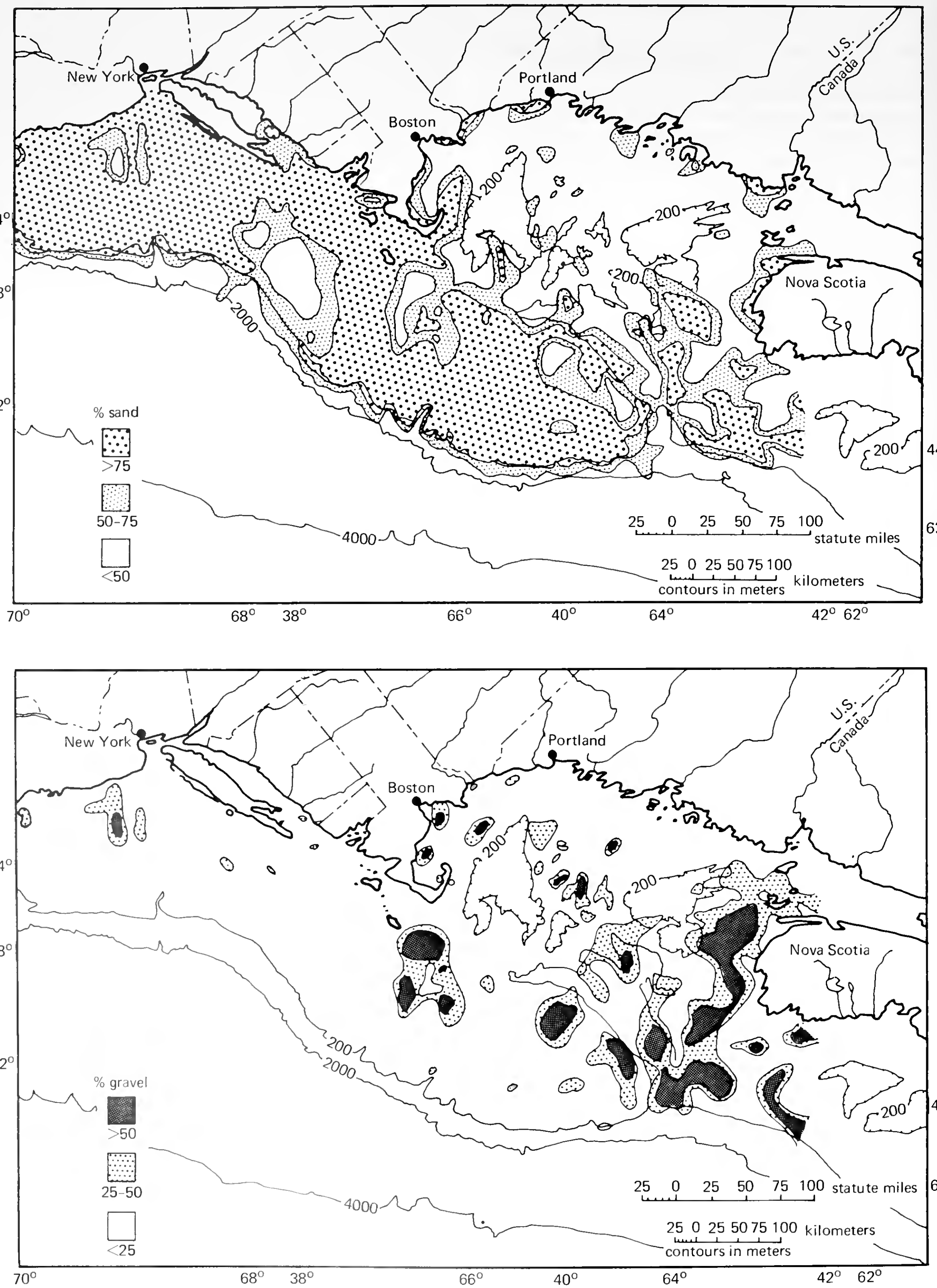

Figure 1. Distribution of sand and gravel on the continental margin off the northeastern U.S. (From Geological Survey professional paper 529H, 1970; modified by F. T. Manheim)

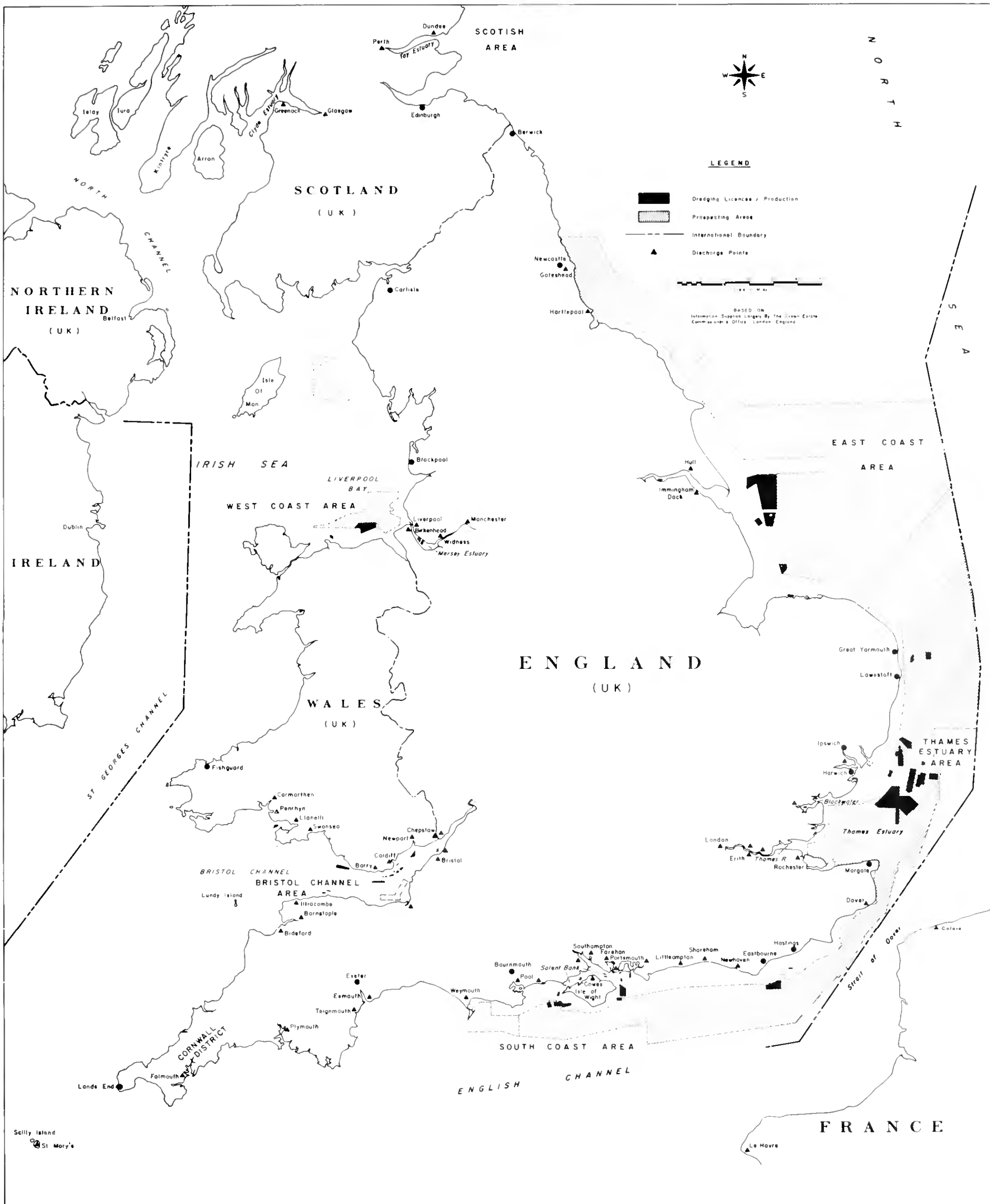

Figure 2. Marine sand and gravel map of the U.K. showing sources of sea-dredged material, prospect areas, and discharge points. (Hess, 1971)

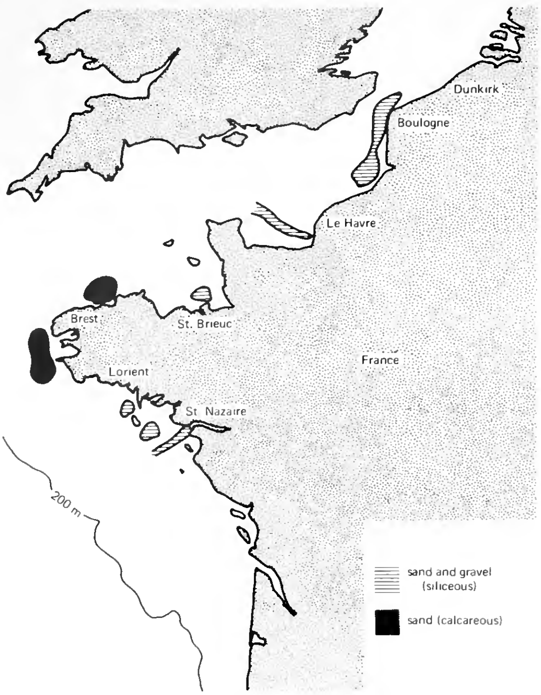

Figure 3. Status of knowledge of the distribution of marine aggregates on the French continental margin in 1974. (CNEXO and ISTPM Research Program, Paris)

harbors and breakwaters; and of the fabrication of massive concrete structures for use at sea.

A classic example is the construction of Treasure Island in San Francisco Bay as a site for the Golden Gate Exposition before World War II (Scheffauer, 1954). The area to be reclaimed was about 400 acres, in water depths ranging from less than 1 meter to 8 meters maximum at low water (Figure 8). The gross quantity of fill required was just over 22 million cubic meters. Of the total, 1 million cubic meters was procured by hopper dredges and dumped directly into the deeper parts of the shoal area. Another 5.6 million cubic meters was dredged by the same means and deposited in deep basins where it was stockpiled for dumping onto the fill area by pipeline dredges. Borrow areas were selected close to the site. Five hopper dredges were used on the project to bring coarse sands and gravel for the perimeter and foundations of the construction, while the major part of the internal fill consisting of finer materials was emplaced by stationary pipeline dredges.

More recent experimental work by the U.S. Army Corps of Engineers has shown that large offshore accumulations of sand can be used in beach nourishment. A detailed experiment conducted off the New Jersey coast at Sea Girt in 1966, and reported by David Duane (1968) of the U.S. Army Coastal Engineering Research Center, proved the feasibility of utilizing offshore deposits for beach replenishment through the use of a sea-going hopper dredge with pump-out capabilities (Mauriello, 1967). In this experiment the Corps' *Goethals* dredged and pumped ashore about 200,000 cubic meters of sand in 13 working days. Mining a deposit in approximately 13 meters of water with a distance of 2.4 kilometers from source to offshore pipeline terminus, the vessel pumped sand to the beach through a 600-meter-long submerged pipeline. This experiment showed that operations could continue until swells exceeded approximately 2 meters in height. Data indicated that the sand was emplaced at a reasonable unit cost and could be a competitive source in certain areas, assuming that program operations and costs remained similar.

Environmental Problems

It is important in discussing environmental problems to distinguish between maintenance dredging, which involves the removal of obstructions from waterways, and production dredging, in which sand and gravel are produced as a marketable commodity. Open-water disposal of material from maintenance dredging in the U.S. alone amounts to some 200 million cubic meters each year (Boyd et al., 1972). Because much of this material is very fine-grained muds and silts, and a great deal of it (particularly from ports, harbors, and industrial areas) is contaminated, the environmental problems are quite significant. In contrast, production dredging does not require the disposal of waste materials to any great extent, and most deposits are found in areas of coarser-grained and nontoxic bottom materials.

Potential environmental problems from production activities at sea are of three general types: alteration of the shape of the sea floor, interference with other users of the area, and disturbance of marine ecosystems. The present use of trailing suction hopper dredges causes a general lowering of the seabed over the area of the deposit to a maximum of about 5 meters, depending on the number of traverses made, the physical character of the material, and the corresponding slope stability. The width of a single dredged trail by itself is usually not more than 2 meters, and its depth less than 1 meter. Stationary dredges as presently used, mostly for sand, leave a hole in the seabed up to 20 meters deep and 75 meters in diameter, depending on the depth of deposit, the quantity mined, and the character of the material. In both instances there is a release of fine-grained

Table 3. Resources of sand and gravel in selected areas of the U.S. continental terrace as estimated by various workers.

Location	Quantity estimated
New Jersey	3043 million cubic yards[a]
Connecticut	130 million cubic yards[a]
Rhode Island	141 million cubic yards[a]
Massachusetts	137 million cubic yards[a]
Maine	123 million cubic yards[a]
Florida coast	600 million cubic yards[a]
East Coast, total	4174 million cubic yards[a]
New Jersey (gravel)	10–30 billion cubic yards[b]
New England (sand)	450 billion metric tons[c]
New England (gravel)	31 billion metric tons[c]
California, Russian River	100 million metric tons[d]
California, Redondo Beach	5 million metric tons[e]
California, total	"Considerably less than Atlantic"[b]
Alaska, southeast	"Large quantities"[b]
Hawaii, Oahu	370 million metric tons[f]

[a]Duane, 1969.
[b]McKelvey et al., 1969.
[c]Manheim, 1972.
[d]Marine Minerals Technology Center, Tiburon, Calif., unpublished data.
[e]Fisher, 1969.
[f]Campbell et al., 1970.

Table 4. Estimated regional resources of sand and gravel on the U.S. continental terrace.

Location	Area (km^2 x 10)	Resources (metric tons x 10^6)	Basis for estimate
Hawaii	10	370	Table 3
Alaska	2000	800 x 10^3	Equivalent to 50%
Pacific Coast	237	24 x 10^3	10% Atlantic Coast/unit area
Atlantic Coast	497	481 x 10^3	Table 3
Gulf Coast	581	90 x 10^3	15% Atlantic Coast /unit area
Total U.S.	3325	1395 x 10^3	
Value		\$1.69 x 10^{12}	\$1.21/metric ton

solid materials into the water near the dredge, either from perturbation of the seabed by the dredgehead or from overflow of the hopper. The release of toxic substances into the water is not a general feature of sand and gravel dredging.

Dredging may change the shape of the seabed sufficiently to alter local wave and current patterns. This could lead to changes in coastal erosion or deposition and could cause destruction of beaches, siltation of harbors, removal of offshore banks, and disruption of longshore sand transport systems.

Experience in Europe and elsewhere has shown that mining operations can be hazardous to other marine activities or emplacements, causing collisions in shipping channels, disturbance of navigational buoys or anchorages, and cutting or displacement of buried cables or pipelines. Fishing activities have been disturbed by the creation of obstructions to bottom trawls, particularly where deep pits have been excavated in fishing grounds or large boulders have been exposed by removal of the surrounding substrate (Hess, 1971). In some areas, illegal dredging has allegedly destroyed

Figure 4. Suction hopper dredge Cambrook *working in a stationary mode in the River Thames estuary. Over 2000 tons capacity, the vessel is one of the largest of the U.K. fleet. (Skyfotos, Hythe, England)*

maricultural nursery grounds.

The potential impact of marine mining on ecosystems is the least-known area of environmental concern and, without doubt, the most difficult one to assess. For the most part, effects are secondary and due to some alteration in the existing physical, chemical, or trophic equilibrium. Impacts on the coastal zone tend to be more significant than those on the outer continental shelf because of the higher physical and biological energy levels generally recorded there and the proximity to population centers. Physical changes that may induce biological effects include variations in temperature, current patterns, amount of suspended particulates present, nature of the sea floor and substrate, and light penetration and photosynthesis; and the introduction of new habitats. Significant chemical changes may be those in the presence of nutrients, trace elements, or toxics. Possible trophic changes include removal of or influence on existing species by involving them in the dredging operation. In general, alterations in temperature and chemistry are unlikely and would normally occur only as a result of induced changes in current patterns near shore, where local temperature and chemical gradients were very significant because of natural or man-induced conditions.

Criteria on which to judge pollution or significant environmental change are often arbitrary and, where they are given, may err on the side of safety, based mostly on the assumption that no change is the preferred state. This assumption is open to argument, and much more data are required before generalizations can be made—if, in fact, they can ever be made for such a varied and dynamic environment (Clark, 1974). Standards established or proposed by the U.S. Environmental Protection Agency for coastal waters include quantitative criteria for temperature, oxygen, and pathogens and toxic substances; and qualitative criteria for circulation, turbidity, sedimentation, habitat, salinity, nutrients, fauna, and productivity. The assessment of these items for any mining area or operation necessitates considerable field study and experience. Effects of operations on living marine resources can be judged beneficial, insignificant, or adverse. To date, some beneficial effects have been recorded or discussed, such as the attraction of fish to offshore structures, the enhancement of substrate habitats and biomass productivity by alteration of the texture of the seabed, the enhancement of substrate habitats by the presentation of new surface nutrients by mixing and replacement of the seabed material, thermal stimulation of plant and animal growth, introduction of nutrients by mixing of water masses, and enhancement of phytoplankton growth by increasing turbidity in ultraclear waters.

The list of potentially adverse effects is much longer. For example, the direct effects of pollutants on individual organisms include abnormal growth, decreased productivity, behavioral changes, accumulation effects in the trophic chain, restriction of motor functions, erosion of gill filaments, suffocation by burial, retardation of metabolic efficiency in filter-feeding animals, pressure shock, embolism, and thermal shock. Changes in diversity and abundance and other secondary effects on the community and ecosystem structures may be caused by disruption of food webs, changes in predator-prey relationships, reduced community stability in response to

Figure 5. Trailing suction hopper dredge Yolanda *underway while dredging sand and gravel in the North Sea. The vessel is almost fully loaded. (Skyfotos, Hythe, England)*

Figure 6. Ocean-going clamshell, or grab bucket, dredge Landguard *at work in U.K. waters. This type is used mostly for harbor clearance but also may dig for gravel. (Skyfotos, Hythe, England)*

environmental fluctuations, changes in age structure of populations by selective mortality, changes in dynamic behavioral patterns, concentration of toxic fractions through food chain transfers, loss of bottom habitat, provision of new habitat, migration of population, and introduction of dormant species from bottom to surface waters.

Analyses of the potential impacts require a knowledge of the undisturbed populations and their natural cycles so that changes can be predicted, verified, and controlled. At the present time there is little agreement within the scientific community about what constitutes an adequate knowledge of pre-operating conditions or baselines. Difficulties arise in the selection of indicator species that will adequately represent the biotic community and its reaction to the disturbances. The idea of measuring baselines is still so new that the effect on local biological communities of long-term regional cycles, for which there are no data, may be overlooked or unsuspected. Conversely, the effect of local impacts on regional or global communities may be underestimated or overestimated with no chance of immediate verification or disproof.

From the foregoing considerations it can be generally concluded that potential disturbances from marine sand and gravel mining operations are dependent on both the mining method and the environmental conditions of the area. Apart from some broad guidelines, conclusions on potential impacts should be operation- and site-specific. Most physical and chemical changes can be measured, but assessing the effects of biological perturbations requires intensive and long-term study.

Future Operations

Although most U.S. coastal states have moratoria on sand and gravel mining or similar activities in the coastal zone, there is every indication that selected deposits on the outer continental shelf (OCS), under the jurisdiction of the federal government, will be developed in the near future under some form of prototype leasing that will allow for extensive environmental monitoring and control during the operation.

Active interest in offshore sand and gravel leasing has already been demonstrated by a number of U.S. companies; and several foreign groups having long-established sand and gravel sea-dredging capabilities are actively working toward sand and gravel operations off the U.S., presumably through arrangements with U.S. producers. Following implementation of a federal hard minerals leasing program, it is estimated that annual sand and gravel production from the OCS could reach 12 million short tons or more within the first five years. Estimates of sand and gravel operations assume average annual production rates of 1 million to 2.5 million short tons per project. In the first year, with one operation, annual production would be between 1 million and 2 million short tons; in the fifth year, with 8–10 operations, annual production would be from 12 million to 25 million short tons.

Sizable operations on the OCS would probably be near the larger metropolitan areas on the Atlantic and Pacific coasts, where accessible land reserves are fast approaching depletion and where the greatest demand and correspondingly high prices are found. The most promising shelf areas,

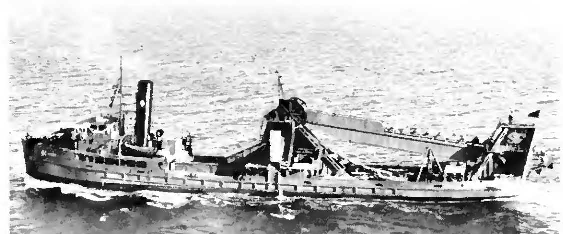

Figure 7. Sea-going bucket ladder dredge St. Alban, *operated by the U.K. Ministry of the Environment for the Royal Navy. Though commonly used for harbor work, where digging is difficult, this type is also employed in dredging sand and gravel or corals in other parts of the world. (Skyfotos, Hythe, England)*

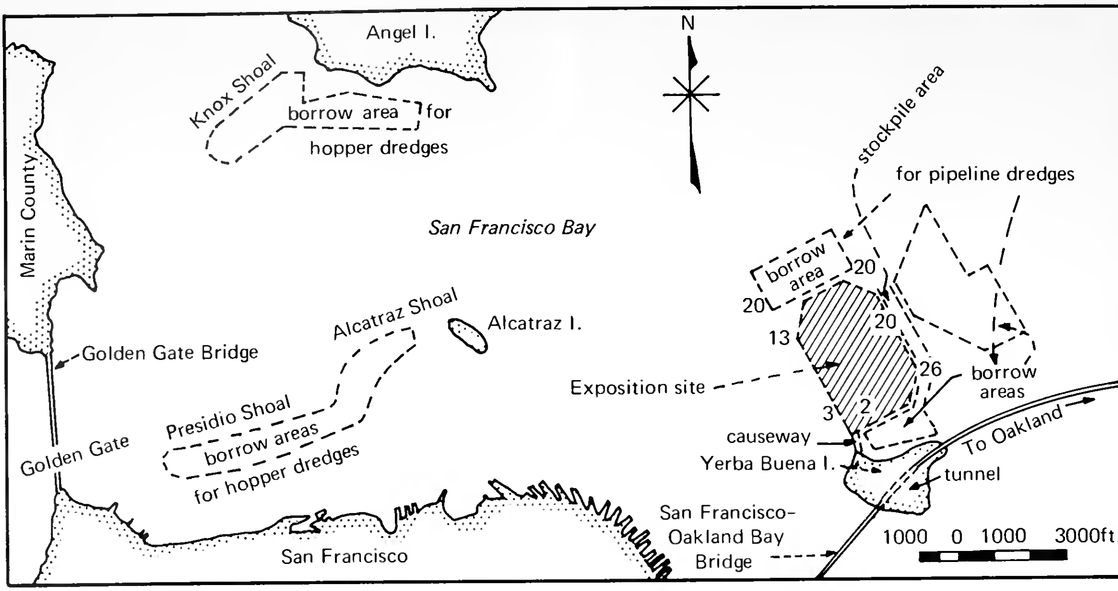

Figure 8. Golden Gate Exposition site in San Francisco Bay showing borrow areas for the 400-acre island, which is now part of the Treasure Island Naval Base. (Scheffauer, 1954)

based on known offshore resource potential, proximity to markets, and industry interest, are shown in Figure 9. They include:

- New England southward to Virginia: Sand and gravel deposits will be used principally to supply the large metropolitan areas of New York, Boston, Washington, D.C., and Norfolk with aggregate for building and road construction. Small quantities may also be used for beach replenishment.
- Florida Atlantic Coast: Extensive deposits of sand have been delineated. Primary use will be for beach replenishment in the larger recreation centers, especially the Miami-Ft. Lauderdale area.
- California: Southern California offshore could provide large amounts of sand and gravel to meet increasing market demands in that area. Land-based sand and gravel operations are being pressed farther and farther away from the market, particularly in the Greater Los Angeles metropolitan area. Demand around Los Angeles Harbor alone is about 22 million tons per year. Extensive deposits of sand and gravel also occur off the San Francisco Bay area and could supply a ready market.

Significant sand and gravel deposits also exist in waters within the 3-mile state-jurisdictional limit of the 50 coastal states. Many of these likewise are close to the larger metropolitan markets and offer potential resources when state moratoria are lifted.

Research Needs

Some major areas for research are suggested by the need for resource conservation and environmental management. To conserve sand and gravel resources, it is essential that the deposits be characterized and well delineated over broad areas so that mining can be controlled in systematic fashion. The ratios of sand to gravel vary widely in different areas, and by utilizing those deposits most suited to user needs at any given time, the mining and related discard of unsuitable material by shipboard or shoreside processing can be reduced. For example, the normal ratio of sand to gravel mined in the North Sea is about 70 to 30, while the ideal dredge material in the London area is considered to be 40 percent sand and 60 percent gravel. In lease areas where an operator cannot achieve such a ratio, shipboard screening is often employed, with recovery of up to 100 percent gravel and over-the-side discharge of sand. In some cases construction specifications for sand or gravel content may be unnecessarily rigid, leading to discard of otherwise usable material. When the availability of deposits is known, it may be expedient to match them to projected needs and mine them selectively.

In order to carry out this type of detailed delineation on the scale required, advances are needed in exploration tools and methods, particularly those of bottom and sub-bottom profiling. It would be very useful, for example, to be able to determine the quantity of sand and gravel in a deposit by remote methods (even present techniques of exploratory drilling are not well developed), and it seems that major advances will entail the adaptation of automated systems to the mapping and control of mining operations (Figures 10 and 11). Onshore the automation of plants for product control and the elimination of dust, noise, and water pollution are problems common to all sand and gravel producers, not just marine operators. However, the contamination of wash water with salt is unique to marine production and must be prevented in those areas where fresh water is scarce, or where the brackish effluent could have undesirable effects.

Knowing the location and extent of the deposits and thus being able to control the mining operations will help to minimize the possibility of upsetting the balance of physical processes in the mining area. However, much research remains to be done on the secondary effects of sea-floor excavations. Reliable data on the rate of natural filling of excavated pits or the replenishment rates of shifting or unstable sands are rare. Many before-and-after studies and long-term monitoring programs are required to develop reliable models for the prediction of such effects. As discussed earlier, the needs for ecological research are many.

Continual monitoring of the local areas will be required. Such programs have been proposed in the past, for example, the New England Offshore Mining Environmental Study, planned and initiated by the National Oceanic and Atmospheric Administration. This study was designed to develop baselines and to monitor a mining operation for sand and gravel in Boston Harbor. Although the actual operation was to have taken only three months, the program (which unfortunately was aborted due largely to local political problems) was to have covered a period of several years. One important aspect of such research is the development of standards for the acquisition and reporting of data. Much additional agreement is required among environmental institutions, on both a national and an international basis, so that comparable data can be used elsewhere.

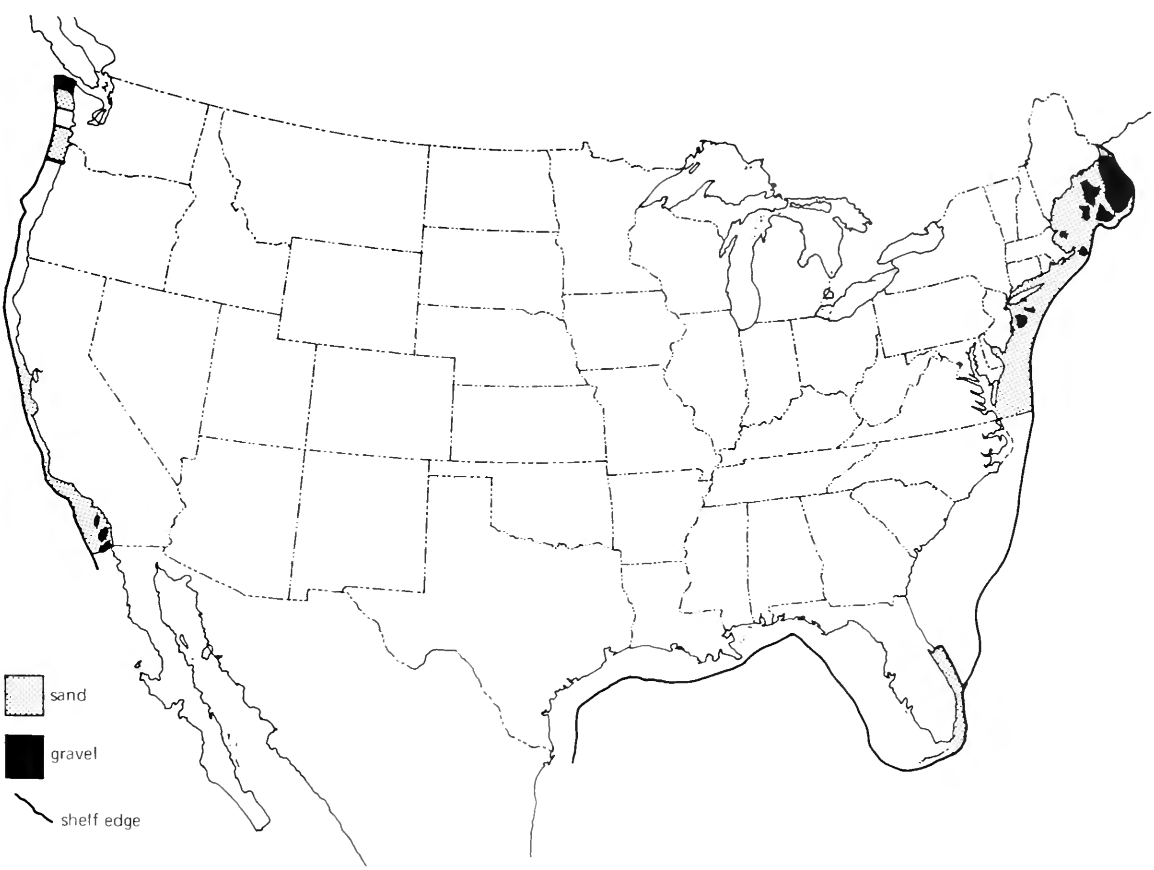

Figure 9. Known distribution of promising areas for marine sand and gravel mining in the OCS areas of the continental U.S.

Figure 10. Analog record from a sector-scan sonar operating in 14 meters of water in the North Sea, showing a pit left by a stationary suction dredge. Dimensions of these pits may vary up to 20 meters in depth and 75 meters in diameter, depending on the amount of material removed and the stability of the sea floor. (U.K. Natural Environmental Research Council, Unit of Coastal Sedimentation)

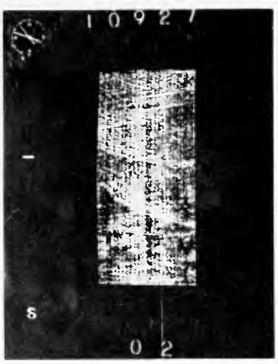

Figure 11. Analog recorder from a sector-scan sonar operating in 14 meters of water in the North Sea, showing tracks left on the sea floor by trailing suction dredges. The tracks are about 1 meter wide and one-half meter deep. (U.K. Natural Environmental Research Council, Unit of Coastal Sedimentation)

J. R. Thompson, in an excellent review of the ecological effects of offshore dredging and beach nourishment for the U.S. Army Coastal Engineering Research Center, cites certain areas where knowledge is lacking; among these are substrate characteristics, nutrient and other chemical exchanges with the overlying water, and population inventories, with particular regard to life cycles and corresponding habitats. Also discussed are material and energy cycles within the existing ecosystems, mathematical models for the coordination and interpretation of data and the prediction of change, and the relationship of cultural (non-natural) systems to the whole.

It may be concluded that mining for sand and gravel on U.S. continental margins is a near-future development of some importance to the industry and the consumer. Current operations indicate that the adverse environmental effects, even if uncontrolled, tend to be more damaging to the physical features of the coastal zone and to the resource base itself than to the ecology. Much research is required, however, to confirm these indications. If supported by adequate information about the deposit and its environment, sound resource management practices could prevent, or at least minimize, the damaging effects of mining operations.

Michael J. Cruickshank is staff mining engineer and Harold D. Hess is staff geologist with the U.S. Geological Survey, Conservation Division, Western Region. They are concerned with the development and planning of Division responsibilities for hard minerals lease management and resource evaluation under the OCS Lands Act of 1953. The material presented in this article was developed by the authors and is not officially endorsed by the U.S. Geological Survey.

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Oil Ports on the Continental Shelf

by John F. Flory

Although the United States has declared a goal of reducing oil imports, most authorities believe imports will have to increase above present levels to replace decreasing domestic production and to meet growing energy demands. The use of very large tankers in conjunction with offshore oil ports can reduce environmental risks and lower the cost of oil imports. Of the various types of ports proposed, the deepwater terminal with single point moorings is considered to be the most attractive. The recently developed single anchor leg mooring is the type of single point mooring that will be used for at least some of these terminals.

U.S. Oil Import Needs

In 1970 the U.S. imported 3.4 million barrels of oil per day, most of this by pipeline from Canada or by medium-sized tankers from Venezuela. Since that time production of crude oil within the U.S. has declined while consumption has increased. According to a recent estimate of U.S. oil needs and supply, 6.3 million barrels of oil per day will be imported in 1975 (Figure 1). Though future trends will depend, in part, on conservation efforts and on the cost and availability of foreign oil, imports at the rate of 10 million to 12 million barrels per day are presently predicted for the 1980s. Approximately 3 million barrels per day of refined products are included in these estimates. Therefore, importation of crude oil is expected to increase from about 3 million to approximately 8 million barrels per day within the next 10 years.

The task of developing tankers and terminals to handle this rapid increase in oil imports is compounded by the need to transport the oil over much greater distances. Canada has already decreased its exports to the U.S. and has served notice it will discontinue exports by 1982 to conserve its petroleum resources for domestic needs. And production in Venezuela is declining. It will therefore be necessary to transport most of the increase in imported oil from Africa and the Middle East, over distances approximately three to seven times as far as Venezuela. More oil carried greater distances will necessitate a considerably larger capacity in the tanker fleet.

Developments in Tankers and Oil Ports

Means of enlarging tanker capacity while at the same time decreasing transportation cost and pollution risks have evolved over the past fifteen years to meet the gradually increasing oil import requirements of Europe and Japan. Before 1960 tankers of 30,000 to 75,000 dead weight tonnage (dwt)* were typical in international service. Beginning in the early 1960s, larger tankers were constructed to carry crude from the Middle East to Europe and Japan. Prior to 1967 maximum tanker size was limited by the dimensions of the Suez Canal, by depths in established ports, and by shipyard technology. Tankers planned in 1966 were typically 100,000–200,000 dwt with drafts of less than 19 meters, to allow them to pass, at least in ballast, through the Suez Canal at depths then projected for its dredging program. They were also the largest vessels that could serve most deepwater ports in Europe and Japan at the time.

The closing of the Suez Canal in 1967 both eliminated one of the principal considerations in tanker designs and dramatically increased the need for more and larger tankers to carry crude the much longer distances between the Middle East and Europe. Tankers between 250,000 and 300,000 dwt became common, and some as large as 500,000 dwt were ordered. Those larger than 175,000 dwt have come to be known as Very Large Crude Carriers (VLCCs). The growth of tanker size since World War II is shown in Figure 2.

Outside the U.S., terminals kept pace with the growth in tanker size. At crude oil loading ports

*Dead weight tonnage is a measure of the total carrying capacity expressed in long tons.

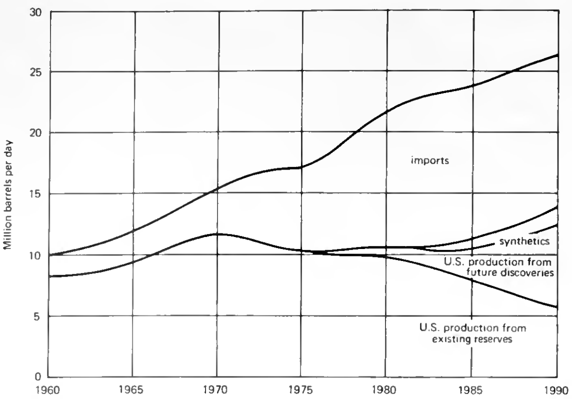

Figure 1. U.S. oil needs and oil supply, 1960-90. (From Energy Outlook 1975-1990, *published by Exxon)*

in the Middle East, piers and sea islands (piers connected to shore only by a pipeline) were built in deeper water. Some European ports were dredged to greater depths or were expanded seaward, and several new ports were created. In Japan larger conventional terminals were built in sheltered harbors, and special moorings were built offshore to serve VLCCs.

Several techniques were developed to better utilize VLCCs. Special transshipping terminals were constructed in Ireland, Japan, and the Caribbean to offload oil from VLCCs to storage facilities onshore, then to reload the oil onto smaller tankers for distribution to shallower ports in the region. Also, methods were devised to bring smaller tankers alongside VLCCs at sea and to transfer crude oil to the smaller vessels (lightering), which carried it to smaller ports. The VLCCs with drafts reduced by lightering or by discharging part of their cargo at one terminal (two porting) could then enter shallower ports.

The most versatile and widely adopted method developed to accommodate VLCCs is the single point mooring (SPM), which consists of a single buoy or tower structure at which the tanker is moored by its bow. Since its introduction in 1959, over 130 SPMs have been installed throughout the world, many to handle VLCCs. The locations of all SPMs in operation in 1974 are indicated in Figure 3. Sixteen are in Japan; none are in the United States.

Oil Terminal Alternatives

Oil terminals must be safe and environmentally sound as well as economical to build and operate. A number of alternative types of terminals have been proposed and studied by the federal government, universities, oil companies, and other groups.

The use of VLCCs could substantially reduce the number of tankers entering U.S. waters. This, in turn, would decrease the risk of tanker accidents and resultant oil pollution, as discussed later. The use of VLCCs would also lower the cost of transporting oil to the U.S.; crude hauled from the Middle East to the U.S. in VLCCs would cost approximately 40 cents per barrel less than that carried the same distance in tankers under 70,000 dwt.

VLCCs can be used in conjunction with transshipment terminals, several of which exist or are planned in Canada, the Bahamas, and the Caribbean. With this method, the U.S. would not have to build terminals for VLCCs. However, transshipping to smaller tankers instead of carrying the crude directly to the U.S. in VLCCs adds approximately 10 cents per barrel to the cost of the crude. Furthermore, transshipment does not reduce the number of tankers calling at U.S. ports as compared with the case of carrying the oil all the way in smaller tankers. Transshipment requires transferring the crude oil four times instead of twice, thus increasing chances of pollution.

Tankers with a draft deeper than 14 meters cannot use existing terminals on the U.S. East and Gulf coasts, which effectively excludes tankers larger than about 75,000 dwt. Since VLCCs draw 18-28 meters of water, they cannot be fully utilized until new or better terminals are provided. Extensive and expensive dredging would be required to enable existing ports on the East and Gulf coasts to accept VLCCs. Only northern Maine, Long Island Sound, and Delaware Bay provide the deep, protected waters suitable for conventional piers capable of berthing VLCCs. However, proposals to use these sites as

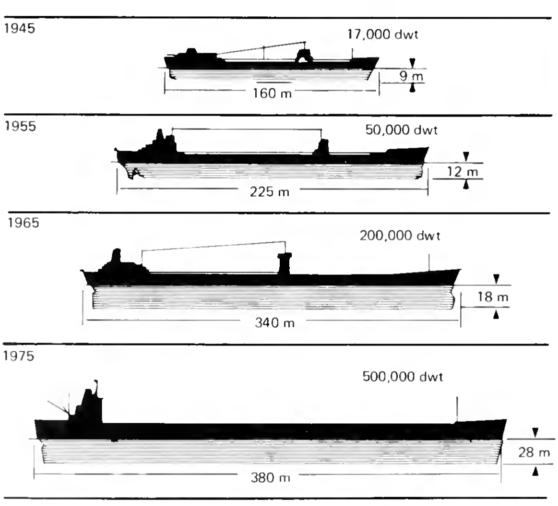

Figure 2. Growth of tanker size since World War II.

Figure 3. SPMs in operation in 1974.

tanker terminals have drawn opposition from local and state governments. No such natural harbors exist between Delaware and Mexico.

If the use of the few natural deep harbors or the dredging of other harbors is ruled out, then VLCC ports must be placed offshore in sufficient water depths. For the largest VLCCs, this means about 30 meters. Distances from shore to sufficient water depths range from about 5 kilometers in some parts of New England to more than 60 kilometers off the Carolinas, and from almost 15 kilometers near Gulfport to over 80 kilometers near Lake Charles and some areas of Florida.

An offshore island—which would consist of a breakwater for a conventional pier and which would support storage tanks, possibly a refinery, and maybe bulk-cargo terminals and other facilities—would be a very expensive alternative (see page 57). The dredging required to create such an island could cause extensive environmental damage, and its presence would significantly alter the environment. If an artificial island were used for a refinery with associated product movement, or if other shipping or industry were placed on the island, the concentration of traffic and the risk of marine accidents would be increased.

Sea islands and multiple-buoy berths have been used for years offshore in relatively sheltered areas to moor tankers. At these facilities tankers are moored at a fixed heading and can remain there so long as the waves, winds, and currents are moderate and approximately in line with the longitudinal centerline of the berth. Tankers can remain moored in waves up to 5.5 meters maximum wave height* from ahead or astern, but only in waves of about 2 meters from abeam; and they cannot enter or leave such facilities in waves higher than about 2.5 meters. Because of these limitations on service, multiple-buoy berths and sea islands are not practical for VLCCs in exposed locations. The offshore sites available for VLCC ports along the U.S. East and Gulf coasts are too exposed and subject to severe waves, winds, and currents to make multiple-buoy berths or sea islands viable.

A number of studies, both government and private, have concluded that the SPM is the most practical and most desirable type of berth for East Coast and Gulf Coast VLCC ports. The SPM is suitable for open-sea conditions because it allows the tanker to swing and head into the winds, waves, and currents. Thus, mooring forces are minimized, and tankers may remain safely moored in more severe environments. SPMs are generally designed to allow tankers to remain moored in waves of 8.5 meters maximum wave height, and some have been designed for over 11.5 meters maximum wave height. Extensive experience has been gained in designing and operating SPMs in other parts of the world: installation requires little or no dredging and constitutes a minimum modification of the environment, and there is very little risk of accident during maneuvering. Reduced operational downtime and ability of the vessel to get underway without

*Maximum wave height, used throughout this article, is approximately 1.9 times significant wave height, a statistical average of the highest one-third waves.

tug assistance are other advantages of an SPM over a pier or sea island.

Environmental Impact

It is frequently assumed that tanker terminal operations are a major source of marine pollution because such activities are highly visible and because tanker accidents receive wide publicity. Actually, terminal operations cause less than 1.5 percent of all petroleum pollution in the oceans (Figure 4). All tanker activities result in less than 30 percent of the pollution, and half of this is from non-LOT (load-on-top) sources. Load-on-top, in which oil tank washings are retained inside the vessel, is practiced on most VLCCs. Nevertheless, tanker and terminal operations do contribute to ocean pollution, and every effort is being made to limit this source of pollution.

Operating experience has shown that VLCCs are less likely to be involved in accidents than are smaller tankers. The safety record of VLCCs is partly a result of the fact that they usually berth offshore or in special areas near the mouths of harbors where they are less likely to be involved in the groundings and collisions related to congested harbors. The safety record is also due to the fact that they are better equipped than most older, smaller tankers.

The U.S. Coast Guard study for the Council on Environmental Quality concluded that VLCCs

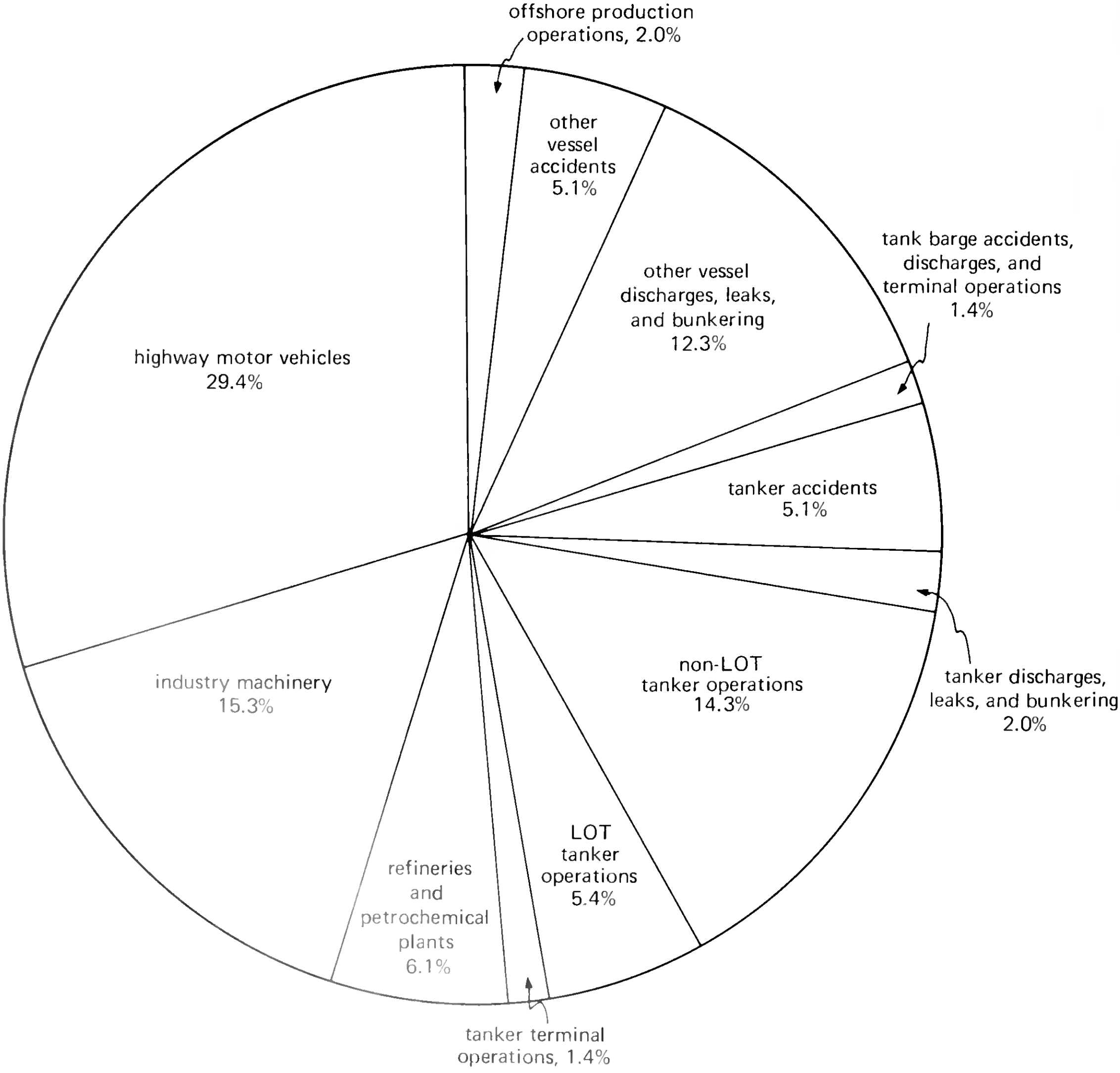

Figure 4. Sources of petroleum pollution in the oceans. (Porricelli and Keith, 1974)

used in conjunction with deepwater ports would reduce both the number and the volume of oil spills by a factor of 10 as compared with transshipping. Data compiled by the Coast Guard indicated that during the period 1969–72, nearly 70 percent of collisions and groundings—the principal causes of major oil spills—were in harbors and harbor entrances. If offshore ports are not built, tanker traffic to existing harbors will approximately triple during the next 10 years.

The safety record of the SPM deepwater oil ports is impressive. Approximately 125 SPMs are in operation throughout the world, some of which have been in service for more than 10 years. The average oil spill rate at SPM discharge terminals has been less than 1 barrel for every 1 million barrels handled.

An oil spill at an offshore port is less likely to cause damage than if it had occurred in a harbor. The Coast Guard acknowledges this in defining a major oil spill as 240 barrels in a harbor but 10 times this amount offshore. The Department of the Interior's Deepwater Ports Study shows that if spill containment and cleanup are not undertaken, the probability of an oil spill off the East Coast reaching shore is reduced by a factor of 5 if the spill originates 25 kilometers or more from shore as compared with a spill originating within 8 kilometers of shore. The farther a spill must drift before it reaches shore, the greater opportunity there is for spill containment and cleanup. Also, there is more evaporation and dispersion of the toxic portion of the crude oil before it reaches shore.

Pipelines connecting an offshore port to shore can also be expected to have an outstanding safety record. Such pipelines would be buried, thus eliminating the possibility of damage by anchors dragging or similar accidents. Statistics for buried pipelines on the continental shelf indicate a 32-kilometer-long pipeline could be expected to spill about 0.1 barrel per 1 million barrels handled.

Single Point Moorings

The first type of SPM, known as the Catenary Anchor Leg Mooring (CALM), was developed simultaneously and independently by Shell Oil Company and IMODCO, then a Swedish company but now a U.S. company based in Los Angeles. Shell installed a number of CALMs in the Far East in the early 1960s through contracts with IHC, a Netherlands shipbuilding company. IHC became a licensee of the Shell CALM and through a subsidiary, SBM of Monaco, has supplied over half of the CALMs in the world today. IMODCO developed CALMs for the Swedish and German navies, then became a major supplier to oil companies; the company also has furnished a number of CALMs for the U.S. Armed Forces in the Far East and for handling fluidized iron ore and liquid propane. Figure 5 shows a CALM operated by Exxon at Singapore.

A CALM consists of a large flat buoy, approximately 10–12 meters in diameter and 3–5 meters high, that is anchored by four or more chains extending in catenaries to anchor points on the sea floor, sometimes as far as 400 meters from the buoy (Figure 6). The tanker is moored by bow hawsers to a turntable on the deck of the buoy. Floating loading hose connects through piping on this turntable to a fluid swivel in the center of the buoy. Underbuoy hoses connect this swivel with a manifold at the end of the submarine pipeline.

Another type of SPM consists of a fixed mooring tower with a mooring turntable on its deck. The first such mooring tower was installed by an Exxon affiliate in Libya in 1963 (Figure 7). As shown in Figure 8, the tower features an underwater loading arm extending from the turntable to a riser positioned beside the tanker's midship manifold. Several mooring towers that employ floating loading hoses have been installed in Italy.

In the mid-1960s, an Exxon Research and Engineering study concluded that new concepts would be needed to moor and load the very large tankers then contemplated for the 1970s. A major research program, initiated in 1966, developed the Single Anchor Leg Mooring (SALM) to meet these needs.

The SALM consists of a mooring buoy at the sea surface, which is attached to a base on the sea floor by a single anchor leg (Figure 9). The buoy is drawn down against its buoyancy by tension in the anchor leg. Tankers moor through lines to the buoy, and a swivel in the anchor leg or on the buoy allows the tanker to swing around the mooring point. A fluid swivel is mounted concentric about the anchor leg, either on top of the base or on top of a riser pivoted from the base and forming part of the anchor leg. Cargo hoses connect to an arm on the fluid swivel and rise to the surface, where they float and extend to the tanker manifold.

Development of the SALM

Extensive model-tests were conducted on the SALM in a variety of wind, wave, and current environments to determine the effects of parameters such as buoy size and shape, depth of water, length of anchor leg and mooring lines, and tanker size on mooring performance. From the results of these tests, methods were developed to design the mooring system and to predict mooring loads.

Figure 5. CALM at Exxon's Singapore refinery.

At the same time, studies of structural and mechanical arrangements were underway. Fluid swivel joints, as large as 1.2 meters in diameter, and a high-load-capacity anchor chain swivel, all with corrosion-resistant seals, were developed through contracts with manufacturers. A giant universal joint structure was designed as a pivot for the riser required in deepwater installations. The very large anchor swivel, 152-millimeter anchor chain, and universal joint used to moor a SALM buoy are shown in Figure 10.

The first SALM was installed by Exxon's Libyan affiliate at Brega in 1969. Set in 43 meters of water, it was designed to moor tankers as large as 300,000 dwt in seas up to 8.5 meters maximum wave height, and to load crude oil through a single hose 0.6 meter in diameter at a rate of 50,000 barrels per hour. This prototype has operated with minimum maintenance and no major problems.

The Brega SALM (Figure 9) has a large steel base approximately 19.5 meters in diameter, filled with sand to resist uplift and held by piles to prevent sliding. The lower section of the anchor leg is a pipe connected to the base by a large universal joint. At the top of the riser is a load-carrying shaft surrounded by a rotatable fluid swivel unit. The mooring buoy, approximately 4.9 meters in diameter and 7.6 meters high, is attached to the top of the shaft by a short length of anchor chain. Tankers are moored by synthetic ropes attached to brackets on the deck of the buoy. Crude oil passes through the riser to the fluid swivel unit, then through the hose to the tanker manifold.

A second SALM was installed at Okinawa in 1971 (Figure 11). This system differs from the Brega SALM in that the fluid swivel unit with center shaft is mounted directly on the mooring base. The riser is unnecessary in the 27-meter water depth at

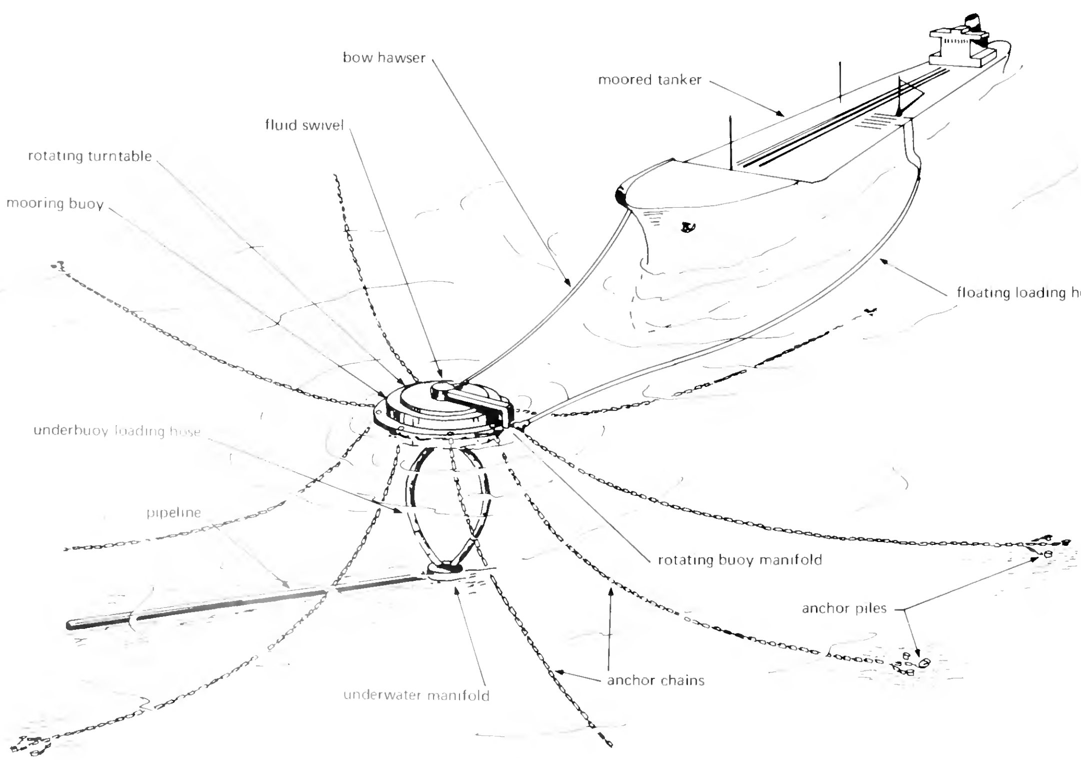

Figure 6. CALM system.

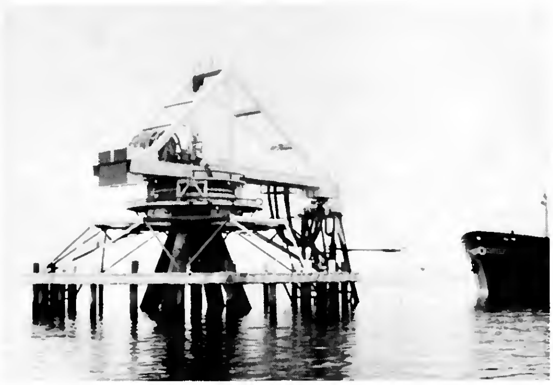

Figure 7. SPM tower at Brega, Libya.

the site. Two hoses, each 0.6 meter in diameter, were installed on the Okinawa SALM to accommodate a design flow rate of 75,000 barrels per hour. A tanker moored to the Okinawa SALM is shown in Figure 12.

Another SALM was installed in 1974 at a production field in the South China Sea approximately 70 kilometers off the coast of Borneo. The water depth at the site is approximately 90 meters, which makes this the deepest SPM in operation to date. A fourth SALM is being fabricated for placement 300 kilometers east of the Malay Peninsula in approximately 73 meters of water. Both these moorings are similar to the Brega SALM, except their risers are much longer because of the water depths. Both facilities will be used to permanently moor storage vessels that will receive crude oil from nearby production platforms and load it onto tankers moored alongside. Initially, the mooring off Borneo is being used to load tankers directly from production (Figure 13).

Technology for the SALM has been licensed by Exxon to SBM, IMODCO, and SOFEC of Houston, all of which are designing and fabricating SALMs for a number of sites. Two will be installed off the coast of Saudi Arabia to export crude for ARAMCO. The Chinese Petroleum Corporation has ordered a SALM to import oil to Taiwan. And a contract has just been awarded by Burmah Exploration for a SALM to be located in 160 meters of water in the North Sea—an especially severe environment. Upon installation in 1977, this SALM will be the deepest tanker mooring.

Exxon recently placed an order for a SALM to be installed in approximately 32 meters of water 1 kilometer off the California coast in the Santa Barbara Channel in early 1977. Oil from an offshore production platform will be stored in tanks

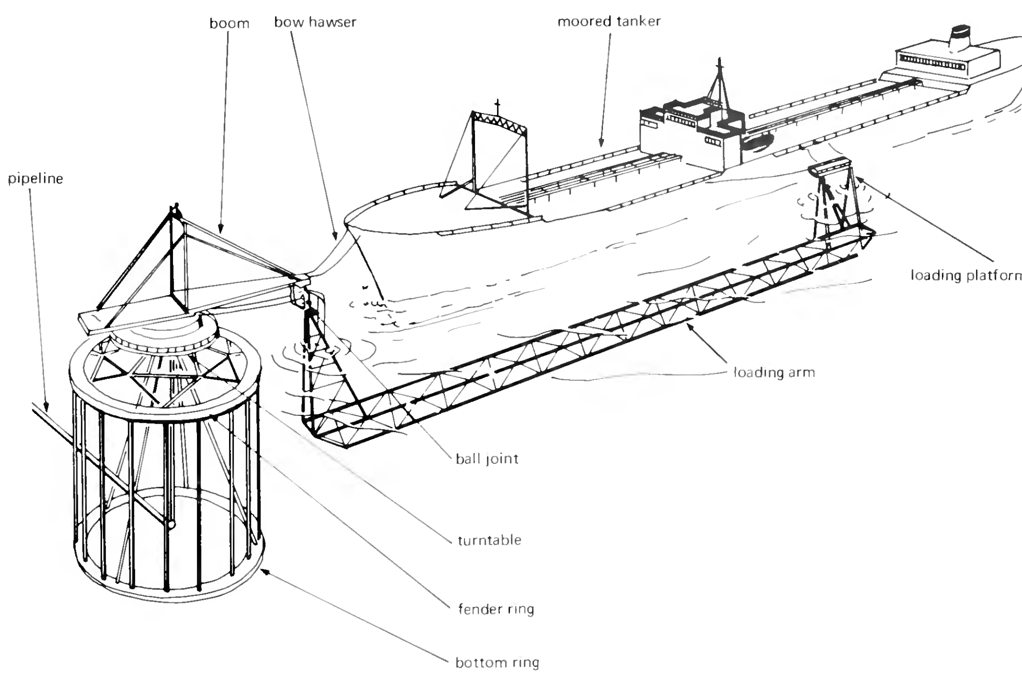

Figure 8. SPM tower with underwater loading arm.

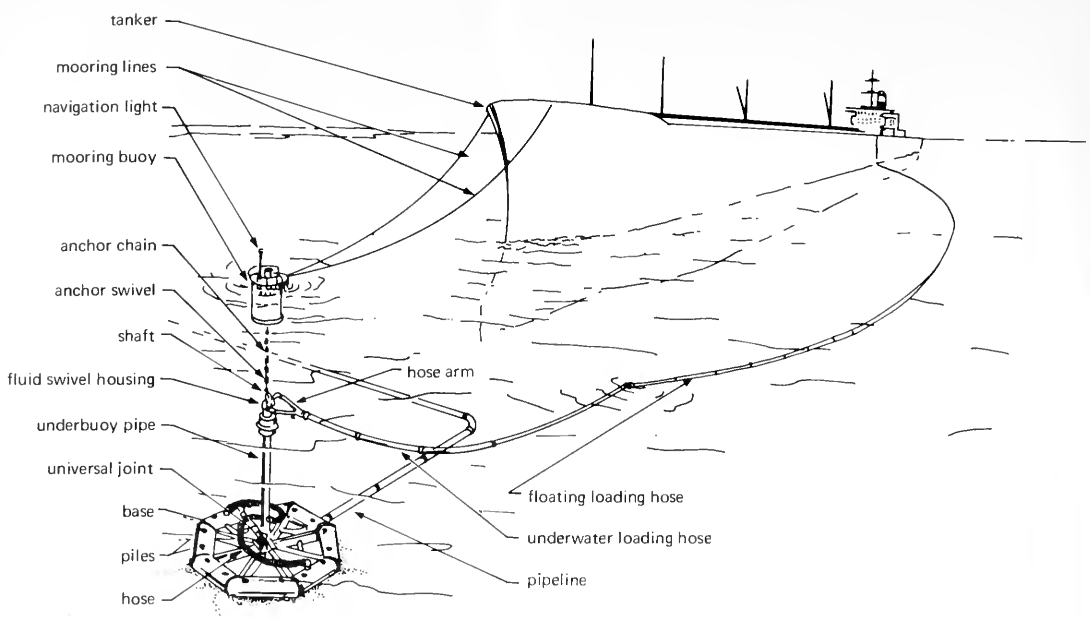

Figure 9. SALM system at Brega, Libya.

onshore, then loaded through the SALM to tankers near shore. This SALM will be the first SPM in the United States.

Operation of an SPM Terminal

One concept of an offshore oil terminal involves a cluster of SPMs around a central control platform (Figure 14). A pipeline links each SPM to the platform, which contains valving, pumps, and controls, and is connected by pipeline with storage tanks onshore. The platform houses operating personnel and serves as a control center and base for pilots and launch crews who assist in mooring the tankers.

The following operation is typical of that practiced at most SPMs. A pilot meets an incoming tanker some distance from the terminal and directs it along a designated ship lane to the mooring site. He plans his final approach on a course into the predominant environment so that maximum control is maintained and so that the buoy passes to one side, usually to port of the vessel. Since this approach is in open water, and the heading of the vessel can be planned to maintain steerage, tugs are rarely used.

Prior to the approach a launch crew inspects and prepares the SPM. During the final approach one launch pulls the floating hose to the side away from the tanker's path, while another launch takes a messenger line lowered from the bow of the tanker and proceeds ahead of the tanker until contact is made with a floating pickup line attached to the mooring line.

The last stage of the approach is made at very slow speed so that the tanker comes to a stop 25-50 meters from the buoy. The messenger and pickup lines are winched on board, and the end of the mooring line is made fast to fittings on the bow of the tanker.

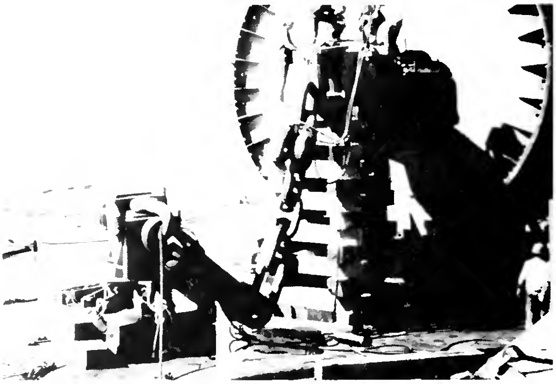

Figure 10. SALM buoy, anchor chain, anchor swivel, and universal joint being assembled.

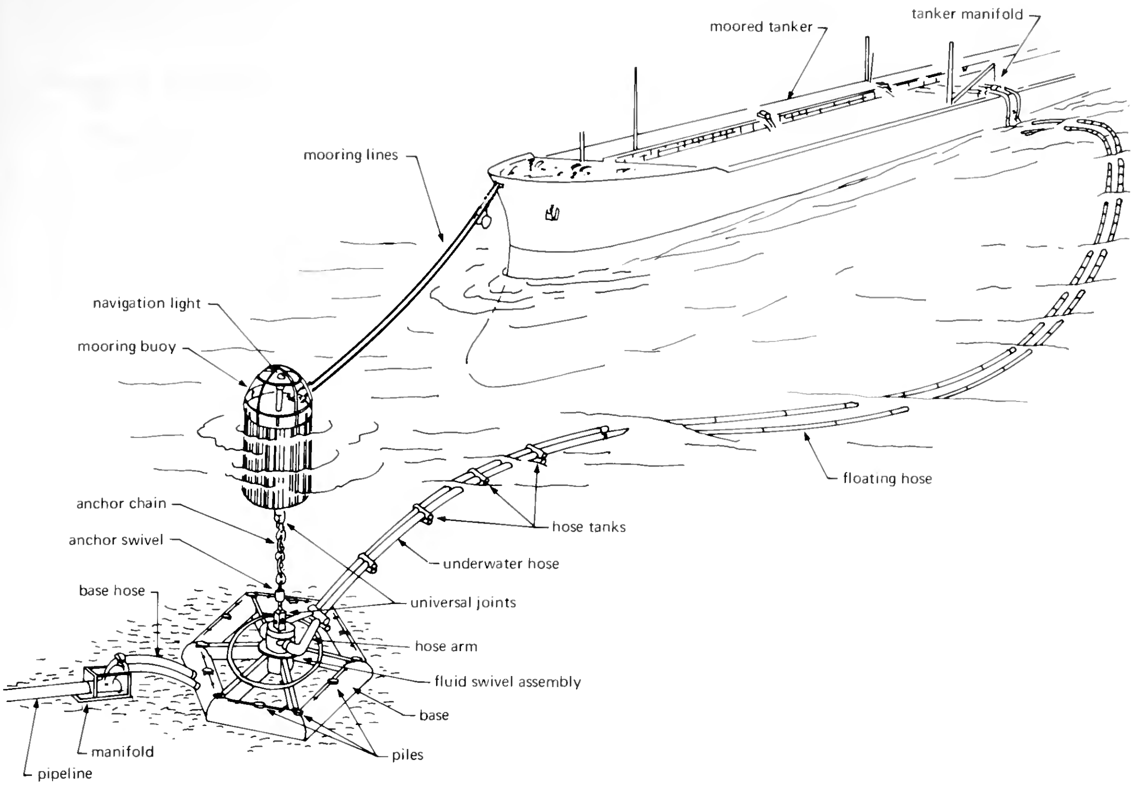

Figure 11. SALM system at Okinawa.

One of the principal concerns at piers and sea islands is striking the fixed structure during maneuvering to the berth. At an SPM the tanker does not have to maneuver so close to the mooring, and there is less chance of impact. SPM buoys are designed to take a direct impact without damage to the buoy or the tanker. As an example, at Brega a tanker accidently passed completely over the SALM buoy without causing any damage to buoy or tanker and without endangering the oil-carrying parts of the system.

After the tanker is securely moored to the buoy, the ends of the floating hose strings are brought to the side of the tanker. The ends are lifted to the deck and connected to the tanker manifold. After a final inspection of the system, valves are opened and pumping begins–slowly at first, to assure there are no problems. Throughout the entire pumping operation, vigilance is maintained for leaks in the piping system and for other potential problems. Although SPMs are usually designed to moor tankers safely in waves of 8.5 meters maximum

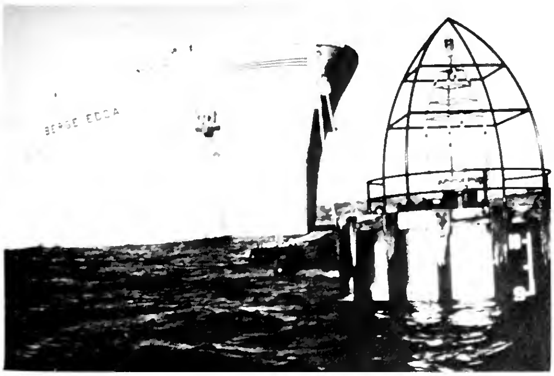

Figure 12. Tanker moored to Okinawa SALM.

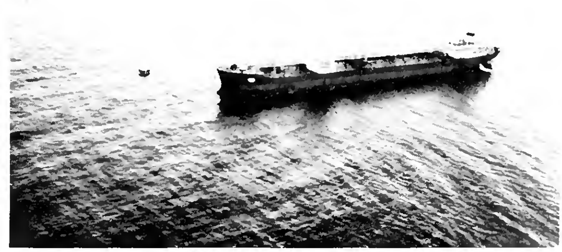

Figure 13. Tanker loading crude oil from production through SALM.

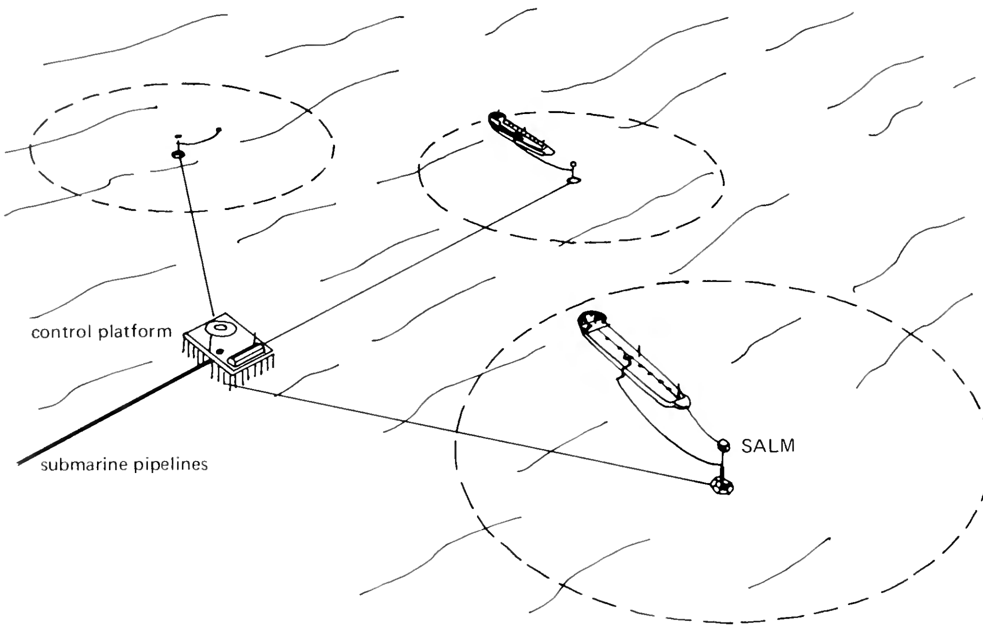

Figure 14. Offshore terminal with platform and SPMs.

height or more, pumping operations are normally suspended above about 7 meters maximum wave height.

At the conclusion of cargo transfer, or when it is necessary to leave the mooring due to worsening storm conditions, pumping is stopped and valves on the tanker manifold and pipeline are closed. A valve at the end of the SPM hose is also closed. The small amount of oil between the tanker and hose valves is drained into a drip pan beneath the manifold as the hose is disconnected, to assure that no oil escapes into the ocean. The hose is then lowered back to the sea surface.

Finally, the tanker applies power to move forward on the mooring while the mooring line is disconnected, then sails from the SPM. Because launches are not needed during unmooring, the tanker can safely depart even in a storm.

Offshore Port Plans

The Deepwater Port Act of 1974 established that the Department of Transportation administer deepwater ports. The Secretary of Transportation has set up the Office of Deepwater Ports to prepare rules and coordinate activities of the Department of Transportation and other federal agencies in carrying out the provisions of the law. The U.S. Coast Guard, which had already organized a deepwater ports group, plays a key role in these activities. Proposed rules for the design, construction, and operation of deepwater ports, prepared by the Coast Guard, were published in the May 7, 1975, *Federal Register.* Final regulations are expected to be issued late in 1975.

Studies of offshore oil ports for several sites have progressed to the point where applications for permits will be made as soon as the new Deepwater Ports Office is ready to receive them. Seadock plans to construct a port approximately 40 kilometers off the coast of Freeport, Texas. LOOP (Louisiana Offshore Oil Port) intends to build a port approximately 30 kilometers off the Louisiana coast, almost due south of New Orleans. Each project is sponsored by a separate consortium of oil, pipeline, and chemical companies; and each calls for a cluster of SPMs arranged about a central control platform, as shown in Figure 14. The oil would be distributed to refineries in the area and to long-distance pipelines. LOOP and Seadock looked at the CALM and SALM in operating and hurricane conditions as part of an extensive model-testing program in 1974; LOOP has decided to apply for permits for the SALM as its tanker mooring system.

There have been several other proposals for deepwater ports, but they are not so far along in planning. Ameriport is being considered for a location approximately 50 kilometers off the coast of Mobile, Alabama, and would be developed by Southern Pacific Pipeline International Tank Terminals, a private company. Initially the project was sponsored by Alabama and Mississippi. Like LOOP and Seadock, Ameriport would consist of a platform and several SPMs. Another plan, Massport is sponsored by the Massachusetts Port Authority and involves construction of several offshore SPMs north of Boston. Proposals have also been made for sites off the coasts of Maine, New Hampshire, New Jersey, Delaware, and the Carolinas. However, these projects are only in preliminary stages and some may not proceed.

In summary, the use of very large tankers and offshore ports is the best solution to the problem of transporting large quantities of oil over long distances. Simple and economical, this method can also dramatically reduce the risk of environmental damage due to accidents. It has been proven to work in other parts of the world and can work in the U.S. as well.

John F. Flory is a senior project engineer at Exxon Research and Engineering Company, Florham Park, New Jersey. He has been engaged in research and development of offshore oil terminals for Exxon for the past nine years and currently heads a group responsible for the design and development of single point moorings.

Except where noted, illustrations are courtesy of Exxon Research and Engineering Company.

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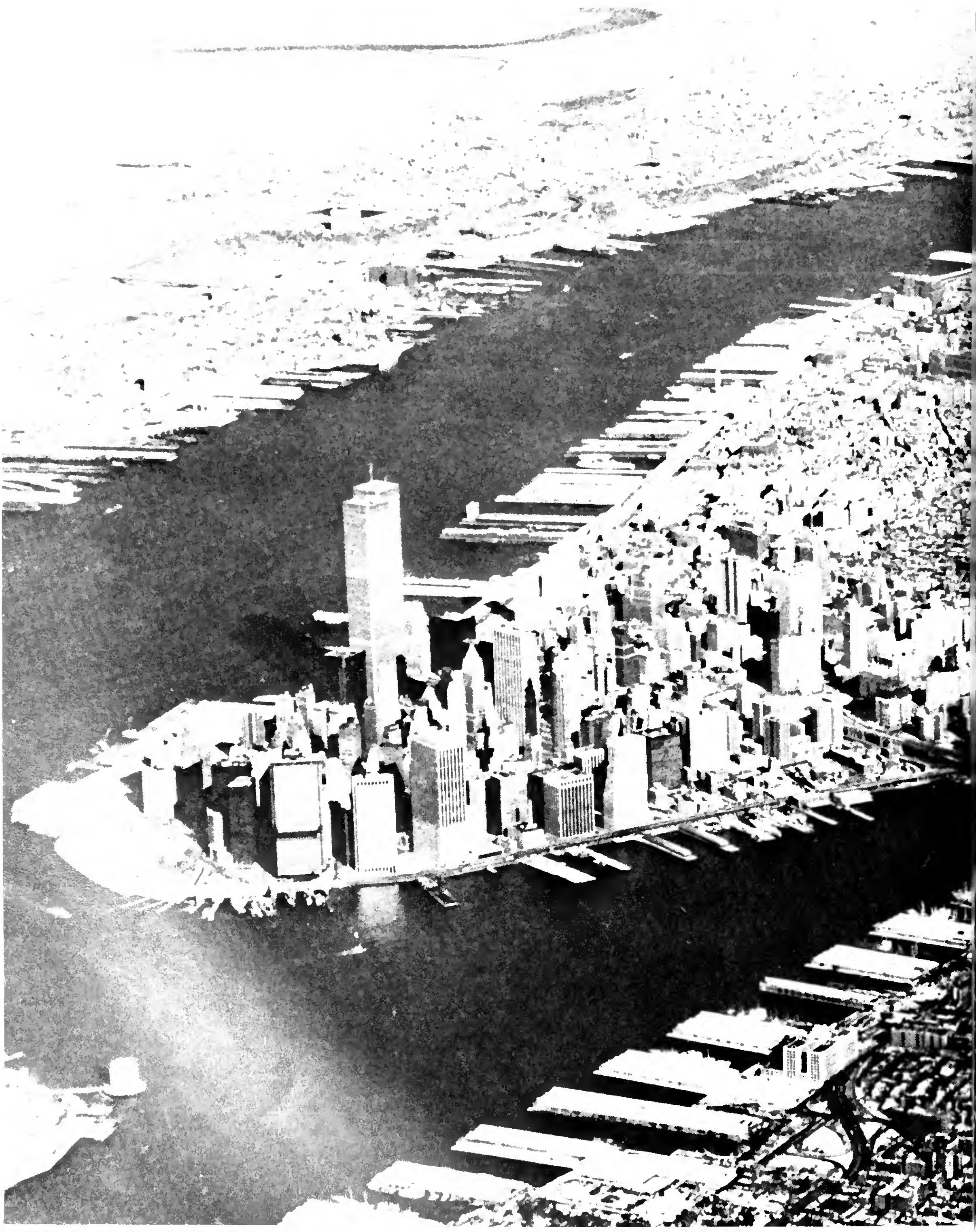


Offshore Industrial-Port Islands

by Robert B. Biggs

When the United States was still an agriculture-based society, ports were developed to transport goods and products from the hinterland. Ports were generally located as far inland as possible, and road-rail transport systems were developed accordingly. As the country evolved into an industrialized society, these ports became the hubs of activity. Industrialists took advantage of the fact that water transportation of raw materials and products was cheap, the harbors contained abundant water for cooling and waste disposal, and a supply of workers was already available. Through the late nineteenth and early twentieth centuries, industrial activity, the quantity and diversity of effluents, and the population all increased around these ports. Technology of ship construction improved so that ships' drafts exceeded the water depths of most ports, necessitating extensive dredging operations to deepen the channels. This in turn forced new industries to locate along the channels to receive or ship materials.

As ports developed, occasional fish kills occurred and there was a general decline in commercial fishery production of estuaries. In the mid-twentieth century, researchers studying estuarine processes began to document the biological importance of the estuary as a spawning and nursery ground for a significant part of the coastal area. Oceanographers learned that circulation of estuarine waters is generally weak and that their capacity to absorb pollutants is limited.

Major industrial centers, such as New York, are located on estuaries too shallow to accommodate many modern ships, too limited to assimilate industrial wastes, and too crowded to provide suitable sites for the construction or expansion of basic services and heavy industries. (The Port Authority of NY and NJ)

The U.S. is now in the position where major industrial centers, dependent on water transportation, are located on estuaries that are too shallow to handle modern ships and too small to assimilate wastes, and that are incredibly valuable as a biological-recreational resource. Further, the U.S. is now confronted with a complex situation affecting its industrial development and its ability to maintain a vigorous economy and an adequate national defense posture. On the Atlantic Coast in particular, and on the Gulf Coast to a lesser extent, there are intensive onshore population pressures and the need to develop facilities for basic services and heavy industries. Among the industrial activities essential to the economy but difficult to construct, expand, and operate are petroleum refineries and petrochemical plants; deepwater terminals for petroleum and petroleum products, and dry-bulk cargo; electric power plants; unloading and regasification facilities for liquefied natural gas (LNG); and solid-waste, sludge, and dredge-spoil disposal.

With a broad range of economic, environmental, and social constraints, it is becoming increasingly difficult to find suitable sites for deepwater ports close to areas that can accommodate heavy industrial plants that refine, concentrate, and convert the bulk raw materials into oil products, primary metals, and fertilizers. Some of these processes are heavy users of electric power and can best be justified if located close to generating plants. It is also becoming increasingly difficult to find acceptable sites for electric power plants to serve the highly developed but still rapidly growing coastal metropolitan areas.

The National Science Foundation funded a conceptual design study of multipurpose industrial-port islands suitable for construction off the Atlantic and Gulf coasts and built to accommodate the type of industries listed above. The U.S. has limited experience with the concept of single-purpose offshore structures. A nuclear power plant has been proposed for location off the New Jersey coast, and a sand-filled coal transshipment island has been suggested for Lower Delaware Bay.

The artificial industrial island concept argues that in a conventional setting there are some activities that are both necessary and noxious. It suggests that, based on the geography of demand, there are locations that will better accept the presence of such activities, be it for a social, ecological, or other "noneconomic" reason. It then argues that the economic feasibility can be judged only when activity and real estate value have been integrated for maximum effectiveness while recognizing relative cost differences between natural and created land, and the potential cost differences for pollution management, process development, and logistic support.

In order to complete a conceptual design of a multipurpose offshore industrial-port island, one must answer the following questions:

- What industries would be suitable for island location?
- Where, based on market demand, could an island be built?
- How should the industries be arranged on the island, what raw materials would be required, and what wastes would be produced?
- How could such an island be built?
- What would be the environmental effects of construction and operation?
- What legal-jurisdictional arrangements are available or need to be developed?

Industry Candidates and Location

Several of the main criteria used in the preliminary selection of island candidates were the importance of the industry to the economy and the national defense; the history of plant site acquisition problems; the source, volume, and form of raw materials needed; the noxious, nuisance, or hazardous nature of the industry; and whether the industry is labor or capital intensive. Based on these criteria, a list of eleven candidate industries was developed: petroleum refining; petrochemicals manufacturing; electric power generation (both nuclear and fossil fueled); deepwater terminals; LNG regasification; urban solid-waste processing and disposal; fertilizer manufacturing; paper manufacturing; electrometals processing; iron reduction and steelmaking; and nuclear fuel reprocessing.

D. M. Bragg of Texas A&M University has assessed the possiblity of siting such industries on artificial islands and concludes that oil refining, electric power generation, petrochemicals manufacturing, LNG regasification, and nuclear fuel reprocessing are the most promising candidates. (Table 1 presents a summary of general mainland problems and island advantages for these industries.)

As for the location of a multipurpose sea island based on high market demand for industrial products and unavailability of on-land sites, the Atlantic Coast from Hatteras northward is a prime area for consideration. The southeastern Atlantic Coast and the Gulf Coast have either low market demand or adequate onshore sites.

Table 1. Candidate industries by rank.

Rank	Industry	Mainland problems	Island advantages
1	Oil refining	1. Emissions and air quality 2. Aesthetics of plant 3. Land use conflicts 4. Possibility of oil spills 5. Danger of fire and explosions 6. Delivery of imported crude oil 7. Strong public opposition	1. Emissions would dissipate over ocean 2. No aesthetic conflict 3. No land use conflict 4. Oil spills would be kept away from coast 5. Removal of fire hazard from community 6. Direct delivery of imported oil
2	Electric power generation (fossil only)	1. Disposal of waste heat 2. Removes large land areas from other uses 3. Disposal of waste sludge from stack scrubbers 4. Transmission line corridors have poor aesthetics and tie up large areas of land	1. Could use ocean as heat sink 2. Could receive boiler fuel via water transportation 3. Could dispose of waste sludge as island fill 4. Part of power transmission activity would be underwater and out of sight 5. Source of power for island industries
3	Electric power generation (nuclear)	1. Disposal of waste heat 2. Fear of radiation leakage 3. Large area of land tied up for radiation exclusion zone 4. Fear of nuclear blast 5. Strong public opposition	1. Could use ocean as heat sink 2. Would remove plant from contact with people 3. Water area around island would create exclusion zone
4	Petrochemicals manufacturing	1. Lack of feedstock supplies 2. Land use conflicts 3. Possibly hazardous emissions 4. Aesthetics of plants 5. Impact of local air quality 6. Danger of fire and explosion 7. Strong public opposition	1. New refineries could provide feedstocks 2. Emissions would dissipate over ocean 3. No land use conflict 4. Removes plant from contact with public
5	Liquified natural gas regasification	1. Safety problems with LNG vessels in crowded harbors and channels 2. Fear of leaks and explosions at terminals 3. Extent of hazard from explosions and fires unknown	1. LNG ships would stay out of crowded harbors 2. Danger of leaks and explosions removed from populated areas 3. Would provide source of natural gas for other industries on island
6	Nuclear fuel reprocessing	1. Radiation hazards 2. Large land area tied up for exclusion zone 3. Security of plutonium from theft for use as weapon material is difficult to maintain	1. Radiation hazard would be removed from populated areas 2. Water around island would form exclusion zone 3. Security of plutonium more easily maintained on an island

Source: Bragg, 1975, *Market demand and general location options for artificial islands.*

Plant Size, Raw Materials, and Products

Island industries can be organized in any number of ways. For example, the core industry could be fossil-fueled electric power generation for the mainland; then satellite industries would be sized around the availability of "excess" electric power. Alternatively, a petrochemicals facility or a refinery could serve as the core around which an industrial complex is built. Obviously the number of workers needed, the pollutants discharged, and the raw materials and products moving to and from the island will vary with the kinds and size of industry.

Given that the northeastern Atlantic Coast lacks suitable onshore industrial sites and that refinery siting seems to be a particularly acute problem (Table 2), I have selected a 500,000-barrel-per-day refinery as the core industry in developing *an example* of a complex that could be constructed off the northeastern United States.

W. G. Yeich of Gilbert Associates has developed the needs for area, workers, utilities (power steam, water, etc.), and raw materials for an industrial island with a refinery core. Figure 1 shows the flow of materials at an island site based on a 500,000-barrel-per-day refinery. The key input to the island is imported crude oil and/or oil produced in nearby offshore fields. The key outputs are refined petroleum products and petrochemicals. All of the other industrial tenants are rational extensions of these key facilities, as secondary processing, maintenance and operation support, or waste disposal. The complex is served by a common waste collection and treatment facility.

The crude-oil refinery and petrochemicals plant produce high-value clean fuels, industrial chemical feedstocks, and polymers for export. Off-gas not committed to the refinery is used as fuel and feedstock for an ammonia fertilizer industry. Refinery wastes having fuel value are used in the island's steam electric power plant. Waste heat from the refinery and power plant is used to the maximum extent possible by the food processing and paper industry tenants. Chemical effluents are processed in the island's waste treatment facility to achieve chemical recovery and maximum water reuse.

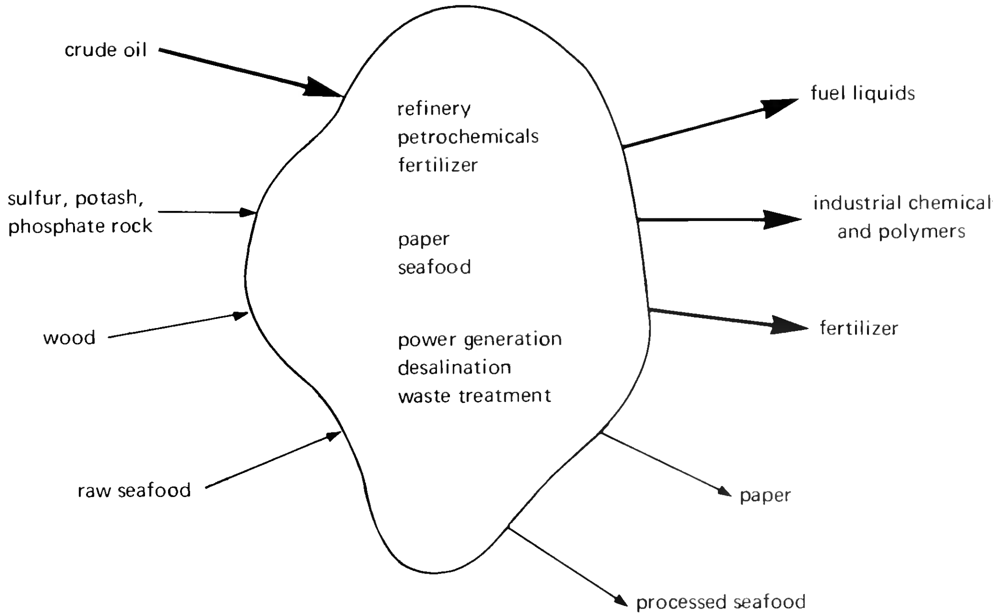
Table 2. Refineries planned but not constructed.

Company	Location	Size (bbl/day)	Final action blocking project
Shell Oil Company	Delaware Bay, Del.	150,000	State reacted by legislature passing bill forbidding refineries in coastal area.
Fuels Desulfurization[a]	Riverhead, L.I.	200,000	City Council opposed project and would not change zoning.
Maine Clean Fuels[a]	South Portland, Me.	200,000	City Council rejected proposal.
Main Clean Fuels[a]	Searsport, Me.	200,000	Maine Environmental Protection Board rejected proposal.
Georgia Refining Co.[a]	Brunswick, Ga.	200,000	Blocked through actions of Office of State Environmental Director.
Northeast Petroleum	Tiverton, R.I.	65,000	City Council rejected proposal.
Supermarine, Inc.	Hoboken, N.J.	100,000	Hoboken project withdrawn under pressure from environmental groups; considering site near Paulsboro, N.J.
Commerce Oil	Jamestown Island, R.I., Narragansett Bay	50,000	Opposed by local organizations and contested in court.
Steuart Petroleum[b]	Piney Point, Md.	100,000	Withdrawn due to pressure from environmental groups.
Olympic Oil Refineries, Inc.	Durham, N.H.	400,000	Withdrawn after rejection by local referendum.

Source: Federal Energy Office, 1974, *Trends in refinery capacity and utilization.*

[a]Maine Clean Fuels and Georgia Refining Co. are subsidiaries of Fuels Desulfurization, and the refinery in question is the same in each case; so the capacity in bbl/day is not additive, but the incidents are independent and additive.

[b]Again being introduced.



Movement of Materials
(average per diem rates)

Raw Materials to Island	
Crude oil	85,000 tons/day (approx. one 250,000 dwt VLCC every 72 hrs. on 24-hr. turnaround)
Potash	2650 tons/day
Phosphate rock	13,000 tons/day
Sulfur	1500 tons/day
Wood	300 tons/day kraft, or 420 cords/day
Raw seafood	270 tons/day
Refuse	24,000 tons/day
Products Leaving Island	
Hydrocarbon liquids	75,000 tons/day
Polymer prills/chips	5000 tons/day
Fertilizer (dry)	8500 tons/day
Salts	230 tons/day
Paper rolls	385 tons/day
Processed seafood (frozen)	270 tons/day

Minimum storage on island, 10 days.
Data provided by W. G. Yeich.

Figure 1. Flow of materials at an island site whose core industry is a 500,000-barrel-per-day refinery.

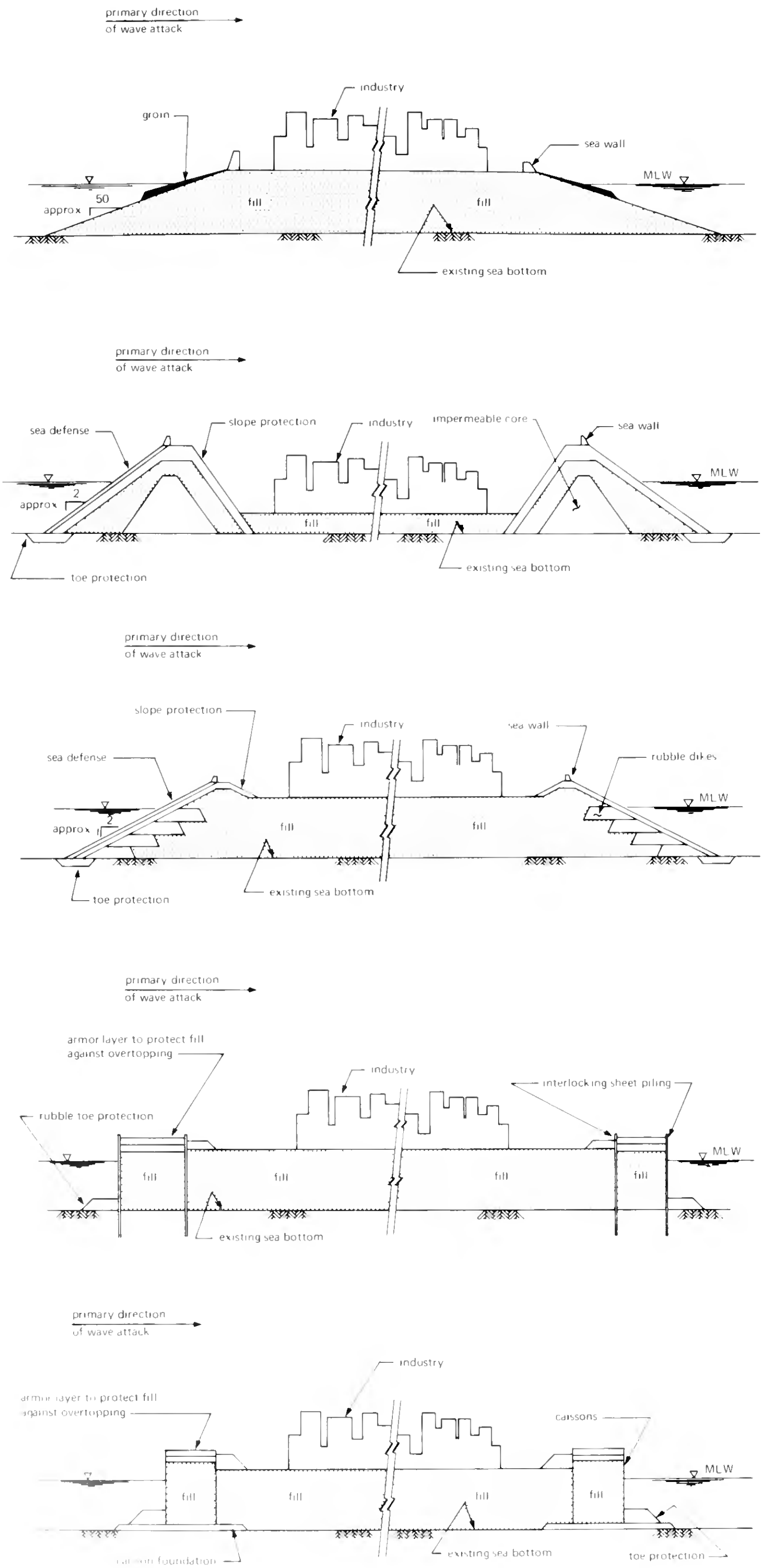


Figure 2. Sections of typical sea island designs, from top to bottom: unprotected beach; polder; dike and fill; sheet pile cell protected; and caisson protected.

Steam and electricity are supplied by the steam electric power plant, which is fueled primarily by combustibles from solid wastes imported from mainland municipalities and beneficiated on the island. Fresh water is produced from seawater in a desalination plant and from recycled waste water, using steam as the heat source. Brine from the desalination plant is evaporated and further processed to produce refractories, commercially valuable salts, metals, and industrial gases. The island's acid requirements are supplied by an acid plant using sulfur recovered from the refinery crude runs, sulfates extracted from brine, imported sulfur and phosphate rock, and ammonia from the fertilizer complex. Thus the liquid wastes produced by the island's industries will be designed to approach zero.

The size of the island is based on present, state of the art, land-based industries. Area requirements, grouped by function, are as follows:

Raw material unloading and storage	285 acres
Product storage and loading	185 acres
Manufacturing plants	995 acres
Utilities	335 acres
Total area	1800 acres

The total number of people employed per 8-hour shift on such an island complex would be about 1600; and the investment in processing units, exclusive of the cost of the island itself, would approach $4 billion.

Building a Sea Island

There are several techniques available for constructing a sea island from 1500 to 2000 acres in size. The Dutch, in particular, have been extremely successful in open-sea construction. The following design-construction methods have all been used or proposed: unprotected beach; polder; dike and fill; sheet pile cell; and caisson (Figure 2).

J. J. Bonasia of F. R. Harris has evaluated each of the methods and has concluded that the unprotected beach and the polder are not suited to open-water, offshore conditions. In the case of the unprotected beach, great amounts of fill are required and constant maintenance is necessary to replace the lost material. With the polder the possibility of a catastrophic failure (with loss of up to 1600 lives) due to an earthquake is high because we cannot predict (in real time) the occurrence of such an event.

In selecting the specific location for a sea island, a number of engineering factors must be evaluated, including the possibility of seismic (earthquake) events; suitability of foundation materials (coarse sands or gravels are preferred); proximity to shipping and air-traffic lanes, as well as disposal areas for munitions; oceanic variables such as waves, tides, storm surge, and currents; and meteorological constraints such as dominant winds, frequency of hurricanes and tornadoes, as well as fog and ice.

The most efficient shape for a sea island, from an engineering point of view, is a circle because it maximizes area and minimizes perimeter (which must be protected with armor). We have not considered innovations in island design that are beyond the state of the art. Decked or multistory refineries, for example, could save considerable land space but have not been designed and tested. Similarly, automated underwater process units might provide significant economies but have not been adequately tested.

A possible configuration for an 1800-acre sea island, with a harbor on the lee side and a smooth curve presented to the principal direction of wave attack, is illustrated in Figure 3. Pertinent data are as follows:

Elevation above mean low water (MLW)	5 meters
Total area	8.0 square kilometers
Radius	2106 meters
Wharfage	5540 meters
Volume of sand required	246×10^6 cubic meters

The circle limits the possibility of localized concentration of wave energy on the sea defense system. The breakwater prevents refracted waves and waves generated by offshore winds from entering the harbor. Minimum oscillation and resonance can be expected. The island is oriented to the southeast, the direction of the principal wave attack. The harbor is also protected from northeast storms.

There is a deepwater, one-way channel with a 23-meter depth at MLW for Very Large Crude Carriers (VLCCs) of 250,000 dead weight tonnage. All vessels would follow the deepwater channel into the harbor and leave by the opposite end, thereby adding to the safety of operations. VLCCs would leave the harbor directly ahead, without the need for turn-around. Floating and fixed visual aids to navigation would mark the channel.

Access to and from the island would be accomplished by ships, aircraft, and a twin-tube vehicular tunnel. If expansion consists of adding an island toward shore, then during the initial construction it would be necessary to provide for a turn-off to the future island. Shift changes could be managed by the use of buses to transport all personnel to and from shore. This method would insure shift changes under all weather conditions.

The tunnel would also provide for truck transport of manufactured products. An alternative plan would be for key personnel to live on the island, perhaps on seven- to thirty-day shifts. Since island real estate is expensive, facilities for island living would be a matter of economics.

The estimated order of magnitude cost to construct the island is $550 million at 1975 prices. These costs include mobilization, dredging and subbase preparation, rock protection, sand fill, deepwater channel dredging, caissons, breakwater, and berthing facilities. The estimated order of magnitude cost of a 13-kilometer-long twin-tube vehicular tunnel is $200 million and includes two ventilation shafts onshore and one at sea. These costs, of course, are extremely sensitive to distance from shore and water depth.

Environmental Effects

The offshore island concept cannot become a repository for all our problems—out of sight, out of mind. Very careful planning for the environment is required. Particulate emission control, liquid waste treatment and disposal, and spill safeguards are important to the public health whether on an island or onshore. However, there may be some environmental advantages to an offshore island: use of the ocean as a heat sink; noise abatement; solid-waste disposal that is favorable to island expansion; and other benefits stemming from distance and diffusion. In addition, it may be more desirable from an environmental perspective to preserve or rehabilitate estuarine and coastal areas at the cost of potentially less productive shelf regions.

Considering the volume of fill necessary to construct an island, dredging could take 10 years. During that time turbidity would be significantly increased in the water near the construction site, and bottom habitat destroyed. On the other hand, 2500 meters of armored protection might improve the local marine habitat and ultimately benefit biological productivity in the area.

L. Watling of the University of Delaware, in attempting to evaluate the biological impact of the construction and operation of an artificial island, has concluded that "this could not immediately be done with any degree of confidence for the following reasons: a) the available information about the present condition of the environment was, for the most part, incomplete; b) little was known about the responses of oceanic species to pollutant additives; and c) as a result of b) there were essentially no usable criteria by which one could measure projected effects."

Large structures built relatively close to the coast will often affect the erosion or deposition of sand along the shoreline. A structure such as a breakwater or an offshore island changes the characteristics of the waves behind it. Waves are refracted and diffracted around the edges of the structure, and the wave heights are lowered in the shadow zone behind the island. If this zone extends to shore, sand moving along the coast will begin to build up in the area of reduced wave energy, cutting off the natural longshore transport of sand and creating an area of erosion to the downdrift side of the island's shadow.

If it is desirable to protect a section of coastline that has a relatively erodable material on the downdrift side, the island should be built far enough from shore to minimize its impact on the coast (but, again, at a higher cost). Extensive refraction and diffraction studies are necessary to insure that the island will have little or no effect on the shoreline.

Other environmental considerations that must be quantified in order to assess environmental impact include the land-side tunnel, dock, and airport. The 1600 employees per shift (in the example given earlier) will have to be transported from the island to their homes on the mainland. The landfall of the tunnel, for example, should therefore be located near highway-railroad transportation away from the coast.

Legal-Jurisdictional Arrangements

At the present time legal-jurisdictional issues are cloudy with respect to the location of an artificial multipurpose industrial-port island on the U.S. continental shelf. If such a structure were to be built within a state's territorial waters (three miles), the state would be able to approve and control island activities. In order to minimize environmental impact (in terms of noise, odor, visual aesthetics; and the effect on the shoreline), the proposed location would probably be farther than three miles offshore.

G. J. Mangone of the University of Delaware, in an assessment of the legal-political aspects of artificial islands, has concluded that, in general, under international law, states may place islands for any purposes within their territorial waters, subject to certain navigation easements. States may also locate islands on their continental shelves for purposes of exploring or exploiting the resources of the shelf. However, there are well-established rules enjoining any attempt by a state to subject any part of the high seas to its sovereignty.

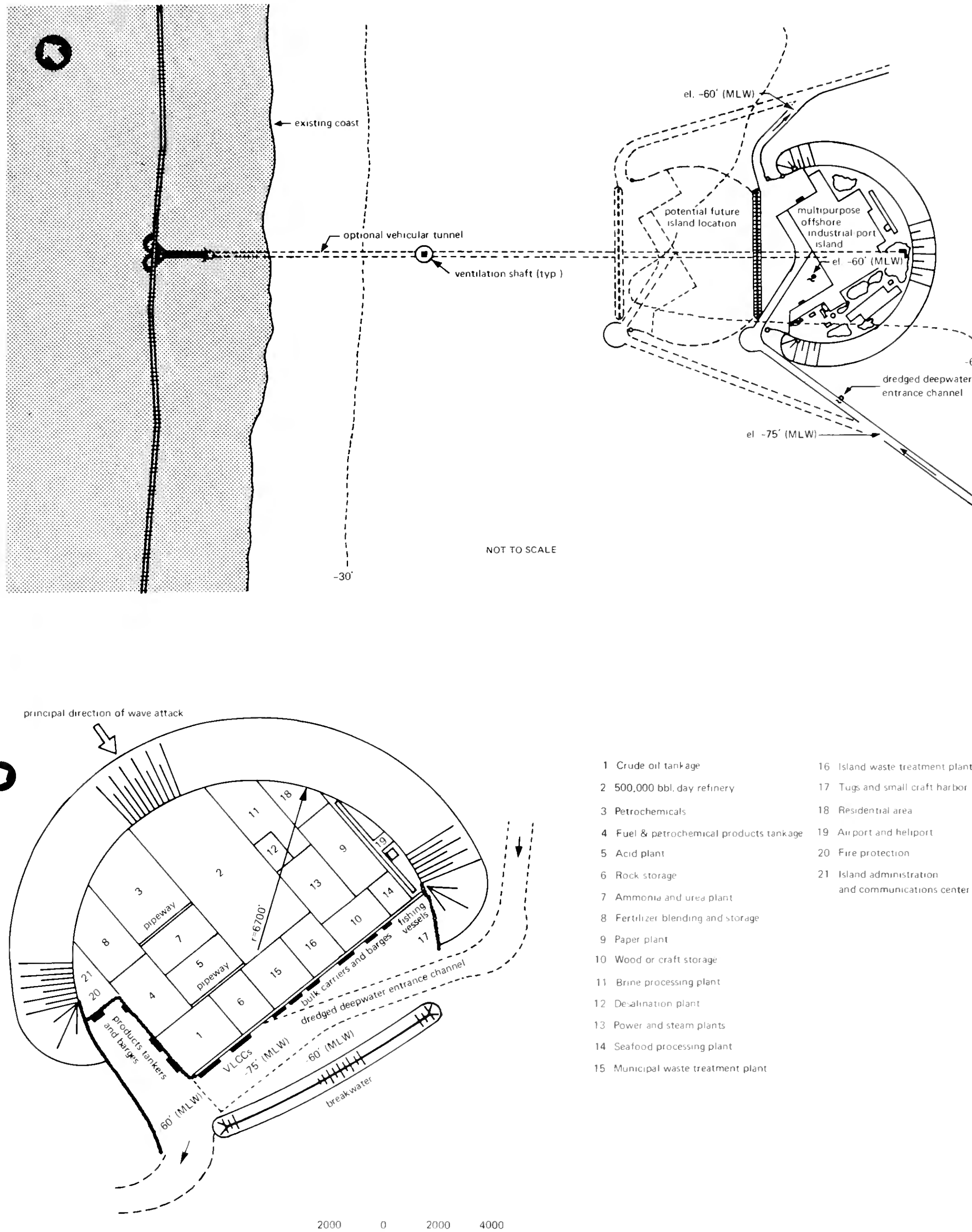


Figure 3. Proposed offshore industrial-port island plan, alternatives 1 and 2.

Only such activities as navigation, fishing, the laying of pipelines and cables, and overflight are permitted to states on the high seas.

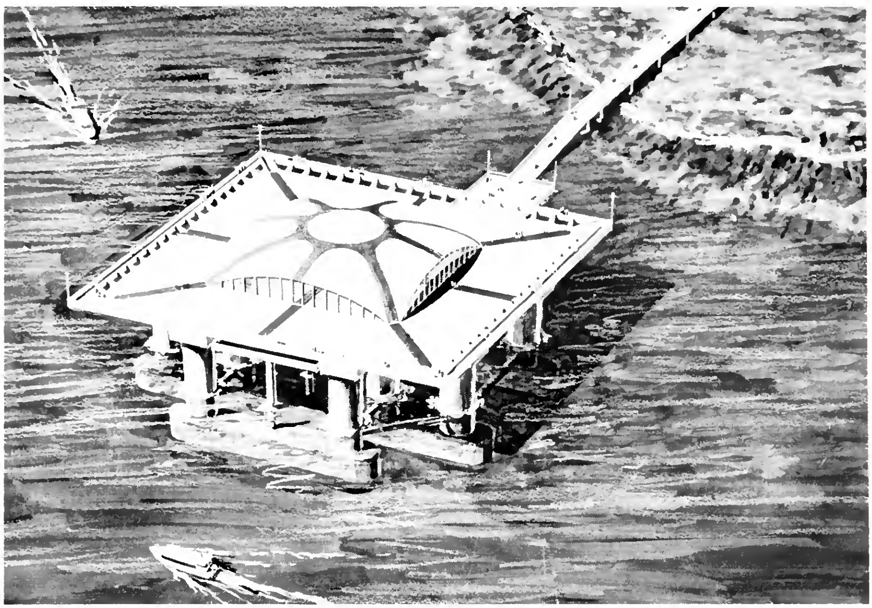
The major legal consideration of the location of an artificial island, from the U.S. point of view, is whether it lies within U.S. waters, in which case it comes under the constitutional jurisdiction of the state as well as the federal government. On the other hand, if it lies beyond the territorial waters, it comes under the jurisdiction of the federal government, except as statute may specifically provide, for the application of state law or a state's participation in federal regulation or control.

Conclusion

In March 1975, W. S. Gaither chaired a workshop on major problems and promising research approaches related to offshore industrial-port islands. There were more than 50 participants, representing federal and state government, industry, and academia. Participants agreed that the major problems to be solved before large-scale investment in island construction can begin center on the legal-political, economic, and environmental issues. The environmental concerns could be eased if a programmatic environmental impact statement were developed. The legal and economic issues are almost inseparable. There is a need for significant new legislation that will permit an offshore island to be constructed and operated, and this legislation will have to be tailored to the economic realities of industries that locate there.

Robert B. Biggs is associate professor of geology in the College of Arts and Science, associate professor of marine studies and assistant dean for academic affairs in the College of Marine Studies, University of Delaware.

Present and Future Uses of **Floating Platforms**



Artist's rendering of Aquapolis, the Japanese government's pavilion at Expo '75 on the Motobu Peninsula of Okinawa. The floating artificial island, 100 meters on a side, is considered to be a prototype of the future marine city. (Consulate General of Japan, New York)

by John P. Craven

On April 23, 1975, the 18,000-ton floating platform Aquapolis arrived at its destination in Okinawa after a long tow from its construction site in Hiroshima. The feature attraction of the 1975 International Ocean Exposition, it is architecturally designed to demonstrate the floating city of the future. For many people this exhibit will be futuristic; for a perceptive few it will represent a practical concept to be realized before a decade is over.

On July 4, 1975, Mobil Oil's production platform Condeep, displacing 330,000 tons, was towed from its fabrication site in Stavanger, Norway, to its production area some 190 kilometers at sea. For many individuals this leviathan is merely a feature of energy production, with little relevance to the world in general; for a perceptive few it is overwhelming proof that major industrial facilities and complexes can be economically and environmentally best located on floating or quasi-floating artificial structures.

When viewed in combination, the Aquapolis represents the most advanced functional concept for floating platforms, while the Condeep proves that the engineering can match the functional concept. These facilities are but two of the ever-increasing flotilla of floating platforms for commercial and industrial use. Nearly 300 mobile drilling rigs have been built on a world-wide basis. Of these about 15 are submersible units, approximately 140 are jack-up (self-elevating) rigs, 70 are drill ships or barges, and 75 are semi-submersibles. In addition to oil-oriented designs, there are a number of specialized geophysical drill ships, several ship-borne chemical plants, a few incinerator ships, some floating universities, and the Ekofisk and Dubai oil storage facilities.

In the advanced planning and design stage, with a committed capital investment, are floating nuclear power plants and liquified natural gas facilities. In advanced concept design are floating airports and fossil-fueled power plants. Other operations that are under consideration include military staging bases, steel mills, oil refineries, manganese nodule processing plants, and ammunition storage depots. Indeed, there are few urban or industrial activities that could not be carried out to advantage on a floating or quasi-floating structure.

Three factors combine to increase the number and variety of sea-based platforms: stability, economics, and environmental suitability.

Stability

Stability has been achieved through the use of either a conventional hull with very large displacement or, more easily, a semi-submerged platform. The concept of stable ocean platforms is not new. The modern semi-submersible was first proposed for the Armstrong Seadrome of the 1930s, which was designed as an oceanic airfield to make possible the trans-Atlantic flight of short-range passenger planes. A number of these platforms were to have been located in the Mid-Atlantic, spaced in accordance with the range of existing aircraft. Development of the Seadrome was thwarted by the successful extension of the range of commercial aircraft.

World War II saw the installation of fixed offshore platforms as radar stations. Many of these "Old Shakeys" did not survive the storm conditions to which they were exposed. Nevertheless, they were the predecessor of the "Uncle Charleys" (the standard oil rigs of the 1960s) and a wide variety of mutations thereof. The fixed platform became increasingly less economic as facilities were sited in greater depths. A number of jack-up rigs were designed, some as tall as major skyscrapers, but they are becoming a smaller percentage of the oil industry fleet. Dynamically positioned (unmoored and propelled) drill ships were also developed. However, the surviving dominant structure appears to be the semi-submerged, dynamically positioned platform. As of May 1975, 100 floating drill rigs were under construction, compared to 63 jackups; and of the floating rigs, 59 were semi-submersibles.

Semi-submersible units have demonstrated that stability in high seas is possible and that station keeping can be accomplished without mooring. The basic principle of the semi-submersible is that the major portion of the hull is located in deep water, well below the influence of waves. Rather thin struts with a small water plane area extend above the surface. Well above the average wave height is a platform on which are mounted light fixtures and man-occupied spaces. The most advanced structure of this type was represented by the Mohole (for the so-called Mohorovicic discontinuity) platform, designed to drill through the earth's crust. It was partially fabricated, at a great expense to the U.S. taxpayer, then terminated in 1966 by the Executive and the Congress. Adopted by Japanese shipbuilders, the design became the basis for their highly successful mobile oil rigs.

Stability has many advantages beyond the safety of the structure itself. It is possible to design platforms that will never in their expected lifetimes exceed accelerations of .02*g*, the limit of human ability to perceive motion. Of equal significance, this acceleration is far below earthquake loads. As a result, structural requirements for machinery and buildings on the platforms are much lower than for those built on "solid" ground. It is also possible to use the platforms for functions that are absolutely demanding in terms of human performance (e.g., precision manufacturing, observatories, billiards).

Economics

While stability and safety initially led industry to choose stable platforms, economics dictates the current trend. Factors that make offshore floating platforms economically competitive with land-based counterparts are multiple production in a single facility, economies of scale, and use of prestressed concrete. The Westinghouse-Tenneco study of floating nuclear power plants showed them to be more economical than the land-based equivalents after a limited production run. Cost-saving features included the elimination of site-specific design; shipyard fabrication as opposed to on-site construction; bargeloads rather than truckloads of concrete; lessened impact of an earthquake; and the elimination of foundation and site preparation costs, land acquisition costs, and logistic connections, such as roads and utilities.

Other research has indicated similar economies. Two conservative studies of floating fossil-fueled power plants by the Oceanic Institute at the University of Hawaii indicated essentially a cost trade-off between land-based and fixed platform facilities. But with floating complexes there is an economic advantage of about two years' less lead time due solely to the elimination of administrative procedures that now encumber coastal zone construction.

The emerging conclusion is that floating platforms are economically equal or superior to their land-based counterparts when the function to be performed requires high volume-to-area ratios, when the absolute size of the structure is large (i.e., greater than 15,000 tons), and where competing land costs are high (i.e., from $1 to $10 per square foot). Thus office buildings, manufacturing plants, bulk storage facilities, and power plants are amenable to siting on floating platforms, whereas airports, which require large amounts of surface area, are rarely if ever cost competitive.

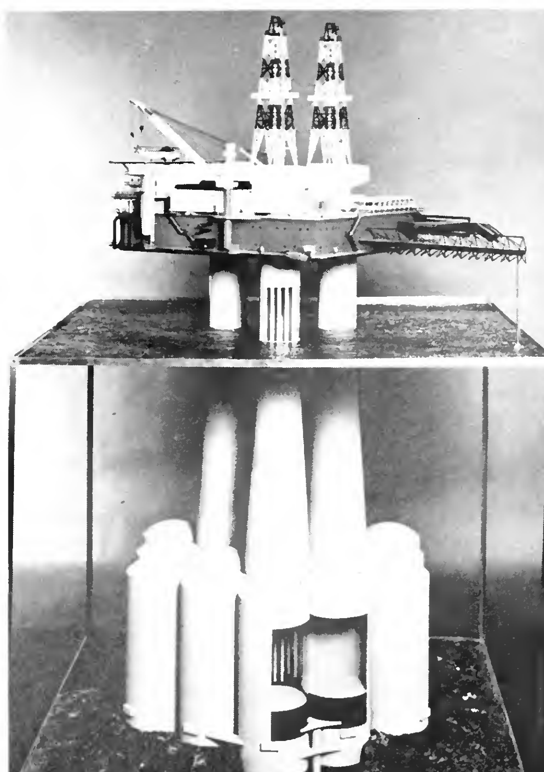
Environmental Suitability

With this feature there is a curious counter effect. Simply stated, the *open ocean* is perhaps the easiest and safest environment for industrial processes vital to the society; but the public has been led to believe that the open ocean is the most fragile and easily polluted of man's environments. This scientific absurdity exists despite the fact that the extensive body of data indicates that such major oil spills as *Torrey Canyon* and Santa Barbara have as yet had no measurable long-term environmental effect; that such major nuclear accidents as the loss of the submarines *Thresher* and *Scorpion,* whose reactors must have ruptured, have not produced and do not produce measurable nuclear effects; that the mercury in highly migratory species such as swordfish and tuna is produced not by man but by nature; that thermal pollution of the ocean is a technological feat beyond the power production capabilities of man, even if he were inclined to engage in such a project; that there is more biological waste than treated waste in the ocean;* and that the ocean is the only major environment that rapidly terminates virus vectors. As long as due care is taken to protect the food chain, the open ocean is environmentally superior to any other environment for the siting of potentially polluting facilities.

A major caveat, of course, is that these statements do not apply to estuaries, small bays, and other bodies of water having limited circulation. Floating platform communities would therefore be positioned seaward of these vulnerable areas, at least three miles from the coast. Further, they would be deployed only where continental shelves are narrow and oceanic waters close to shore. Such conditions exist along the western coasts of most continents, around the Caribbean, and off such island groups as Hawaii and Japan.

Social Considerations

The three technological advantages of floating platforms—stability, economy, and environmental suitability—do not of themselves guarantee the extensive use of platforms. Sociological factors must be equally attractive. The record of man's socialization indicates that the trend to floating platforms is as attractive for this reason as it is for others. Indeed most human societies evolved about a configuration of land and water that was appropriate for the scale of their technology. In tracing this evolutionary process one notes the Neolithic lake communities of 2000 B.C., which matched the capabilities of the coracle and raft; the river societies of the Nile, the Indus, and the Tigris and Euphrates, which equalled the scale of the river barge; the Aegean societies chronicled by Homer, which corresponded to the capabilities of the elemental galley, even as the Phoenicians dominated the eastern Mediterranean with biremes and triremes, or the Romans the entire Mediterranean with the zenith of that line. The Hanseatic League of the fourteenth century matched the scale of the cog, which, evolving into the carrack and the caravel, gave impetus to the brief domination by Spain



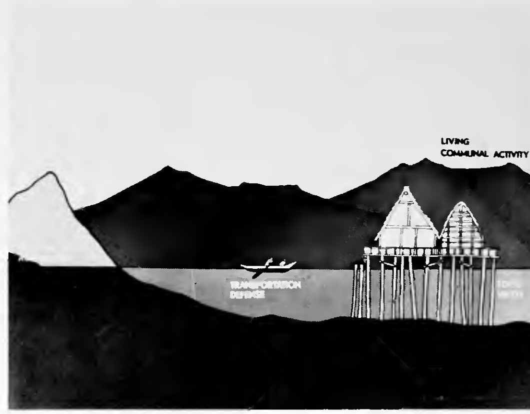
Model of the 330,000-ton Condeep Beryl A *platform (see cover). Nineteen caissons form the base, each 167 feet high and 66 feet in diameter, with 2-foot-thick concrete walls. Three 310-foot-high concrete pylons support the two-level deck structure, which is about the size of a football field. Along one side of the deck are five-story-high living quarters. A heliport and two drilling derricks top off the $300 million platform. (Mobil Oil Corporation)*

*According to John Isaacs of Scripps Institution of Oceanography, the almost 6 million metric tons of anchovies off Southern California alone produce as much fecal material as 90 million people, or about 10 times the population of Los Angeles.

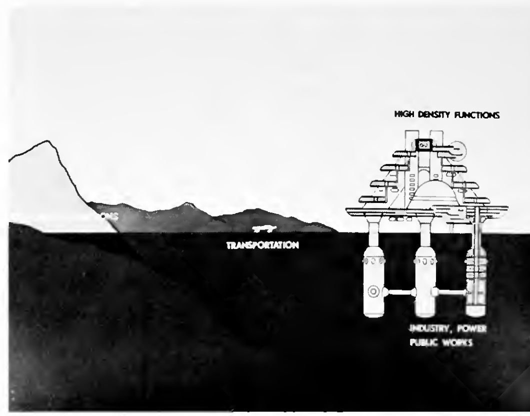
and Portugal and provided the means for British rule with the frigate, brig, brigantine, and schooner. This pattern can be observed in modern times when the nations of rising affluence are those dominating the sea lanes with supertankers, large cargo carriers, floating platforms, and artificial islands.

Identification of historical changes in sea technology is rather easy, unlike predicting which land-sea complexes will be most important in years to come. It is nevertheless possible to detect some patterns in ancient civilizations that may form the basis for a model of the *new* oceanic societies. In particular, the Neolithic lake societies of Britain, Switzerland, Africa, and Asia had so many features in common that one can conclude that their independent evolution resulted from the basic needs of social man. As a hunter, man followed the small game that migrated to the shores of the lake seeking water. The seeds of berries and plants dropped on the shore by these animals began to grow and mature, inducing the hunter to adopt agrarian ways and settle on the lake shores. These societies quickly learned that the best means of moving the large and heavy game caught on the mountain slopes was to drag them downhill to the nearest point on the lake shore and transport them by raft to their destination. The advantages of water transport and the need for defense against predators–animal and human–resulted in the construction of platforms on stilts in the center of the lake. The lake also served as a reservoir for the disposal and oxygenation of wastes, which provided food for an abundant supply of fish.

The basic requirements of defense, waste disposal, food supply, shelter, and socialization gave rise to communities organized along similar lines on a world-wide basis. This pattern serves as a model for what a three-dimensional water-based Neolithic society might have looked like. In such a society the land is reserved primarily for sites of low-density functions and agrarian uses, such as game preserves, farms, recreational fields, and ceremonial grounds. Sites of high-density activities–dwellings, community gathering places, and facilities for "industrial" processing, energy generation, and waste disposal–are located on platforms in the water. The platforms are organized on three dimensions. The area below the water is for "industrial" functions, such as waste treatment processing and heat rejection, while above the water man lives and socializes. These two areas are organized from lowest density at the periphery to congregation at the center. The water surface is used for transportation from the land mass to the platforms–as well as under the platforms so that goods may be discharged vertically where needed.



The Neolithic lake society.



The coastal valley/stable platform community–the lake model on a modern scale.

Although Neolithic lake communities were quite stable, overpopulation and the conversion of lakes into land masses of artificial platforms resulted in their demise. (Today we have the technology for population control, but its implementation is far from complete.)

Considering the success of the Neolithic lake community as a social organization, one may well ask why the pattern was not replicated on a larger scale in bays and estuaries, even in the open ocean. Indeed it was repeated in sheltered coastal waters, and exists today in African lakes and Southeast Asian bays; but its widespread development was hindered by two basic problems: the perils of storm, and the discomfort of seasickness. If modern ocean technology can resolve both of these problems, then we may expect to see new coastal societies evolving in a pattern not unlike that of the Neolithic lake communities.

The envisioned end point is a community consisting of a redeveloped coastal valley and a complex of offshore floating platforms. The valley's slopes would be reserved for agricultural use and urban dwellings; the coastal plain for universities, government centers, parks, golf courses, stadiums, and other low-density sites. The airport would also be located on land because it requires a large area. Power plants, heavy industry, and waste treatment facilities would be located on the floating platforms, but below water. The spaces above water would be occupied by condominiums, office complexes, shopping centers, theaters, and other buildings for which economics dictates a high population density (a floating platform community would house roughly 10,000 people). Connection between the floating complexes and the land would be accomplished by marine transport systems for goods and passengers. These transport systems would have to be fast, frequent, and stable; they should not terminate at the coastline but penetrate the land mass through its valley streams, rivers, and canals.

Prospects

Although one can envision floating platform communities, the cost of just one complex is prohibitive, even as an experiment. The realization of such societies in the near future is therefore a function of evolution, the pattern of which is already identifiable. Three essential growth paths must exist: the development of large, low-cost-per-unit-volume, super-stable (i.e., with accelerations less than $.01g$) ocean platforms; community acceptance of the location of urban functions in a sea-based environment; and the evolution of rapid, efficient, low-motion, quiet marine mass transportation.

High-speed passenger transit is provided by the Boeing Jetfoil 929 hydrofoil, this one on SeaFlite service in Hawaii. The craft can carry as many as 250 passengers through high seas at almost 45 knots. Such forms of marine transportation will facilitate the evolution of floating platform communities. (Boeing Aerospace Company)

All three of these evolutionary trends are already well advanced. Large ocean platforms are a reality, and their sophistication is increasing rapidly. Although floating platforms face opposition and rejection in the U.S. where public understanding of the ocean is, in my opinion, poor and self-defeating, their acceptance in Europe, Asia, and Japan is demonstrated by the artificial islands of Holland, the ocean-based energy facilities of the North Sea, the Persian Gulf, and the South China Sea, and the floating factory ships of Japan.

The concept of ocean platforms will be strengthened by increased attention, at least in the U.S., to economically and environmentally sound marine mass transportation systems. Though development and survival of the forms of marine transit have been left more to "natural selection" than to informed planning, it is possible to predict where we are headed. For canal, river, and calm water application, almost any craft will do: displacement barge, fixed-foil hydrofoil, air-cushioned vehicle, hydroski; and where change of elevation is involved, even the hovercraft. Fixed-foil craft are in operation on most waterways and canals in the U.S.S.R., on Swiss lakes, in the Straits of Messina, and in the Baltic. When sea state is a factor, the incidence-controlled hydrofoil, now operating on the Hong Kong–Macao run and on Hawaii's inter-island service, will be the surviving mode for high-speed passenger transit (now more than 40 knots in high seas). The concrete-hulled semi-submersible, a derivative of stable platform development utilizing one or more submarine hulls, struts, and a cargo platform above the sea, will be the survivor for roll-on/roll-off light-cargo and passenger service. Several commercial versions are now under construction for use as work boats in the North Sea. Finally, the displacement hull will be the long-term choice for heavy freight and bulk cargoes.

The development of economic and effective forms of marine transportation will open the way for the seaward extension of urban systems and will provide the missing link in the evolution toward the coastal valley/stable platform community—the Neolithic lake model on a twenty-first-century scale. The prospect is not unpleasant and, indeed, suggests solutions for many of the problems of a society facing congestion in its coastal zones.

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FOOD FROM THE SEA, Winter 1975–Fisheries biologists and managers are dealing with the hard realities of dwindling stocks and increasing international competition for what is left. Seven articles explore these problems and point to ways in which harvests can be increased through mariculture, utilization of unconventional species, and other approaches.

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THE SOUTHERN OCEAN, Summer 1975–The first of a regional series (in planning are issues on the Mediterranean and Caribbean) examining important marine areas from the standpoint of oceanographic disciplines most interested in them. Physical, chemical, and biological oceanographers discuss research in antarctic waters, while a geologist looks at the ocean floor, meteorologists explain the effect of antarctic weather on global climate, and a policy expert sets forth the strengths and weaknesses of international scientific and political relations in the area.

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