Deep Seabed Mining

Final Programmatic Environmental Impact Statement

Volume I

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Ocean Minerals and Energy

September 1981

NOTES TO THE READER

This document is by nature quite complex. In an attempt to clarify the text, technical terms are defined in the Glossary (Section V, Appendix 2) and capitalized at first usage in each section. The document also includes an Index (Section VII) of the most important descriptors. A general Table of Contents is included for the entire document and is supplemented by detailed Tables of Contents preceding each section. Conversion factors used in calculating metric and English values are listed on the inside back cover.

No major changes were made in the draft Programmatic Environmental Impact Statement (PEIS) in response to comment letters (Volume 2). However, two policy changes were made during the course of preparing the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b) designed to assess the environmental impacts of deep seabed mining exploration. First, the licensee is now asked to address all site specific concerns, not just short-term, near-field concerns.

Second, NOAA has added a third alternative to license phase issue #1, environmental monitoring. Industry is apprised of what parameters to examine but not how to examine them (page 131). The DOMES methods are described in an appendix to the Technical Guidance Document, but the use of equivalent or better methods is welcomed.

As promised in the draft PEIS (page 100), NOAA's latest thinking on the likelihood of trace metals uptake into zooplankton tissue is discussed. Briefly, preliminary indications are that, because of the relatively low bio-availability of the trace metals associated with the surface discharge, the probability is low for zooplankton accumulating trace metals above natural concentrations. However, if substantial accumulation did occur, any adverse effects would tend to be mitigated by (1) the short time (1-3 days) that particles are available for ingestion, (2) the tendency of the metals not to biomagnify in the food web, and (3) the tendency of the metals to be excreted by normal biological processes. Accordingly, NOAA has reranked this concern from one with the potential for significant adverse impact to one that has low probability of occurrence and that is without potential for significant or adverse impacts. Nevertheless, because NOAA intends to verify the status of all important concerns prior to commercial mining, this concern will be addressed through NOAA research and, if necessary, during mining systems tests as well.

This final PEIS also reflects a thorough editing, including the correction of minor technical errors detected by preparers of the draft PEIS. This assistance is gratefully acknowledged.

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Final Programmatic Environmental Impact Statement
Volume I

Prepared by:
Office of Ocean Minerals and Energy
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September 1981

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Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

Office of Minerals and Energy
James P. Lawless, Acting Director

DESIGNATION: Final Programmatic Environmental Impact Statement (Final PEIS)

TITLE: Proposed Deep Seabed Mining Program

ABSTRACT: This PEIS is prepared pursuant to the Deep Seabed Hard Mineral Resources Act (P.L. 96-283, "The Act") and the National Environmental Policy Act of 1969 (NEPA) to assess the impacts of deep seabed mining for manganese nodules. Exploration by United States citizens will be authorized by license from the National Oceanic and Atmospheric Administration (NOAA) beginning in the next few years, followed by commercial mining under NOAA permit no earlier than 1988 and continuing indefinitely. The area of interest is the Pacific Ocean (about 4,500 m or 15,000 ft deep) in a 13 million km^2 (3.8 million nmi^2) area of the equatorial high seas, roughly between Central America and Hawaii. The PEIS includes the marine and onshore impacts of the mining of nodules from the deep seabed, their transport to onshore, onshore processing, and waste disposal. Four strategic metals (nickel, cobalt, manganese, and copper) will be produced by this new U.S. industry. Mining in other ocean areas, at-sea processing, and mining with techniques other than hydraulic methods are not discussed in depth in this PEIS.

Deep seabed mining will occur in ocean areas beyond the jurisdiction of any nation. Therefore, mining probably will be conducted in cooperation with other nations licensing deep seabed miners through a system of reciprocal state agreements. Authorization may also be granted by an International Seabed Authority should a Law of Sea treaty enter into force for the United States.

Marine impacts occur in the water-column and on the seafloor. In the water column, the major effect with potential for significant adverse impact involves effects on fish larvae. On the seafloor, organisms will be lost during the collection of nodules from the ocean floor. Neither of these impacts is expected to be significant during the exploration phase. The PEIS discusses regulated mining under the Act as NOAA's preferred alternative, with continuing review of environmental impacts through monitoring and environmental research. It also discusses examples of mitigation measures and approaches to conservation of resources likely to arise through commercial recovery.

NOAA will serve as lead agency for environmental review of onshore processing and facilitate other government approvals to the extent practicable and desirable.

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COMMENTS: The draft of this environmental impact statement was filed with EPA on March 20, 1981, and the final by September 18, 1981.

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The National Oceanic and Atmospheric Administration (NOAA) has prepared this programmatic environmental impact statement (PEIS) pursuant to Section 109(c)(2) of the Deep Seabed Hard Mineral Resources Act (The Act) and the National Environmental Policy Act (NEPA) to assess the environmental impacts of exploration for and commercial recovery of manganese nodules from the deep seabed. Exploration and commercial mining will be authorized by NOAA beginning in the next several years and continue indefinitely in the deep waters of the equatorial Pacific Ocean in a 13 million km^2 (3.8 million nmi^2) area between Central America and Hawaii (Figure 1). Manganese nodules will be collected from the surface of the seabed at a depth of approximately 5 km (about 3 nmi), pumped up a pipeline to a ship, and transferred to shore for processing. This PEIS assesses the potential marine and onshore environmental impacts of mining, transportation, and processing of manganese nodules and alternative strategies for managing those impacts.

Headings in this Executive Summary are followed by cross references to other appropriate sections of the PEIS.

- The Deep Seabed Hard Mineral Resources Act (see Section I.B)

Industry and international interest over the past 20 years in developing the technology for and beginning commercial recovery of manganese nodules, including discussions within the context of the negotiations for a Law of the Sea (LOS) Treaty toward establishing an international regime, led to enactment on June 28, 1980, of the Deep Seabed Hard Mineral Resources Act. The Act authorizes NOAA to issue licenses for exploration after July 1, 1981, and permits which authorize commercial recovery to commence no earlier than 1988. The Act is intended: (a) to provide sufficient regulatory certainty to enable continued development of the deep seabed mining industry, and (b) to provide an orderly progression from the current situation of no regulation of deep seabed mining activities to, first, United States regulation of its citizens who conduct deep seabed mining with mutual recognition of miners operating under comparable regimes of other countries and, ultimately, mining under the international regime established in the LOS negotiations if and when an LOS treaty enters into force for the United States.

In principal features, the Act:

(a) authorizes issuance of licenses and permits for exploration and commercial recovery operations by United States citizens, subject to regulations imposed by the Administrator of NOAA and appropriate terms, conditions, and restrictions. Commercial recovery vessels must be documented in the United States and, except in limited circumstances, recovered minerals must be processed at plants located in the United States;

(b) requires promulgation of regulations addressing such issues as protection of the marine environment, conservation of natural resources, and safety of life and property at sea. Regulations pertaining to exploration are in 15 CFR Part 970, Deep Seabed Mining Regulations for Exploration Licenses. A site-specific environmental impact statement must be prepared for each license or permit. A license or permit may not be issued if the activity can reasonably be expected to have a significant adverse affect on the quality of the environment that cannot be avoided or appropriately mitigated or to pose an inordinate threat to life and property at sea. Where significant effects on safety, health, or

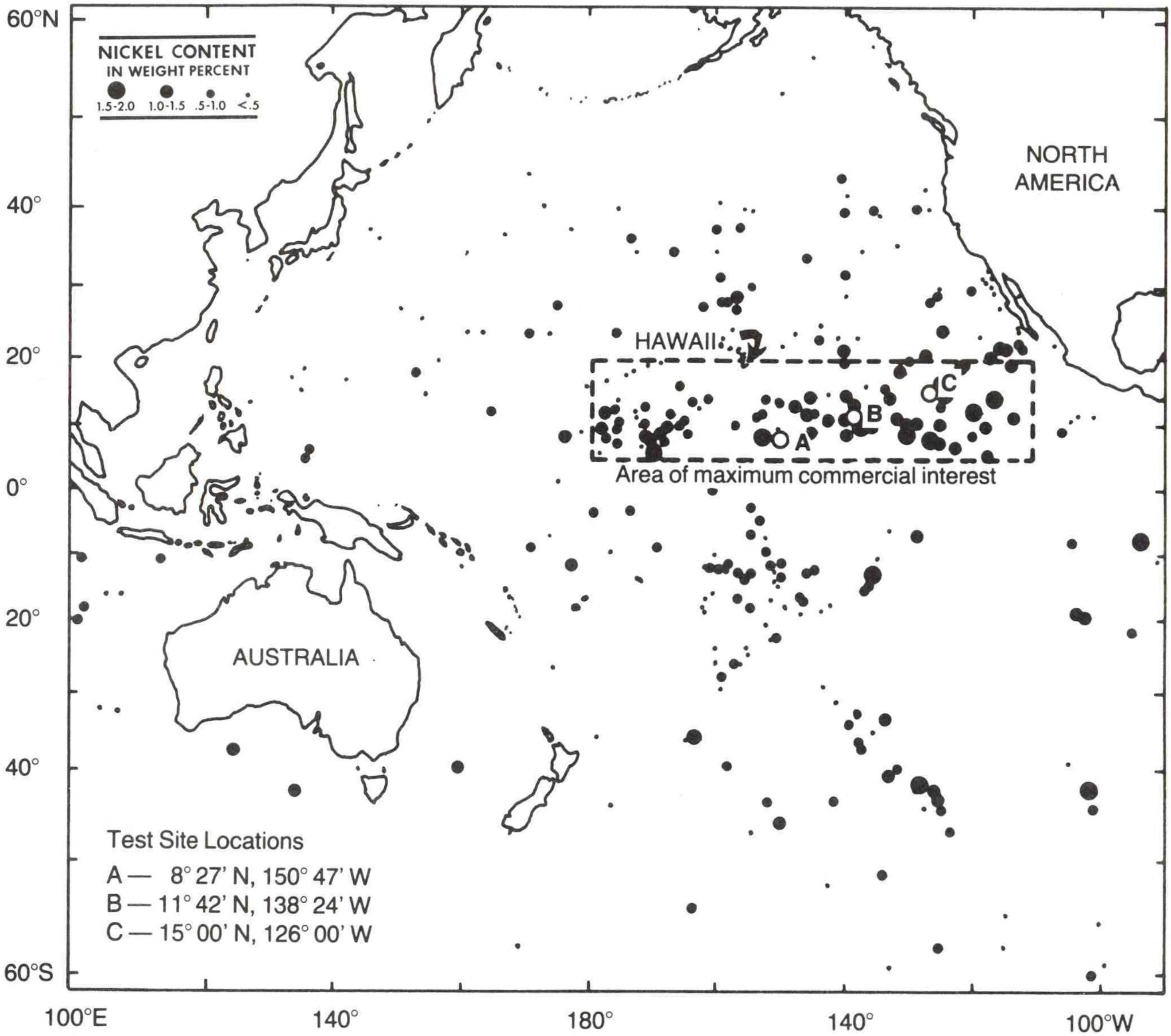

Figure 1.--Area of manganese nodule maximum commercial interest and high nickel concentration in nodules with DOMES test site locations (Horn, Horn, and DeLach, 1972).

the environment would result, NOAA must require use of the best available technologies to mitigate those effects unless the benefits from using the technologies are clearly insufficient to justify their costs;

(c) authorizes the Administrator in appropriate cases to amend regulations and terms, conditions, and restrictions (TCR) in licenses and permits as experience with deep seabed mining is gained, to monitor compliance with the provisions of the Act, and where necessary to apply enforcement sanctions including suspension, revocation, or modification of a license or permit;

(d) directs the Administrator to conduct an accelerated program of ocean research to support environmental assessment activities necessary to determine whether ocean mining activities will have a significant adverse effect on the marine environment. NOAA must prepare a Five-Year Research Plan (National Oceanic & Atmospheric Administration, 1981a) for conducting this research program and must enter into negotiations (which were initiated on June 16, 1981) with other countries to establish stable reference areas to be set aside for environmental and resource assessment purposes; and

(e) encourages conclusion of a comprehensive LOS treaty which assures non-discriminatory access to deep seabed hard mineral resources under conditions as protective of the marine environment as those provided in the Act, empowers the Administrator to designate foreign nations as reciprocating states for the purpose of providing mutual recognition of mining rights if the laws of those nations regulate deep seabed mining in a manner compatible with the Act and its implementing regulations, and establishes a revenue-sharing fund for the purpose of making such payments as may be required by the revenue-sharing provisions of an LOS treaty, if and when one enters into force with respect to the United States.

- <u>The Resource (see Section I.C)</u>

Manganese nodules are fist-sized concretions of manganese and iron minerals that occur on the sea bottom in areas of low sediment deposition around the world. Manganese nodules are rich in four strategic metals -- nickel, cobalt, manganese, and copper. Nickel, currently supplied to the United States chiefly from land-based mines in Canada and New Caledonia, is used mainly in stainless steel and other high-temperature steel alloys. Cobalt, which the United States currently obtains primarily from Zaire, is used in the electrical industry for permanent magnets, and for high-temperature alloys used in aircraft. Manganese, which is supplied to the United States by Brazil, Gabon, South Africa (expected to be our major source in the future), and Australia, is essential to the production of steel. Copper, in which the United States is nearly self-sufficient, is used mainly in electrical equipment. If commercially feasible, nodule mining can provide an increasingly important domestic source for these strategic metals as foreign producers retain more of their domestic output (and therefore export less) in the years ahead. The economic impact of deep seabed mining on present sources of these metals is beyond the scope of this PEIS.

- <u>Scope of the PEIS</u>

The Act requires preparation of a PEIS which assesses the environmental impacts of exploration and commercial recovery in the area of the oceans in which United States citizens are likely first to engage in such activities.

The four international consortia with United States corporations as members have indicated that initial mining will likely occur in a 13 million km^2 (3.8 million nmi^2) east-west belt in the east central Pacific Ocean. This area has been the focus of a cooperative NOAA/industry research effort over the past six years known as the Deep Ocean Mining Environmental Study (DOMES). The DOMES area was chosen because it is the main area in which industry has expressed commercial interest. This PEIS thus focuses on the environmental impacts of deep seabed mining in the DOMES area, relying primarily on research results from the DOMES and related efforts. The DOMES area is about 8% of the Pacific Ocean.

Because technology and associated environmental concerns may change in the future, this PEIS addresses only first generation mining. For purposes of analysis, this document assumes that: (a) during exploration, five ships will test at about two months each; (b) during commercial recovery, five consortia will phase into full production by 1994 (Appendix 5), processing a total of about 11 million MT (12.1 million tons) of nodules annually.

Based on an analysis of metal supply and demand, NOAA speculates that the Pacific belt nodule mining industry could evolve through three generations between 1988 and about 2040. The first generation through about 1995 will likely involve the initial consortia (the four with United States participation and possibly a fifth French group) mining nodules at a rate determined by the world demand for nickel. Second generation mining, from 1995 to 2005 or 2010, could involve an additional five to 10 consortia, perhaps associated with large processing plants that service two to three mine sites. Third generation mining, until about 2030 or 2040 depending on the resource size and rate of exploitation, would level off at about 25 to 30 operational sites and 10 to 20 processing plants worldwide.

This PEIS is comprehensive and is intended to limit the scope of information required in site-specific statements. Site-specific EISs serve the purpose of providing new information or updating parts of the PEIS. Activities covered include those anticipated pursuant to reciprocating states arrangements. Should new technology be developed, operations outside the DOMES area be undertaken, or at-sea processing of nodules be initiated, a supplement to this PEIS or a new PEIS may be prepared. Federal action concerning other ocean minerals, such as metalliferous sulfides and placers, is outside the scope of the Act and this PEIS.

- <u>Technical Guidance Document</u>

NOAA prepared a Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b) to assist in assessing the environmental aspects of deep seabed mining exploration activities. It is designed to serve as a companion document to the regulations and this PEIS. The document is addressed primarily to the environmental specialists in the mining consortia who will be compiling information to submit to NOAA at the time of request for an exploration license, and later. The information will be used by NOAA mainly to prepare a site-specific EIS on each license to develop TCR for each applicant, and to monitor exploration activities.

- Marine Impacts (see Section II)

The DOMES region is characterized by relatively frequent tropical storms, fluctuating tradewinds (northeast and southeast trades), a north-to-south series of counter-flowing water currents (westward-flowing North Equatorial Current, eastward-flowing North Equatorial Countercurrent, and the westward-flowing South Equatorial Current), and deep (about 5,000 m or 16,500 ft average) waters of stable temperature and salinity. Suspended particulate concentrations are quite low but typical of the open ocean, with a peak of about 30 to 40 ug/l (see page 208 for definition) in the summer and about double that in the winter in the upper water columm; particulate concentrations in the lower water column are progressively lower until just above the bottom where a slight increase in particulate matter signals the presence of a weak nepheloid layer, a water boundary zone occurring between water masses of differing densities.

Species populations within the DOMES area are often composed of relatively fewer individuals than shoreward marine environments but diversity is very high. Many species, such as the bottom-dwelling sea worms and isopods, may be found in significant numbers; some commercially-harvested species such as the tunas and billfish also occur in relatively high numbers compared to other oceanic regions. Although only one threatened or endangered species of marine mammal or turtle has been observed in the DOMES area, sixteen species are thought to migrate through the DOMES area or reside, breed, or feed in transportation corridors. Marine bird populations may also occur along those corridors near island and mainland coasts.

The geology of the DOMES area is typical of the abyssal Pacific Ocean. The DOMES area is part of both the central and eastern North Pacific Basins, a zone composed of rolling abyssal hills, several long fracture lines, and occasional island and seamount upheavals. Seismic activity is low throughout the DOMES area but higher along the west coast of the Americas and in the Hawaiian archipelago where some transportation corridors may terminate. The seafloor is dominated by soft sediments overlain with occasional rock out-croppings and manganese nodules of varying size, shape, and concentration.

Because the DOMES area is relatively isolated from shore and population centers (except Hawaii), human activities near the mine sites can be typified as occasional, mobile, and non-intensive. Four major activities have been identified in the DOMES area: commercial fishing (tuna, billfish); marine transportation; oceanographic research; and naval operations. Fishing activities include Japanese and United States vessels, the latter with the Hawaiian Islands as a home port. Transportation through the DOMES area includes major domestic and foreign routes across the Pacific, many of which stop in the Hawaiian Islands. Research trips, which have been occurring at rates of perhaps five to 10 per year by those mining consortia which include groups from the United States, will probably expand over the coming years as mining operations expand. The number of foreign trips is unknown but includes research ventures from Japan, France, Russia, and perhaps others. Naval operations such as submarine maneuvers or convoys have not been quantified although they probably occur during transit or as more long-term projects. All naval operations are accompanied by a public Notice to Mariners from the Defense Mapping Agency.

The principal potential marine impacts on the environment are those associated with mining activities, offshore processing, and transportation to port.

1) Mining (see Section II and Appendix 3)

Nodules will be recovered from the deep seabed by means of a collector up to 20 m (66 ft) wide which is pulled or driven along the seabed at about 3.6 km (2 nmi) per hour. Collector action will result in adverse environmental impacts through direct disturbance of benthic biota and through creation of a benthic sediment plume which will affect biota beyond direct contact. In addition, when the nodules are received in the mining ships, the remaining residue consisting of bottom water, sediments, and nodule fragments will be discharged over the side of the ship; the resulting surface discharge plume also has the potential for adverse impact.

The first two important impacts arise from activities at the seabed. Collector action and the consequent heavy sediment disturbance next to the collector track will probably destroy benthic biota, an impact which appears to be both adverse and unavoidable (see Section II.C.2.1). The effect of this disturbance will depend upon the kinds of equipment used and intensity of mining. The affected biota (see Section II.A.1.2.2) include animals such as sea stars, brittle stars, sea urchins, sea cucumbers, polychaete worms, and sea anemones. None are mammals, amphibians or other higher forms of life. NOAA is not aware of any benthic endangered species in the area that may be affected by bottom disturbance. Most benthic animals, based on counts of individual organisms, are minute detritus feeders that live in the upper centimeter of sediment and receive their food from the rain of organic detritus that descends from the upper waters. Their ecological function is to break down the organic matter in the sediment and thus recycle basic nutrients back into the ecosystem. The most comparable land equivalents of these marine organisms are the snails, insects, and worms that inhabit the leaf litter in a forest ecosystem. A worst case estimate is that the benthic biota in about one percent (130,000 km^2 or 38,000 nmi^2) of the DOMES area may be killed due to impacts from first generation mining activities. Although recolonization is likely to occur following mining, we do not yet know at what rate. No effect on the water column food chain is expected. It is unlikely that any mitigation measures will be available to reduce this unavoidable adverse impact. We are unable at this time, however, to conclude that this impact is significant.

Another important type of impact is due to a "rain of fines" away from the collector which may affect the smaller seabed bottom animals beyond direct collector contact through smothering and interference with bottom feeding (see Section II.C.2.2). This plume can extend tens of kilometers from the collector and last several weeks after mining ceases. The increase in nutrients, increased oxygen demand, and additional food supply for scavengers from this activity appear not to have the potential for significant impact (see Section II.C.1.2.2). Nor is any effect on the water column food chain expected. However, interference with the food supply for the bottom-feeding animals listed above and clogging the respiratory surfaces of filter feeding benthic biota may have the potential for significant adverse impacts involving the biota in an estimated additional 0.5 percent (65,000 km^2 or 19,000 nmi^2) of the DOMES area.

With respect to near surface related disturbance, it is estimated that a 5,000 MT (5,500 tons) per day mining ship will discharge roughly 2,000 MT (2,200 tons) of solids (mainly seafloor sediment), and 25,000 m^3 (2.96 million ft^3) of water per day (see Section II.B.1.1). The resulting surface discharge plume may extend about 38 to 54 nmi (70 to 100 km), and will be detectable for three to four days following discharge.

One other impact resulting from the surface plume is potentially significant. Surface plumes may adversely affect the larvae of those fish, such as tuna, which spawn in the open ocean (see Section II.C.2.3). While the likelihood of significant impacts during exploratory mining appears remote, the potential for significant impact during commercial recovery is uncertain at this time.

The three potential environmental impacts noted above will be addressed in the next few years, as described in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a). The highlights of the planned research and examples of mitigation strategies are outlined on Table 1.

A number of the effects of the surface plume have low potential for significant impact (see Section II.C.1.2.2), including:

- interference with shipping, research, and naval operations;
- harm to migrating fish or endangered species;
- oxygen depletion in surface waters due to bacterial growth;
- alteration of phytoplankton species composition;
- increased zooplankton mortality;
- phytoplankton blooms due to increased nutrient levels; and
- inhibition of primary productivity due to trace metal uptake by phytoplankton.

Because the determination of environmental significance in this PEIS is based on brief periods of pilot-scale mining, NOAA intends to verify or update the conclusions in this PEIS by requiring monitoring of the demonstration scale mining tests to be conducted by industry during the license phase.

2) Offshore Processing (see Section II.B.1.3 and Appendix 3)

Offshore processing would mean refining nodules and disposing of wastes at sea rather than on land. The potential impacts of such activities are not yet known and will be addressed in NOAA's Five-Year Research Program (National Oceanic and Atmospheric Administration, 1981a). Primarily because of limitations imposed by ship motion, metallurgical processing at sea is currently impracticable. Processing offshore is therefore not expected to occur during first generation mining. Should offshore processing become probable, a supplement to this PEIS may be prepared.

3) Offshore Waste Disposal (see Section II.B.1.4 and Appendix 3)

Waste disposal is likely to take place onshore. However, a second method of disposal that industry may consider is ocean dumping or discharge through an ocean outfall. The former requires a permit under the Marine Protection, Research, and Sanctuaries Act and the latter a permit under the Clean Water Act; since the characteristics of nodule processing waste are unknown, the likelihood of receiving the necessary permit approval and the probable impacts of ocean disposal are uncertain.

4) Transportation (see Section II.B.2 and II.C.1.1 and Appendix 3)

The principal transportation-related effects of deep seabed mining are those associated with transfer of nodules from the mining ship to ore carriers (see Section II.B.1.2) and transport to port (see Section II.B.2). Nodules

POTENTIAL BIOLOGICAL IMPACTS	POTENTIAL SIGNIFICANCE*	EXAMPLES OF POSSIBLE MITIGATION STRATEGIES	SUPPORTING RESEARCH
FISH LARVAE FEEDING BEHAVIOR MODIFICATION	UNCERTAIN (Very low probability of occurrence)	PREMATURE	• DETERMINE OCCURRENCE • DETERMINE POTENTIAL YEAR CLASS EFFECT
DESTRUCTION OF BENTHIC BIOTA IN COLLECTOR TRACK	UNAVOIDABLE	PREMATURE	• EVALUATE EFFECT ON BENTHIC COMMUNITY
SMOTHERING AND STARVATION OF BENTHOS	UNKNOWN	VARYING MINING PATTERN REGULATE DISPERSION OF BENTHIC PLUME ("RAIN OF FINES")	• MONITOR RECOLONIZATION FOLLOWING DISTURBANCE • IDENTIFY FACTORS IMPORTANT IN RECOLONIZATION • EVALUATE EFFECTIVENESS OF VARIOUS MINING STRATEGIES IN MINIMIZING IMPACT • DEVELOP CAPABILITY FOR LONG-TERM MONITORING OF SUSPENDED PARTICULATE MATTER CONCENTRATIONS AT MINE SITE BOUNDARIES

TABLE 1. POTENTIAL BIOLOGICAL IMPACTS AND SUPPORTING RESEARCH TO EVALUATE POSSIBLE MITIGATION STRATEGIES

*Uncertain is used when prediction is based on some knowledge, although insufficient. Unknown is used when prediction is primarily conjecture, being based on very minimal knowledge. (National Oceanic and Atmospheric Administration, 1981a) are likely to be pumped to ore carriers in a seawater slurry; discharges of seawater and accidental discharges of nodules are possible. Seawater discharges from nodule transfer are unlikely to add significantly to discharges associated with nodule recovery. In the unlikely event of a nodule "spill", significant impacts are unlikely since the nodules appear to be inert in their natural form.

Nodules will be transported to shore by ships subject to regulation by the U.S. Coast Guard (see Appendix 3). An average of one nodule transportation ship per day is expected to travel in and out of the DOMES area during first generation mining. This level of vessel traffic is not expected to cause any significant impacts on shipping, fishing, research, or naval activities. The potential for significant impact on sea turtles or migrating mammals appears equally small (see Section II.C.1.1.2); however, this issue will be addressed in site-specific environmental statements.

5) Summary and Implications at Exploration Phase

NOAA anticipates that exploratory mining activities will have little or no potential for significant adverse impact; the impact area can probably be constrained to less than 0.01 percent of the DOMES area due to the relatively brief duration of the mining tests. Industry will monitor in conformance with NOAA TCR and NOAA will review the actual impacts of mining exploration to determine whether the effects predicted in this statement are exceeded (see Section II.C.4). NOAA will give special attention during mining system testing to the effects of the benthic plume and the impact of differing patterns of mining and shape of the mine test site.

At the commercial recovery stage, collector contact, benthic plume, and harm to fish larvae are potentially significant adverse impacts. Therefore, NOAA has begun to undertake research to determine their significance and the need for appropriate mitigating measures.

NOAA intends that applicants for licenses or permits provide information in tandem with the development of the mine site (see Section II.C.3): license phase pre-testing activities; license phase testing; and permit activities. NOAA environmental documents on specific sites will rely on the assessments and findings in this PEIS, coupled with environmental data on the proposed site.

- Alternatives for Managing Nodule Recovery

Alternative approaches to managing the at-sea recovery of manganese nodules that have been considered are of two fundamental types -- approaches other than that established by the Act (and therefore requiring legislation) and alternative approaches for implementing the Act.

1) Alternatives Under the Act (see Section II.D.1)

Before issuing a license or permit, NOAA must determine, among other things, that the proposed activities cannot reasonably be expected to result in a significant adverse impact on the quality of the environment. NOAA must impose terms, conditions, and restrictions (TCR) on licenses and permits, including those necessary to assure conservation of natural resources, protection of the environment, and safety of life and property at sea. Within this framework, nine issues with potential environmental consequences must be resolved, three at the exploratory phase and six at the commercial recovery stage.

With respect to exploration licenses, NOAA must decide: (a) to what extent it should dictate the monitoring which must be undertaken by industry; (b) whether and how mine sites should be spaced; and,(c) what criteria, if any, to apply to selection of stable reference areas. In order to assure that monitoring results are compatible with the studies on which this PEIS is based and adequate to test the impact predictions contained herein, NOAA's Technical Guidance Document (National Oceanic & Atmospheric Administration, 1981b) defines the parameters of concern during license phase mining system tests (see Section II.C.3). This guidance will be the basis for TCR on monitoring. NOAA would take a generally laissez-faire approach to site spacing, but would review applications to ensure that alternatives at the permit phase are not precluded. NOAA has initiated consultations with reciprocating states to identify the criteria to be used in selecting stable reference areas.

At the permit stage, two environmental, three resource conservation, and one international issue must be resolved. With respect to the first environmental issue, the level of detail of information required in permit applications, NOAA proposes to require detailed design and operating information on selected components of the mine system as well as the proposed monitoring program to determine whether the system is likely to operate in the fashion described in this PEIS and to assure that the monitoring strategy is appropriate to the system being proposed. If future research suggests such mitigation, in order to minimize potential barriers to recolonization posed by a long swath of mined-out areas, NOAA would require that mine sites be spaced so as to avoid a linear alignment which could block recolonization or require provisions for "bridges" at a spacing to be estimated based on research results.

Resource conservation issues include whether to: (a) require pattern mining; (b) permit mining of the richest zones of a mine site first; and (c) require retention of manganese tailings by first generation miners who engage in three-metal operations. These issues each require a trade-off between the desire to allow market forces and economic efficiency to determine the rate, pattern, and method of mining and the risk that such an approach will lead to waste of resources because of the unusual environmental conditions and aggravated environmental harm due to the need to expand the areas mined. On these issues, NOAA would: (a) defer a decision on whether to require pattern mining of the site until demonstration scale mining tests are observed; (b) allow selective-mining, i.e., mining of richest areas first but only if conducted in accordance with a long-term plan for mining "leaner" zones as well; and (c) undertake a study in concert with the General Services Administration and the Federal Emergency Management Agency of the feasibility and desirability of stockpiling manganese tailings as part of the National Defense Stockpile. This study will be coordinated with the joint NOAA/Bureau of Mines research into the character of the manganese-bearing rejects as well as a planned U.S. Bureau of Mines research project to develop techniques to recover manganese in useable form from the nodule processing tailings.

The international issue involves the development of criteria to use in designating reciprocating states. NOAA would establish specific criteria for designating reciprocating states, including continuing consultations on environmental issues and research.

2) Alternatives to the Act (see Section II.D.2)

Alternatives to the Act include unregulated mining, prohibition of deep seabed mining by United States citizens, and delay of deep seabed mining activities until either a LOS treaty enters into force for the United States or the environmental implications of deep seabed mining are better understood. Each of these alternatives has been found by NOAA and industry to be less desirable than regulated mining under the Act.

Unregulated mining would provide maximum flexibility for industry; each miner would be free to take what resources it could recover. However, mining claims would have no legal status (and therefore no protection), and no means to resolve conflicts (foreign or domestic) would exist. This alternative is not preferred by industry since security of claims is essential to assure the financial investment necessary for continued development of the industry. Unregulated mining could also have serious adverse environmental impacts since no environmental controls would be imposed and any adverse impacts would likely be beyond the authority of any government to control. Also we would have no legal status with respect to a new deep seabed mining international regime.

Prohibition of deep seabed mining would have equally adverse impacts. Such a prohibition would delay initiation of domestic activities and give other mining nations an advantage in the market place. To the extent such a prohibition precluded or significantly delayed deep seabed mining activities, increased reliance on land-based mining would result. Delay in initiating deep seabed mining until, say 2010, would result in the mining of roughly 18,400 ha (46,000 a) of land and the emission of as much as 30 million MT (33 million tons) more of sulfur dioxide into the atmosphere. Finally, prohibiting United States mining activities would result in continued reliance on foreign sources of these strategic metals with potentially serious effects on cost and availability of the resources and on national security. This alternative is thus undesirable for environmental, economic, and national security reasons.

The alternative of delaying implementation of the Act would result in similar impacts without compensating benefits. Other nations are likely to proceed with mining activities in the interim period before a LOS treaty enters into force. The reciprocating states provisions of the Act provide a mechanism for assuring that the activities of the other mining nations proceed under environmental controls that are compatible with those of the U.S.; failure to participate in reciprocating state arrangements could result in environmentally more harmful mining activities. Similarly, environmental standards adopted by the major seabed mining nations as a result of reciprocating state arrangements would likely serve as a model for the international rules and regulations to be drafted by the Preparatory Commission for a LOS Treaty; less stringent environmental provisions could otherwise result.

Finally, delay of mining activities would preclude acquisition of information that would enable understanding of the environmental effects of deep seabed mining. Most concerns appear to have a low probability of occurrence. To examine the nature and significance of long-term effects will require the monitoring of demonstration scale mining tests during exploration. A research and monitoring program will be established while the industry is in the testing and exploration phase. This program is intended to ensure the early detection of any significant adverse environmental impacts. This research and monitoring process will be well underway prior to granting commercial recovery permits and well within the time frame necessary to establish or to modify appropriate terms, conditions, and restrictions. Since tests during exploration are necessary to achieve greater understanding of environmental impacts, a delay of deep seabed mining would be counterproductive.

For all of these reasons, implementation of the Act is NOAA's preferred alternative and the environmentally preferable alternative.

- Impacts of Onshore Facilities (see Section III and Appendix 3)

As indicated above, first generation processing of nodules will almost certainly take place onshore. Since commercial scale nodule processing has yet to be demonstrated, however, neither the specific sites where manganese nodule processing facilities might be located nor the specific technologies which will be used for nodule processing can be identified. Sites as biophysically and economically diverse as Valdez, San Francisco, Brownsville, Tampa, and the island of Hawaii may be considered. The environmental, socio-economic, and cultural impacts of onshore facilities will vary dramatically depending on their location and the choice of processing technology; a detailed assessment of onshore impacts thus must await site-specific environmental statements. Nevertheless, certain generic impacts of onshore activities can be described.

Four major activities associated with onshore processing have the potential for significant impact: (1) use of port facilities; (2) transportation of nodules from port to processing plant; (3) processing of the nodules; and (4) waste disposal. Each of these activities will have construction and operational effects.

The consequences of terminal facilities would be those normally associated with expanding commercial ports. Development is expected to take place in an existing port because a deep seabed mining project would not itself support development of a new port. Dredging and filling are likely to be involved in construction. Ship exhaust emissions, water use, and for some unloading and storage methods, dust, are the most likely effects of the port operations. A new facility will have to be consistent with approved State coastal management programs and with other land-use programs.

Port to plant transportation will likely be done in a pipeline, either above ground or buried. Once pipeline construction effects end, the pipeline should be unobtrusive. Alternatives to the pipeline are enclosed conveyors, trucks and rail transportation. Each of these modes would have different impacts during construction and operations.

Operationally, the nodule processing plant will be similar to a plant designed to process ores mined on land. In physical size and appearance, it will resemble a relatively small refinery except that there will probably be a storage area for coal instead of oil storage tanks and it will be served by a rail line to bring coal in and move the products out. On-site nodule storage would probably be in either slurry ponds or specially-designed enclosures. The impacts of siting the facility will likely be similar to those from siting any other large industrial facility. Construction phase impacts as well as operations impacts are identified in Section III. The impact of plant operations will depend in part on whether the plant is designed to produce cobalt, nickel, and copper (three-metal) or to produce manganese in addition (four-metal). The principal impacts are those associated with water use, high demand for electrical energy, use and possible discharge of toxic or hazardous chemicals, and air pollution associated with coal combustion. Socio-economic impacts also are discussed in Section III.

Waste disposal presents the greatest environmental concern because of the unknown chemical and physical nature of the wastes and the high volume of waste material. NOAA, the Environmental Protection Agency (EPA), the Fish and Wildlife Service, and the Bureau of Mines have initiated research to characterize the waste materials that will result from the various processing techniques under development, with particular emphasis on identifying any toxic or hazardous components. The volume of waste generated will depend on whether three-metal (3 to 4 million MT or 3.3 to 4.4 million tons of solid waste per year) or four-metal (0.5 to 0.75 million MT or 0.55 to 0.82 million tons per year) processing is involved. Land consumption, contamination of surface and ground waters from runoff and seepage, and dust are the principal environmental concerns associated with onshore waste disposal. Tailings ponds, if chosen as a disposal method, would require sites up to 800 ha (2,000 a) in size for 20 years of operation of a 3 million MT (3.3 million ton) per year three-metal plant; again, both site and waste characteristics will determine the likely impacts.

- <u>Alternatives for Managing Onshore Activities (Section III.C)</u>

Each of the onshore activities described above is subject to the variety of Federal, State and local requirements applicable to siting, construction, and operation on other major industrial facilities, including those imposed by State coastal management programs, local land use laws, and Federal, State, and local laws pertaining to air, water, noise, and solid waste pollution, protection of endangered or threatened species, wetlands and floodplain management, historic and archaeological preservation, wilderness and wild river protection, and prime and unique farmland preservation. Adequate protection of the onshore environment thus appears likely with or without NOAA participation in the onshore permitting process. The issue is whether NOAA involvement is desirable to further the underlying purpose of the Act to promote the availability of deep seabed mineral resources.

Three options for NOAA's involvement exist. The first alternative would provide only for general NOAA review of onshore processing technology and potential environmental impacts; NOAA would play no role in siting and permitting of onshore operations. This alternative represents the least administrative effort for NOAA consistent with the Act but may violate NEPA requirements. Under the second alternative, NOAA would act as lead agency for review of environmental impacts, including preparation of a comprehensive environmental impact statement for each onshore facility, and would work informally with other Federal agencies, State and local governments, and the private sector to facilitate permit decisions. This alternative would be similar to the role the Department of the Interior plays in implementing the outer continental shelf oil and gas leasing program and the Consolidated Application Review in NOAA's Ocean Thermal Energy Conversion (OTEC) program. The third alternative would designate NOAA as responsible for permitting decisions. This alternative would involve NOAA in activities beyond its expertise, and could involve unnecessary Federal intervention into State and local activity. Implementation of this alternative would require amendment of the Act.

NOAA proposes to adopt the second alternative. The first alternative may be legally insufficient, and may in addition fall short of implementing the Congressional intent that NOAA play an active role in facilitating development of the deep seabed mining industry. The third alternative, on the other hand, would be difficult to implement and may be undesirable given the balance of authority in our Federal system of government. The second alternative would assure an effective NOAA role in encouraging deep seabed mining and preserve the flexibility to modify NOAA's involvement as deep seabed mining activities proceed.

I INTRODUCTION

1.A Purpose and Need for Action

The National Oceanic and Atmospheric Administration (NOAA), in consultation with the U.S. Environmental Protection Agency (EPA) and with assistance from other appropriate Federal agencies, pursuant to Section 109(c)(2) of the "Deep Seabed Hard Mineral Resources Act" (the Act) and 102(2) of the National Environmental Policy Act, has prepared this final programmatic environmental impact statement (PEIS). This PEIS assesses the environmental impacts of licensed exploration for and permitted commercial recovery of manganese nodules with respect to the area of the eastern equatorial Pacific Ocean where domestic exploration and commercial activity will likely first occur under the authority of the Act.

The purpose of and needs for this PEIS are fourfold:

1) to describe the Act and its ramifications in this developing industry;

2) to describe the area in the Pacific Ocean where initial, i.e., first generation, mining is anticipated to occur;

3) to assess environmental impacts from exploration and first generation commercial recovery, as authorized by NOAA regulations, including alternative approaches to exercising regulatory authority and programmatic approaches to mitigation and monitoring that are implemented in the regulations and the Technical Guidance Document; and,

4) to help form the basis for reciprocating states agreements (RSA's) between the United States and other nations beginning seabed mining.

These features have several implications. Foremost, the PEIS covers only first generation mining, that is, the industry as it initially develops on a commercial scale during the late-1980's and 1990's. Any future development in technology, mine area, or other key facets of the industry will be covered in a supplement to this PEIS or a new PEIS. Second, this PEIS emphasizes mitigation measures and issues germane to the exploration or license phase of seabed mining.

New information from exploration and research will allow NOAA to update this PEIS at a later date prior to the January 1, 1988 date when commercial mining is authorized by the Act to begin.

I.B The Deep Seabed Hard Mineral Resources Act

The Act establishes a program to encourage and maintain consortia interests in exploration and continued progression toward commercial production capabilities. The Act is transitional in nature, providing an orderly progression from the present situation of no regulation of deep seabed mining to domestic regulation of United States citizens who conduct seabed mining, mutual recognition of miners operating under other nations' comparable domestic regimes, and eventually to a new international system if and when a Law of the Sea (LOS) Treaty enters into force for the United States.

The Act contains the following six principal features:

(1) establishes a system of resource management, environmental protection, and safety regulation for deep seabed mining by United States citizens. This program does not assert sovereignty or sovereign rights of the United States over any area of the deep seabed, but is based upon the principle of reasonable exercise of freedom of the high seas. The Act creates a program for the licensing of exploration and permitting of commercial recovery operations by United States citizens subject to the regulations imposed by the Administrator of NOAA and other applicable law.

(2) requires the Administrator to establish regulations to address specified issues related to seabed mining, including protection of the marine environment, conservation of natural resources, and preservation of safety of

life and property at sea. Licenses and permits are exclusive with respect to the area for which they are issued, and are to be issued subject to terms, conditions, and restrictions necessary to accomplish the purposes of the Act.

(3) provides the Administrator with authority to amend, under certain circumstances, regulations and terms, conditions and restrictions in licenses and permits as experience with deep seabed mining is gained.

(4) mandates the Administrator to monitor seabed mining activities and to enforce the Act, the regulations issued pursuant thereto, and the terms, conditions and restrictions imposed on any license or permit. Enforcement powers, in addition to civil and criminal penalties, include suspension and revocation of a license or a permit, or suspension or modification of particular activities authorized by a license or permit, or forfeiture of the vessel involved in a violation.

(5) empowers the Administrator to designate any foreign nation as a reciprocating state for the purpose of mutual recognition of mining rights if the nation's domestic regime for authorizing seabed mining is compatible with that of the United States under the Act.

(6) establishes a revenue sharing fund to be distributed to the international community in the event that a LOS Treaty governing deep seabed mining enters into force for the United States.

I.C The Resource

Manganese nodules are fist-sized concretions of manganese and iron minerals that occur on the bottoms of many oceans and lakes in areas of low sediment deposition around the world. Although nodules are widespread, their density of occurrence and their metallic composition are highly variable.

One of the most economically promising areas is an east-west belt in the east central Pacific Ocean (Figure 1). This approximately 13 million km^2 (3.8 million nmi^2) area has been the subject of the Deep Ocean Mining Environmental Study (DOMES) which forms the basis of many of the scientific findings presented in this PEIS. It includes the area commonly known as the Clarion-Clipperton Zone.

The manganese nodule mining industry has selected the DOMES area for initial mining for two main reasons. First, the DOMES area has been calculated by Frazer (1978) to contain about 3.6 to 13.5 billion MT (4 to 15 billion tons) dry weight of nodules, a higher concentration of nodules than other surveyed areas. That estimate, coupled with the average percentages by dry weight of primary nodule metals (1.25 percent nickel, 1.03 percent copper, 0.23 percent cobalt, 25.2 percent manganese), indicates the quantity and value of the resource in the area. With the exception of copper, of which the United States is the world's largest producer, the United States is heavily dependent on foreign sources for these primary metals. In 1978, the percentages of domestic consumption of these metals satisfied by imports (either in 1978 or earlier, and then recycled) was 100.0 percent for cobalt, 97.6 percent for manganese, 95.9 percent for nickel, and 24.7 percent for copper (Lane, 1979). Each of these four primary metals is crucial to domestic industrial production, especially steel and electrical industries and products requiring high temperature alloys. Second, nodules in the DOMES area have comparatively high concentrations of nickel. Antrim et al. (1979) concluded that because cobalt and manganese are imported from potentially unreliable sources, they could become of strategic concern to the U.S. by the year 2000. Together, those three metals form a valuable resource of crucial importance to the United States.

Since industry is particularly interested in the DOMES area for initial mining operations, this PEIS covers only the DOMES area. If and when interest rises for other areas, either a supplement to this PEIS or a new PEIS will be issued in accordance with Section 109(c)(a) of the Act.

The manganese nodule mining industry has been evolving since the early 1960's. Much early Federal effort was directed at describing the DOMES area environment and identifying possible locations for and impacts of onshore facilities (see, e.g., Roels et al. 1973; Dames & Moore, EIC Corporation, 1977; Dames & Moore et al. 1977; Ozturgut et al. 1978; Burns et al. 1980; Ozturgut et al. 1980). Marine research has been orchestrated by NOAA with industry in two phases--DOMES I completed in November 1976 and DOMES II completed in early 1979. Other onshore studies have investigated process plant location criteria (Oregon State University, 1978; Bragg, 1979; Hawaii Department of Planning and Economic Development, 1980) and the legal requirements affecting process plant location and operation (Nossaman et al. 1980). This PEIS will utilize the expanding data base to discuss the potential environmental impacts of deep seabed mining, particularly marine aspects that are within direct authority of the Administrator of NOAA.

The mining industry includes four international consortia with U.S. members (Table 2) which are currently testing engineering systems and collecting exploration and environmental data. Exploration and research will continue under a license from NOAA; beginning January 1, 1988, commercial recovery may commence with a permit from NOAA and in compliance with other applicable laws and regulations.

Based on an analysis of metal supply and demand, NOAA projects that the DOMES area manganese nodule mining industry will evolve through three

Table 2. Deep seabed mining consortia involving United States firms including dates of consortia formation.

Nation	Kennecott Corp. (1/74)	Ocean Mining Associates (OMA) (11/74)	Ocean Management Inc. (OMI) (5/75)	Ocean Minerals Company (OMCO) (11/74)
United States	Kennecott Corp. Noranda Exploration, Inc.	Deepsea Ventures, Inc. (Tenneco and *) *Essex Minerals Co. (U.S. Steel) *Sun Ocean Ventures, Inc. (Sun Oil)	Sedco, Inc.	Ocean Minerals Inc. (Lockheed Missiles & Space Co.; Billiton**; BRW***) AMOCO Ocean Minerals Co., (Standard Oil Co. of Indiana) Lockheed Systems Co., Inc. (Lockheed Corp.)
Belgium		*Union Seas, Inc. (Union Miniere)		
Canada			INCO, Ltd.	
Italy		*Samin Ocean Inc. (Subsidiary of Italian Govt.)		
Japan	Mitsubishi Corp.		Deep Ocean Mining Co., Ltd.	
Netherlands				**Billiton B.V. (Royal Dutch Shell) ***BRW Ocean Minerals (Royal Bas Kalis Westminister Group N.V.)
United Kingdom	R.T.Z. Deep Sea Mining Enterprises, Ltd. Consolidated Gold Fields, Ltd. BP Petroleum Dev., Ltd.			
West Germany			AMR	

NOTE: Asterisks show relationship of subsidiaries to their parent companies.

generations between 1988 and about 2040. [Development of additional mining areas or innovative technologies could change these projections.] The first generation (discussed in detail in Appendices 5 and 6) from 1988 until about 1995 could involve the initial consortia (four with United States' involvement and perhaps a French group called Association Francaise pour L'Etude et la Recherche des Nodules (AFERNOD)) mining nodules at rates in harmony with world demand for nickel, the primary nodule metal in terms of economic interest. Second generation mining, from 1995 to 2005 or 2010, could involve an additional five to 10 mining consortia, some associated with large processing plants that service two or three mine sites. Third generation growth could be maintained until 2030 or 2040 depending on the exact size of the nodule resource in the area and the rate of exploitation. During this period, the mature industry could level off at about 25 to 30 operational sites at one time and 10 to 20 processing plants worldwide. This PEIS addresses only exploration activities and first generation mining since technology and associated environmental concerns could change prior to second generation mining.

I.D Major Federal Actions

Major Federal actions covered by the Act include:

I.D.1 Designation of Reciprocating States

To encourage compatibility with and mutual recognition among the legal regimes established by foreign states, the Act provides specific authority for the United States to designate foreign states as "reciprocating states." Under the Act, such reciprocating states: (1) regulate the conduct of their citizens in deep seabed mining in a manner compatible with the Act and implementing regulations; (2) recognize licenses and permits issued by the U.S.

under the Act; (3) recognize priorities of right for applications for licenses or permits in a manner consistent with the Act; and (4) provide an interim legal framework for exploration and commercial recovery which does not unreasonably interfere with the interests of other nations in their exercise of the freedoms of the high seas. Negotiations between the United States and possible reciprocating states have been initiated to help coordinate various national laws. This PEIS covers the environmental impacts of designation of reciprocating states by the Administrator in Section II.D.1.1.

I.D.2 Regulatory Framework

A major objective of the Act is to establish a program to regulate the exploration for and commercial recovery of manganese nodules by United States citizens. This PEIS covers the adoption of regulations called for by the Act. NOAA's regulations governing the exploration stage are in 15 CFR Part 970, Deep Seabed Mining Regulations for Exploration Licenses.

This purpose is the major focus of this PEIS, namely to establish an interim program (pending LOS Treaty agreement and ratification) which will, among other objectives, protect the marine environment from significant damage caused by exploration or recovery of deep seabed hard mineral resources. Toward that goal, the Administrator of NOAA will use his authority to regulate aspects of mining activities such as surface discharge and benthic disturbances. Site-specific issues on land will be dealt with by NOAA in concert with other Federal agencies such as those listed in Table 19 and 20, Section III; safety-at-sea issues will be coordinated with the Coast Guard.

I.D.3 Possibilities for Retaining Manganese Tailings

This statement also covers the proposed study of the potential for manganese tailings to contribute to the National Defense Stockpile (see Section

II.D.1.1), an action that would involve a Federal action on the part of the General Services Administration and the Federal Emergency Management Agency.

I.D.4 National Pollutant Discharge Elimination System (NPDES) Findings by EPA

This PEIS also covers action by the Environmental Protection Agency (EPA) to follow guidance in this statement concerning potential unreasonable degradation of marine waters under Section 403 of the Clean Water Act. This discussion deals solely with discharges from demonstration scale mining tests to be conducted under NOAA exploration licenses.

Page

II. MARINE ASPECTS OF DEEP SEABED MINING (Exploration and First Generation Mining)*

II.A Affected Environment

II.A.1 DOMES Area

II.A.1.1 History of research**

When the prospect of deepsea mining was first proposed, NOAA recognized the necessity to develop an environmental data base to meet the requirements of NEPA. Hence, the Deep Ocean Mining Environmental Study (DOMES) program was initiated as a comprehensive five-year (1975-1980) research effort designed to provide a data base that would allow the assessment and prediction of the environmental impacts of manganese nodule recovery operations. The DOMES program marked the first time in history that such extensive environmental research had been conducted in advance of the birth of a major industry. Periodic workshops (Appendix 4) were sponsored by NOAA after DOMES began in order to assess progress and to help insure public input.

DOMES consisted of two phases: DOMES I-to characterize the region environmentally and DOMES II-to monitor effects from industry pilot-scale equipment tests. The specific objectives of DOMES I were: 1) to establish environmental baselines (biological, geological, physical, chemical) at three sites chosen as representative of the range of selected environmental parameters likely to be encountered during mining; 2) to develop a first order predictive capability for determining potential environmental effects of nodule recovery; and 3) to help develop an information base for the

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*Technical terms used in this section are capitalized at the first usage and defined in the Glossary in Appendix 2 of Section VI., Appendices. Acronyms, abbreviations, and units of measure also are defined in Appendix 2.

**Unless otherwise referenced, all research, data, and conclusions discussed in Section II.A are based on NOAA research in the Deep Ocean Mining Environmental Study (Ozturgut et al. 1978).

preparation of environmental guidelines for industry and government. Environmental characterization of the 13 million km^2 (3.8 million nmi^2) area (Figure 1, Executive Summary) that make up the DOMES area began with a compilation of the available environmental and biological information, from which an estimate of environmental variability was derived. Methods to be used during first generation mining activities (see Appendix 3.1.1) were evaluated in terms of potential environmental consequences (see Section II.C). Based on this analysis and the environmental characteristics of the DOMES area, NOAA, in conjunction with industry, selected three sites, each representative of a peculiar set of environmental conditions likely to be encountered in mining. The placement of these sites was predicated on the need to characterize the range of environmental variability in the region, with particular emphasis given to biological productivity. Because the greatest environmental variability was found to occur from north to south, particularly in the upper water layer, the sampling strategy included five or seven stations located along one north-south transect at each of the sites (Figure 2). These transects crossed the two major surface currents (North Equatorial Current and North Equatorial Countercurrent) in the DOMES area and the DIVERGENCE ZONE. The collected data provided a broad charcterization of the spatial and seasonal variations of major oceanographic parameters in the area of potential mining. DOMES I field operations were completed in November 1976.

The goal of establishing statistically meaningful confidence limits for data collected on the environmental parameters required a carefully replicated sampling program at the study sites. Summer and winter water sampling along the transects was at four separate depths zones within

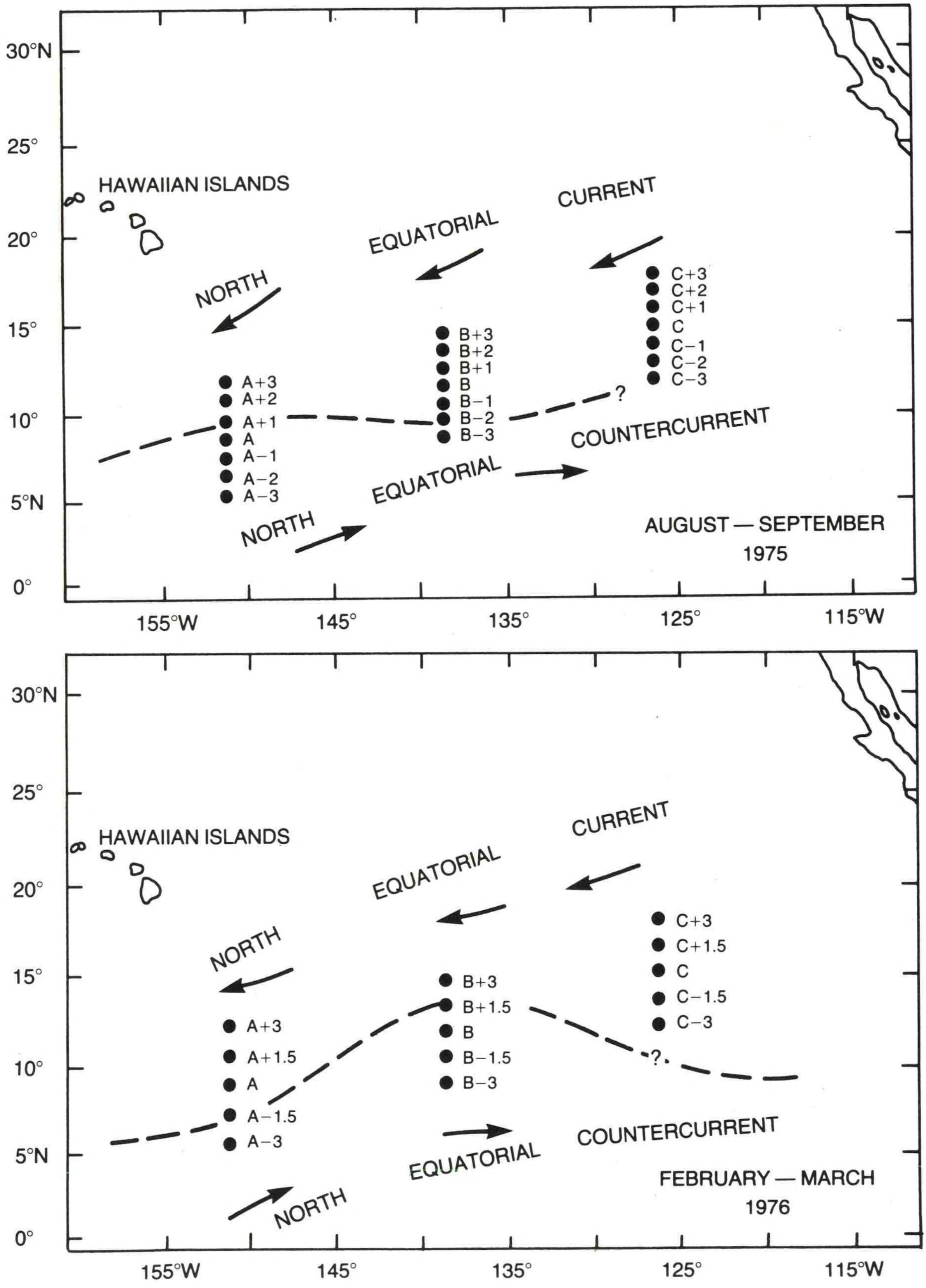

Figure 2.--Stations occupied and generalized surface circulation in the DOMES region. Dashed line indicates approximate location of the equatorial divergence zone. (Ohman et al., 1979).

the upper 1,000 m (3,300 ft): in the SURFACE MIXED LAYER; in the PYCNOCLINE; below the pycnocline to 400 m (1,320 ft); and 400 m to 1,000 m. Sampling of the lower water column and seafloor was conducted in the vicinity of the site stations. The resultant baseline values for the parameters were used to determine impacts on the environment (see Section II.C).

DOMES II involved the monitoring of industrial at-sea, pilot-scale mining simulation tests that were conducted in 1978 and early 1979. The objectives were: 1) to observe actual environmental effects to enhance the environmental impact prediction capability developed in DOMES I; and 2) to refine or modify the information base upon which subsequent environmental guidelines were to be based.

It should be noted that a complete description of the DOMES deep seabed is not possible because of the large area of ocean involved, the limited amount of existing information, and the broad nature of this programmatic EIS. The sparsity of environmental data emphasizes the need for future research, especially via NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a). The DOMES final results are expected to be published in 1981 (see separate 1981 references in Appendix 1 to: Benjamin; Chan and Anderson; Hirota; Jumars; Lavelle and Ozturgut; Lavelle _et al_.; Ozretich a and b; and Ozturgut _et al_. 1981b) and were also submitted to the National Technical Information Service.

II.A.1.2 Environmental setting

II.A.1.2.1 Upper water column

The DOMES area is subject to a variety of meteorological factors that could affect mining operations. The DOMES area is under the influence of the Northeast Tradewinds most of the year. The INTERTROPICAL CONVERGENCE ZONE along the southern border of the area and the Southeast Tradewinds affect the area as the thermal equator shifts northward during the northern summer. Eastern Pacific tropical storms and hurricanes are most frequent in late summer and early fall. The eastern portion of the area has the highest frequency of such storms of any area in the world, an average of six per year, while the western parts rarely have any (Figure 3). More specific information (including tracks, movement, and seasonal occurrence) is available in Crutcher and Quayle (1974). The authors of this worldwide climatic guide present a detailed series of storm maps covering the DOMES area and possible traffic corridors to onshore support or processing facilities.

Several physical oceanographic features are also worth noting. Surface currents (Figure 4), from north to south, are the westward-flowing North Equatorial Current, the eastward-flowing North Equatorial Countercurrent, and the westward-flowing South Equatorial Current. These currents are relatively shallow (500 m or 1,650 ft or less) and vary markedly in speed with depth, location, and season. The mean direction of the current at DOMES Site A (Figure 4) was eastward with a mean velocity of almost 20 cm/s (9.4 nmi/day) at 20 m (66 ft) and 12 cm/s (5.9 nmi/day) at 300 m (900 ft). The mean direction at Site B was eastward with a mean velocity of 3 cm/s (1.3 nmi/day) at 20 m and almost 20 cm/s (9.4 nmi/day) at 300 m. Measurements at Site C showed a mean velocity of almost 17 cm/s (7.9 nmi/day) at 20 m depth in a westward direction; however, the direction at 300 m was eastward at almost 6 cm/s (2.8 nmi/day). Season variations also occurred in the velocity of the surface currents; the North Equatorial Current fluctuated from a velocity of 5 to 30 cm/s (2.4 to 14.1 nmi/day) in the spring to 5 to 15 cm/s (2.4 to 7.1 nmi/day) in the fall.

The thermal structure of the DOMES area is typical of the tropical Pacific. A well-defined surface mixed layer overlays a strong permanent THERMOCLINE below which lie the intermediate and deep waters. Temperature decreased with depth, reaching about 4.5°C (40°F) at 1,000 m (3,300 ft), and exhibited very

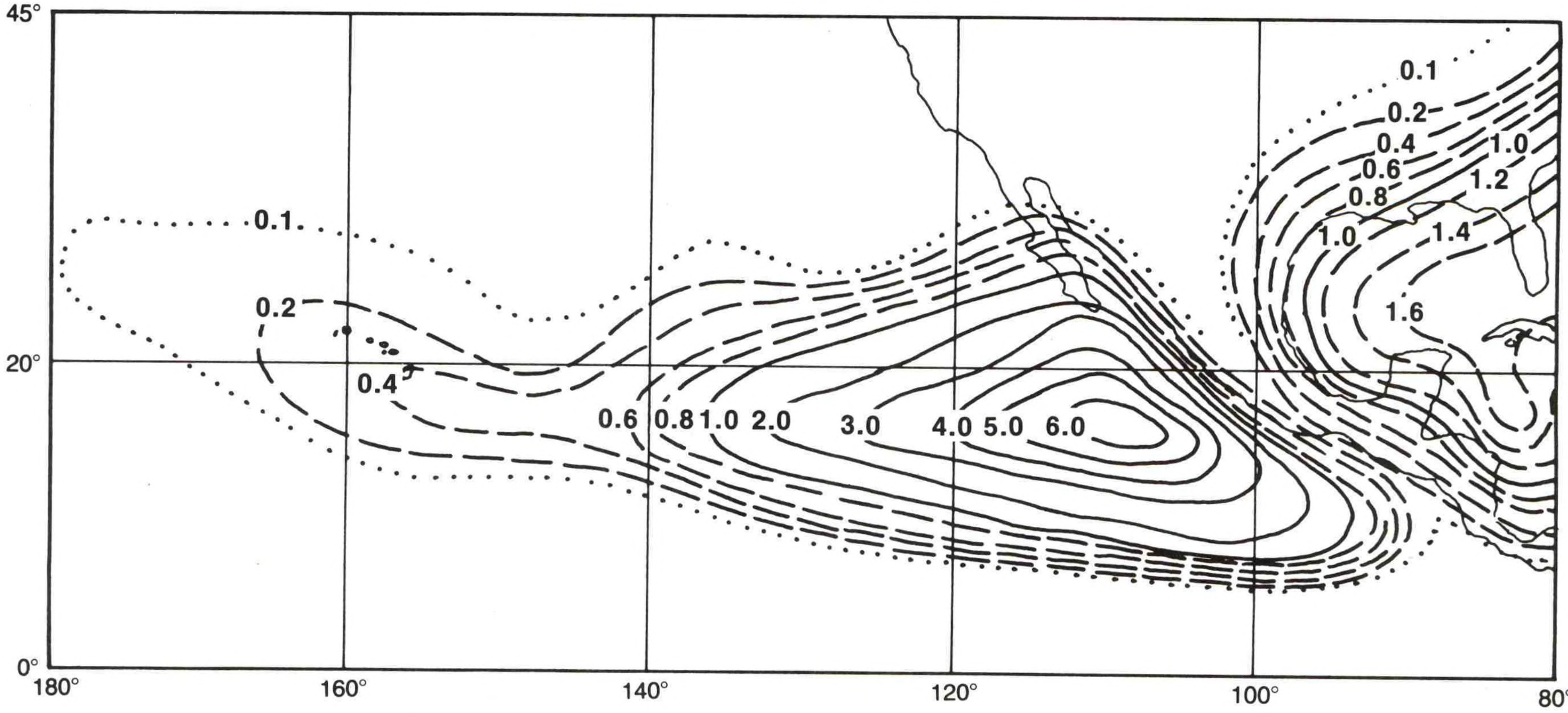

Figure 3.--Frequency of occurrence of tropical storms and hurricanes in the Eastern Tropical Pacific (Crutcher and Quayle, 1974).

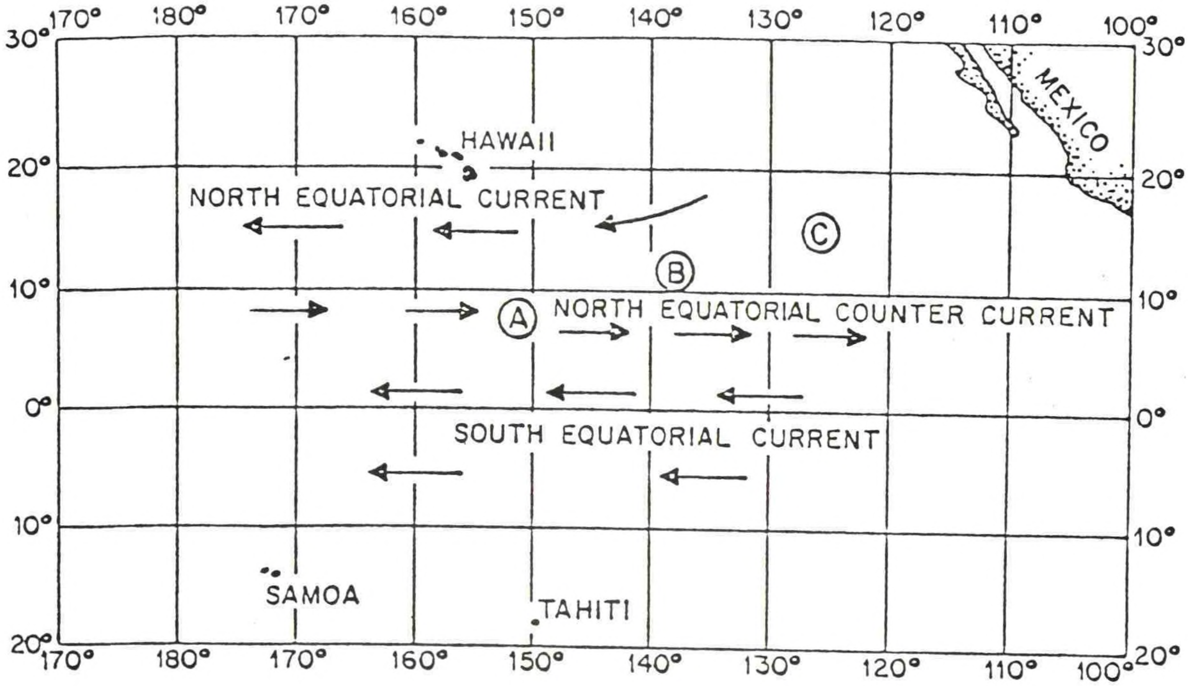

Figure 4.--General surface circulation scheme in the Eastern Tropical Pacific, with DOMES site stations A, B, and C (Ozturgut *et al.*, 1978).

small seasonal changes (Figure 5). Along all three DOMES transects, the upper water column exhibited wide variability in temperature structure over depth. Below the mixed layer, the thermocline extended to a depth of 150 $\pm$ 31 m (495 $\pm$ 102 ft) in summer and to 130 $\pm$ 18 m (429 $\pm$ 59 ft) in winter. The MIXED LAYER DEPTH and the base of the pycnocline varied considerably. The mean mixed layer depth at all DOMES stations was 36$\pm$ 32 m (119 $\pm$ 106 ft) during the summer and 55 $\pm$ 18 (182 $\pm$ 59 ft) during the winter. TEMPERATURE INVERSIONS were common between depths of 150 m (495 ft) and 200 m (660 ft). There was an east-west oriented THERMAL RIDGE underlying the DIVERGENCE ZONE between the North Equatorial Current and the North Equatorial Countercurrent where the thermocline was shallow and the temperature gradient especially strong. The SALINITY in the surface mixed layer showed very little seasonal variation, with a mean value of 34.3 ‰ for summer and winter (Figure 5).

The distribution of dissolved oxygen and nutrients was closely related to thermal structure in the upper 200 m (660 ft). Nutrient and dissolved oxygen levels also varied widely with depth. The mixed layer was oxygenated with concentrations near saturation because of sea-surface interaction with the atmosphere. Oxygen concentrations just below the mixed layer were above saturation (400-500 ug-at/l) in certain locations because the bulk of the PHYTOPLANKTON are located at these depths. The thermocline inhibits vertical nutrient transport. Hence nutrient concentrations were low in the mixed layer due to uptake by phytoplankton. Below the thermocline, nutrients increased while oxygen values rapidly decreased to a concentration minimum.

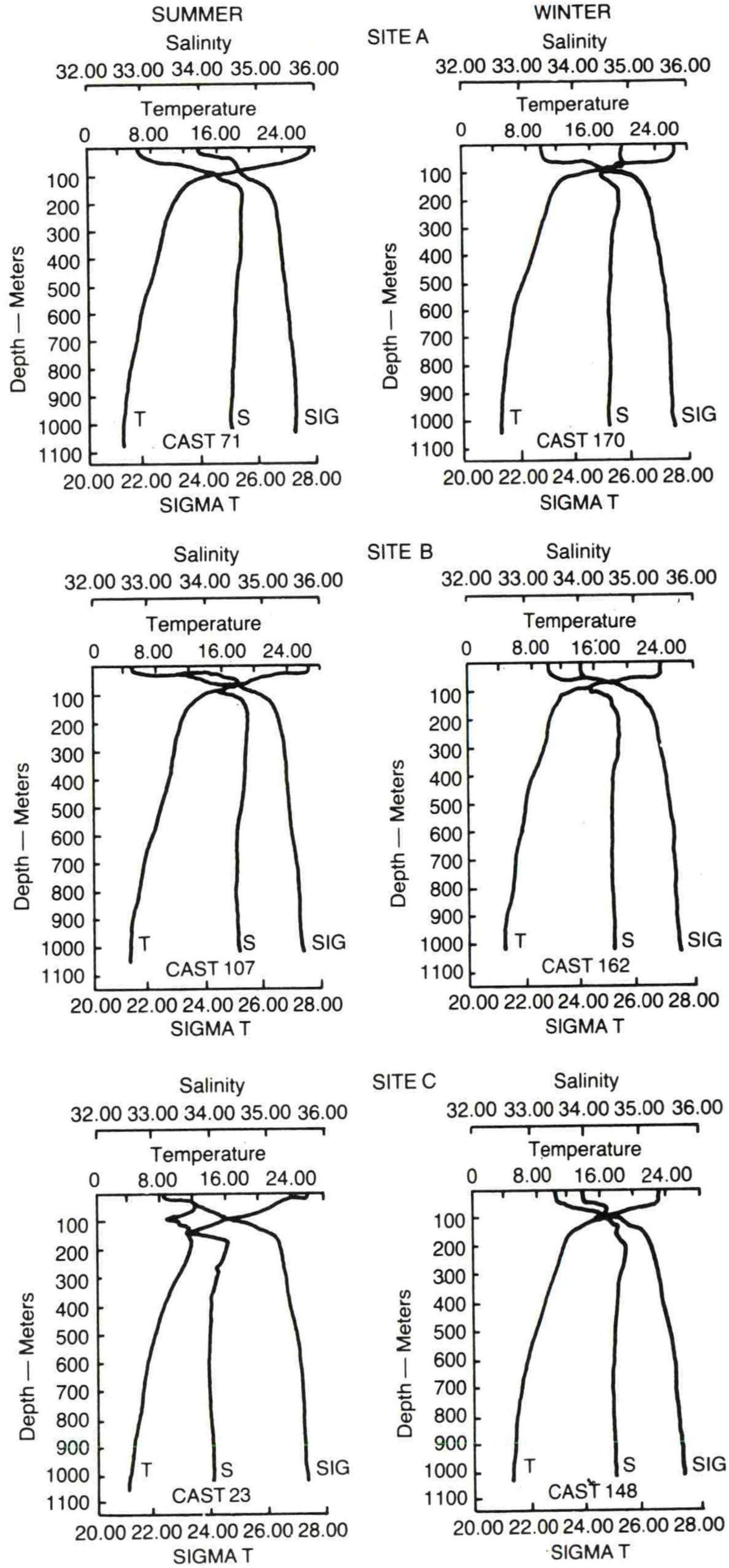

Figure 5.--Vertical profiles of temperature, salinity, and density at the DOMES site stations A, B, and C (see figure 4) during summer and winter (Ozturgut et al., 1978).

The core of this OXYGEN MINIMUM ZONE, where concentrations were as low as 1 ug-at/l, lay at depths of between 300 m (990 ft) and 500 m (1,650 ft) (Ozturgut et al. 1978).

Table 3 shows the dissolved manganese, nickel, and copper concentrations at a site in the North Pacific Ocean (Bruland, 1980; Landing and Bruland, 1980). Dissolved trace metal concentrations were investigated during DOMES I; however, contamination of the samples may have rendered the nickel and copper values too high. The values listed in Table 3 are from a sampling site approximately 700 nm (1295 Km) north of the DOMES area but they represent the most recent data available for the North Pacific Ocean. The vertical distributions of manganese are characterized by maximum concentrations of 0.62 nmol/kg at the surface and 0.71 nmol/kg in the oxygen minimum zone. The vertical distributions of copper and nickel both show increases in concentration with depth. Copper increased from 0.54 nmol/kg at the surface to 5.34 nmol/kg at 4,800 m (15,840 ft); nickel increased from 2.49 nmol/kg at the surface to 10.4 nmol/kg at 4,800 m. The trace metal content of organisms collected during the DOMES cruises is shown in Table 4.

SUSPENDED PARTICULATE MATTER was most abundant in the surface waters with an average concentration of 30 $\pm$ 18 ug/l in the upper 300 m (990 ft). This concentration is quite low but typical of the open ocean. Below the thermocline, concentrations were uniformly very low (7 to 12 ug/l) with a slight increase near the bottom (10 to 14 ug/l) being indicative of a weak NEPHELOID LAYER (Ozturgut et al. 1978). The increase in the inorganic fraction of this suspended particulate matter may indicate that local bottom currents were suspending the fine fraction of the bottom sediments.

Table 3. Concentrations of nickel, copper and manganese in the water column at sampling site in North Pacific Ocean at 32°41'N, 145°00'W, in September 1977 (Bruland, 1980; Landing and Bruland, 1980)

DEPTH (m)	NICKEL (nmol/kg)	COPPER (nmol/kg)	TOTAL DISSOLVABLE MANGANESE (nmol/kg)
<1	2.49	0.54	0.62
75	2.90	0.69	0.65
185	3.79	0.91	0.34
375	5.26	1.34	0.27
595	7.49	1.90	0.57
780	9.07	1.95	0.71
985	9.64	2.05	0.70
1505	9.79	2.09	0.77
2025	10.6	3.18	0.30
2570	10.8	3.46	0.23
3055	10.9	4.00	0.15
3533	10.7	4.26	0.10
4000	10.8	4.77	0.15
4635	10.3	4.85	0.13
4875	10.4	5.34	0.15

Table 4. Trace metal content (ppm) of organisms collected during DOMES cruises. See Hall et al., 1977 for exact locations, tow depth, and other data. (Ozturgut et al., 1978)

Trace Metal \ Number of Samples	Day Neuston		Night Neuston		Day Shallow Bongo		Night Shallow Bongo		Tuna		Mahi Mahi			Squid		Shark			Pilot Fish	
									Muscle	Liver	Muscle	Liver		Muscle		Muscle	Liver		Liver	
	6		17		10		5		3	1	1	37		17		(2)	10		12	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	-	-	Mean	σ	Mean	σ	Mean	Mean	σ	Mean	σ
Cu	3.7	2.6	2.2	3.9	1.7	0.9	2.9	2.8	2.1	6.7	1.2	12.2	7.9	4.3	1.3	0.6	9.4	3.7	19.0	28.6
Ni	1.6	1.0	1.1	2.2	1.1	0.3	1.1	0.6	0.1	0.6	0.1	0.5	0.4	0.2	0.0	0.1	0.3	0.2	1.3	1.0
Mn	2.7	1.2	2.1	0.7	1.3	0.6	4.1	5.9	-	-	-	-	-	-	-	-	-	-	-	-
Fe	88.5	72.7	21.6	15.9	23,1	23.1	16.6	7.4	13.1	14.9	12.3	147.0	75.8	5.7	4.4	3.8	204.5	121.0	193.2	85.6
Cd	1.6	0.4	0.7	0.6	0.9	0.4	1.0	0.5	0.1	2.4	0.0	7.8	4.9	0.6	0.3	0.0	12.3	13.0	8.5	7.1
Pb	7.7	6.2	1.7	2.1	2.0	1.1	2.4	2.0	0.3	0.4	0.3	0.7	0.3	0.5	0.1	0.3	0.5	0.3	1.3	0.4
Cr	1.1	0.7	0.7	0.5	0.8	0.6	0.9	0.6	0.4	0.5	0.2	0.4	0.1	0.5	0.5	0.4	0.2	20.2	0.6	0.2
Zn	57.7	48.2	20.0	19.2	23.0	19.8	105.1	198.4	6.5	49.0	4.4	40.8	6.8	18.6	2.9	38.8	0.0	12.0	35.7	7.6

Studies of CHLOROPHYLL _a_ show the typical low values for phytoplankton standing crop of subtropical ocean waters. The average surface chlorophyll _a_ valve measured at the DOMES sites was 0.12 mg/m^3. Concentrations varied greatly, with significant amounts found below the EUPHOTIC ZONE. The average daily primary production for summer and winter was 133 $\pm$ 62 mgC/m^2/day. In the summer, maximum productivity values were found at the depth where the light was 50 percent of surface light intensity; during the winter, maximum values were at or near the surface.

Standing stocks of MICRONEKTON, ZOOPLANKTON, and NEUSTON varied seasonally from 3 to 8 g/m^2 with the higher average values typical during the winter. The highest concentrations of MACROZOOPLANKTON were found in the upper 150 m (495 ft). The lowest concentrations were found near 200 m (600 ft) in the oxygen minimum zone and below 900 m (2970 ft).

Bacteria are present throughout the water column. Maximum activity of these biological decomposers was found at the sea surface and in the oxygen minimum zone. Bacteria are also associated with manganese nodules; it has been suggested that their activity may affect nodule formation or be responsible for the fact that nodules are not being buried by ongoing sediment deposition.

Finfish and their larvae occur throughout the DOMES area. Commercially important species include bigeye, yellowfin, and skipjack tunas and the striped and blue marlin. Non-commercial finfish and other large organisms include squids, lancet fishes, flying fishes, mackerel, dolphin fish, wahoo, ocean sunfish, swordfish, lanternfish, and rat-tail fish. Results from DOMES investigations of larval fish distribution and species composition suggest that: (1) larvae of commercially valuable tunas occur more abundantly in the NEUSTON LAYER than in the 1 m (3.3 ft) to 200 m (660 ft) depths; (2) larvae found between 1 m and 200 m are mainly of MESOPELAGIC species; and (3) very few larval fish occur in the 200 m to 1,000 m (3,300 ft) depth range. A previous study of the vertical distribution of all fish larvae in the equatorial Pacific (Legand et al. 1972) showed that larvae were most numerous in the 0-200 m (660 ft) layer, especially at night; a second concentration, most noticeable in the daytime, occurred at 750 m (2,475 ft) to 950 m (3,135 ft). This implies that some of these larvae may migrate up into the 0 to 200 m layer at night and move down at daylight. Studies by Ahlstrom (1971, 1972) on fish larvae collected on the 1967 EASTROPAC (Eastern Pacific) expedition showed that over 90 percent of the larvae sampled belong to families that are mesopelagic as adults; only 1 percent of the total were EPIPELAGIC species such as tunas. Ahlstrom also found that larval abundances generally increased toward the equator and varied seasonally for most species. The seasonal maximum:minimum ratios did not exceed 5:1, implying that at least some species produce some larvae all year. Tuna larvae were more numerous in February and March than in August and September. Billfish and yellowfin larvae are found over the entire DOMES area while skipjack larvae are common only to the west of 130°W.

Ten threatened or endangered species of marine mammals and turtles recognized by Federal law could inhabit the DOMES area (Appendix 8). Since detailed surveys of the species in the region have not been undertaken, listings for the DOMES area are based almost solely on projections from known ecological characteristics of each species. The only exception is a sighting of a single Hawaiian monk seal on Johnston Island in 1968, according to

Documentation Associates (1977). However, Appendix 8 should provide a start for site-specific analyses of the species which could be affected by either nodule recovery operations or associated marine transportation activities (supply vessels, increased tanker traffic, submarine acoustics, etc.). Special attention in site-specific EISs should be given to species, or distinct subpopulations thereof, that concentrate in specific locations to feed, breed, or migrate.

Several other points are worth noting. First, the health of nonlisted species being considered for protection under the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), or international treaties must also be assessed. Examples of those species include: Guadalupe fur seal off California that has been nominated for listing under the ESA or marine mammals (Eastern spinner and the coastal spotted porpoise) that qualify for a special MMPA category termed "depleted" for stocks that could become threatened in the near future. Second, available information indicates that there are no other listed threatened or endangered species (fish, invertebrates, etc.) in the DOMES area. However, if a species is found to be eligible for listing, that species could be designated for protected status. The problem of surveying and quantifying oceanic populations throughout their range could slow this already time consuming process of listing a marine species.

Most of the birds observed in or near the DOMES area have been studied within island habitats. Only occasional sightings at sea have been reported in the DOMES area.

II.A.1.2.2 Lower water column and seafloor

Measurements of near-bottom currents from April to November showed a mean speed of 2.1 cm/s (0.97 nmi/day) at Site A and 5.2 cm/s (2.4 nmi/day) at Site B, both to the northwest. Maximum recorded speeds of 24 cm/s (11 nmi/day) at 6 m (20 ft) above the bottom suggest that local erosion and redeposition may occur from time to time.

The chemistry of the lower water column is quite different from that of the surface waters. Salinity within 300 m (990 ft) of the bottom was nearly uniform with an average value of 34.70 ‰ at Site A and 34.68 ‰ at Sites B and C. Dissolved oxygen within the lower 300 m of the seafloor showed a significant decrease from west to east across the DOMES area. Mean values decreased from 359 ug-at/l in the west at Site A, to 344 ug-at/l at Site B, to 332 ug-at/l in the east at Site C. Nutrient concentrations were high in the bottom water. The mean value for nitrate remains relatively constant (36.0 ug-at/l) while mean values for phosphate and silicate increased significantly from west to east (2.33 to 2.42 ug-at/l for phosphate and 136.6 to 147.0 ug-at/l for silicate). Within 400 m (1,320 ft) of the bottom, the suspended particulate matter showed a slight increase over its concentration in the upper waters and was indicative of the presence of a weak benthic nepheloid layer. The near bottom temperature gradient was low (3×10^{-5}°C/m) over the bottom 200 m (660 ft). The average bottom potential temperature was 0.982°C at Site A; 1.034°C at Site B; and 1.068°C at Site C.

The DOMES area includes portions of the Central and Eastern-North Pacific Basins. Water depth increases from about 4,000 m (13,200 ft) in the eastern portion to about 5,600 m (18,480 ft) in the deeper northern and western portion of the basin and in fracture zones. Dominant geographic features are the east-northeast striking Clarion and Clipperton FRACTURE ZONES and the Hawaiian and Line Islands. Although SEAMOUNTS are common, ABYSSAL HILLS predominate. Seismic activity is low except near the Hawaiian Islands and beyond the eastern boundary of the DOMES area.

Sediment distribution (Figure 6) is related to water depth, surface water productivity, calcium carbonate solubility, and the presence of volcanic islands, among other factors. PELAGIC CLAYS are common where calcium carbonate and silica are not abundantly deposited. Between the fracture zones, the pelagic sediments grade into SILICEOUS OOZES and CLAYS. CALCAREOUS sediments, because of their increased solubility with depth, are abundant in the shallower waters in the southern portion of the DOMES area and around seamounts.

Manganese nodules are common on the surface of the sediments of the area (see Section I.C and Figure 7). Their formation, distribution, and mechanism for remaining only half-buried in the sediments are poorly understood. Typically, they are rather fragile and subject to abrasion upon handling. Deep-water sedimentation rates are very low; clays accumulate at 1 to 3 mm (0.04 to 0.12 in) per 1,000 years (Ozturgut et al. 1978) and siliceous ooze at 3 to 8 mm (0.12 to 0.32 in) per 1,000 years (Ozturgut et al. 1978) whereas the nodules themselves are estimated to accrete at rates in the order of a few millimeters per 1,000,000 years (Bischoff and Piper, 1979). The chemistry of the interstitial water in the bottom sediments indicates that the sediments are chemically stable and that bacteria are actively metabolizing the organic matter that is present.

The fauna of the deep sea is composed of an enormous diversity of organisms. These animals are generally small and live in the top centimeter of sediment. The diversity of the ABYSSAL BENTHOS appears to be extremely high; however, the habitat is not well understood because of difficulties associated with

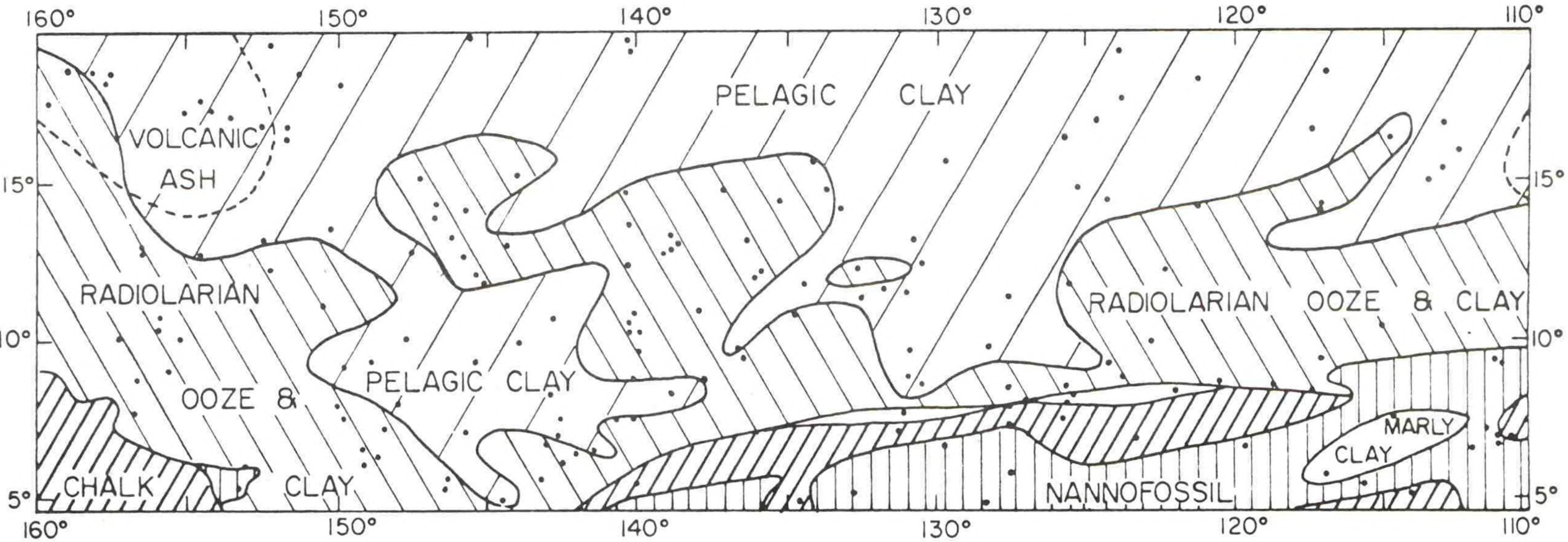

Figure 6.--Distribution of sediments in the DOMES area (Ryan and Heezen, 1976).

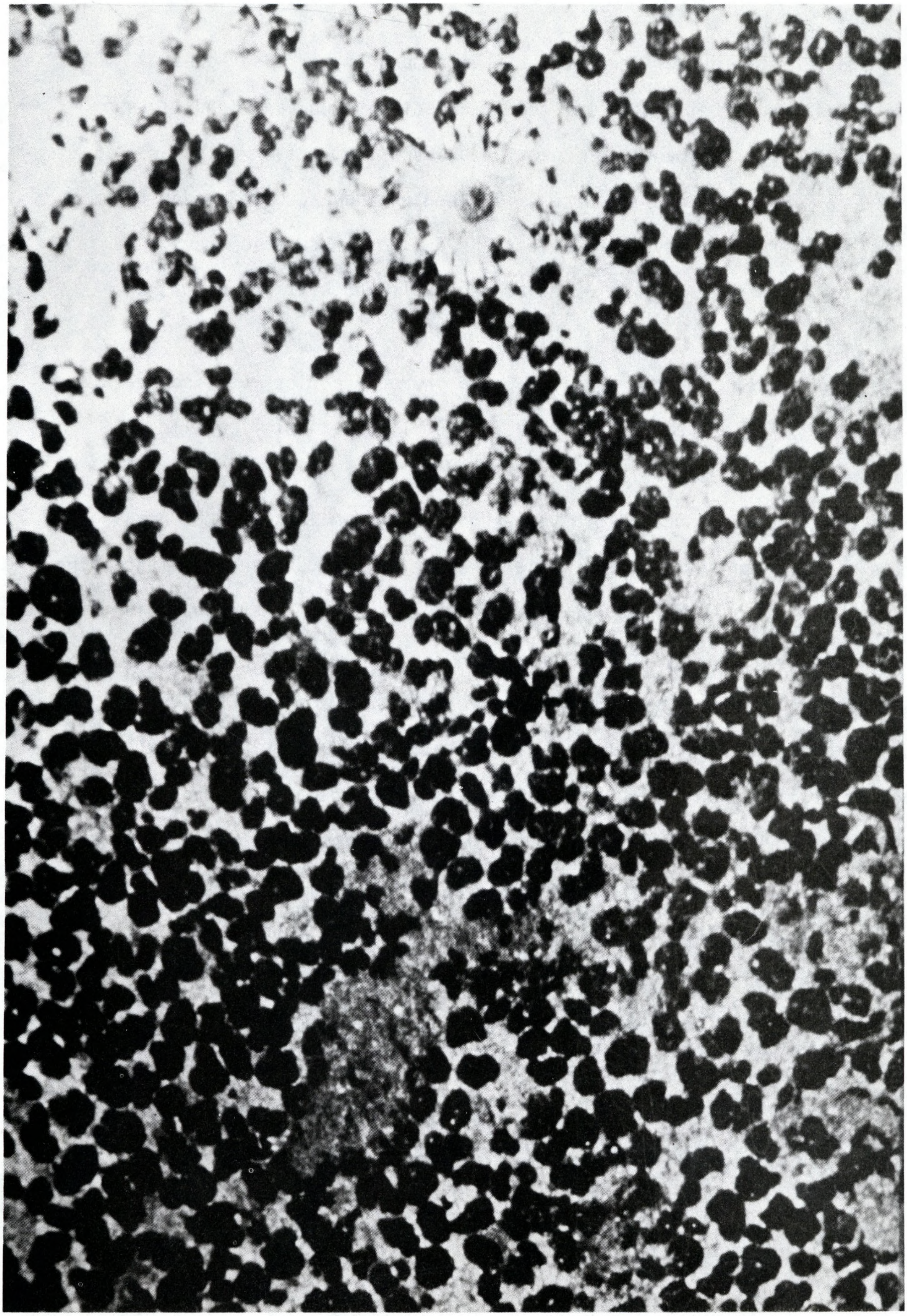

Figure 7.--Manganese nodules on seafloor.

sampling and working in it. The deepsea environment is marked by great temporal stability. It is characterized by relatively constant conditions of low temperature, low sedimentation rates, high pressure, a lack of natural light, and low input of food resources. The benthos have evolved under these conditions to where they have long life spans and long maturation periods. Even though species diversity is high, there are low populations within each species; most species appear to have low reproductive potential and slow rates of colonization. Any generalization of characteristics must include a caveat, however, since examples of trends are still relatively few. The following paragraphs describe the diversity of the system, as well as the taxonomic and TROPHIC structure of the benthic ecosystem in the DOMES area. Analogies will be made to a more familiar system for the purpose of illustrating significant points. The reader, however, should not extend these analogies beyond these illustrative points.

Benthic organisms (Figures 8 to 10) have been surveyed by photography and sampled by box cores, free-fall baited traps, and bongo net tows. The near-bottom macrozooplankton concentration, comprised primarily of CRUSTACEANS (COPEPODS, OSTRACODS, AMPHIPODS, DECAPODS) was very low; fewer than five individuals were caught per sample in net tows. This indicates highly dispersed populations near the bottom compared with upper waters. Bottom scavengers trapped in the area consisted of two families of fish (rat-tails and liparids) and amphipod crustaceans (Figure 11). Amphipods collected during DOMES were found in large numbers (about 50,000 individuals in the 73 samples obtained) and were represented by 10 species. Photographic surveys, which show only the larger organisms and thus are not representative of the

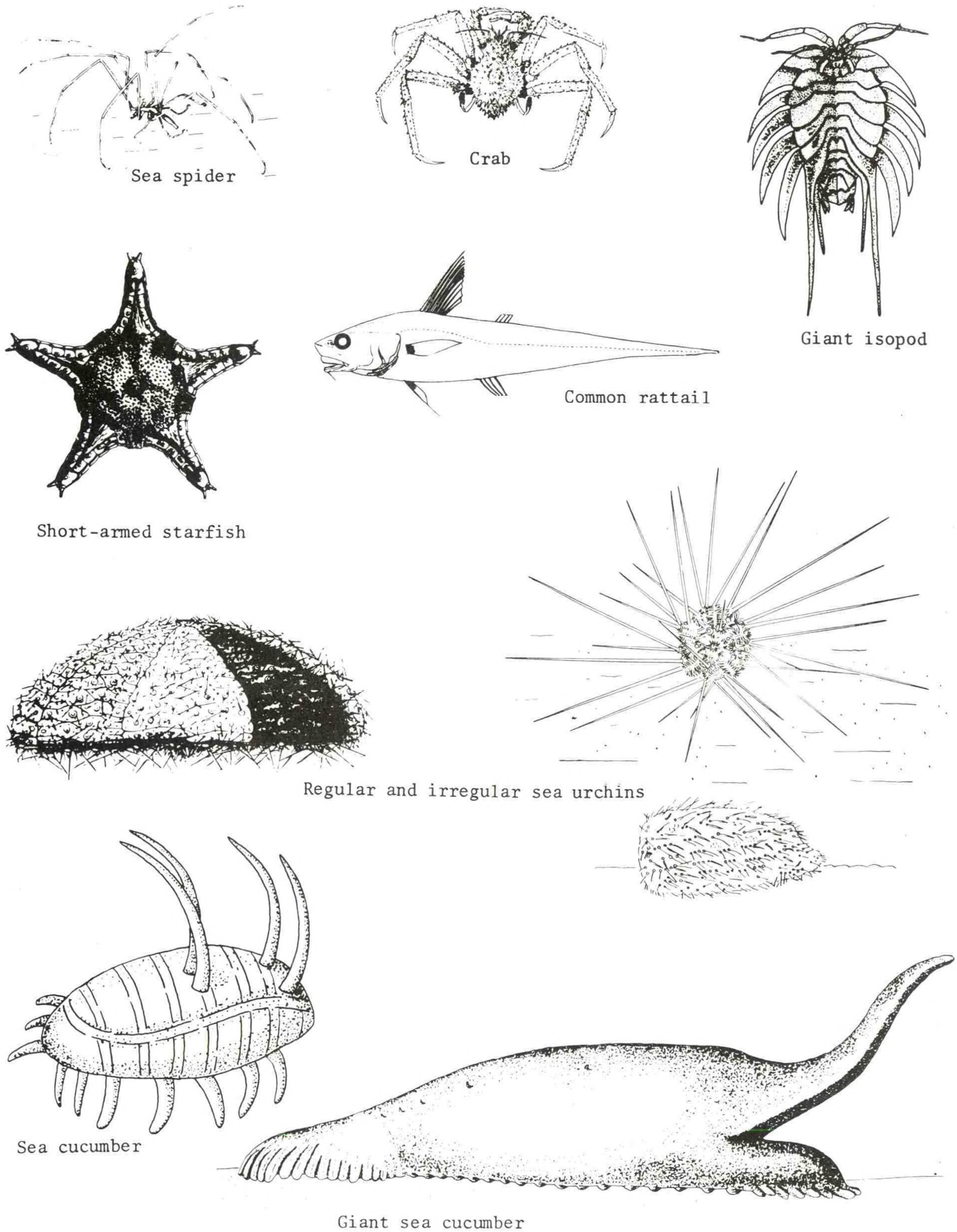

Figure 8.--Abyssal animals that are representative of the phyla inhabiting the DOMES area (OCEANUS, Winter 1978).

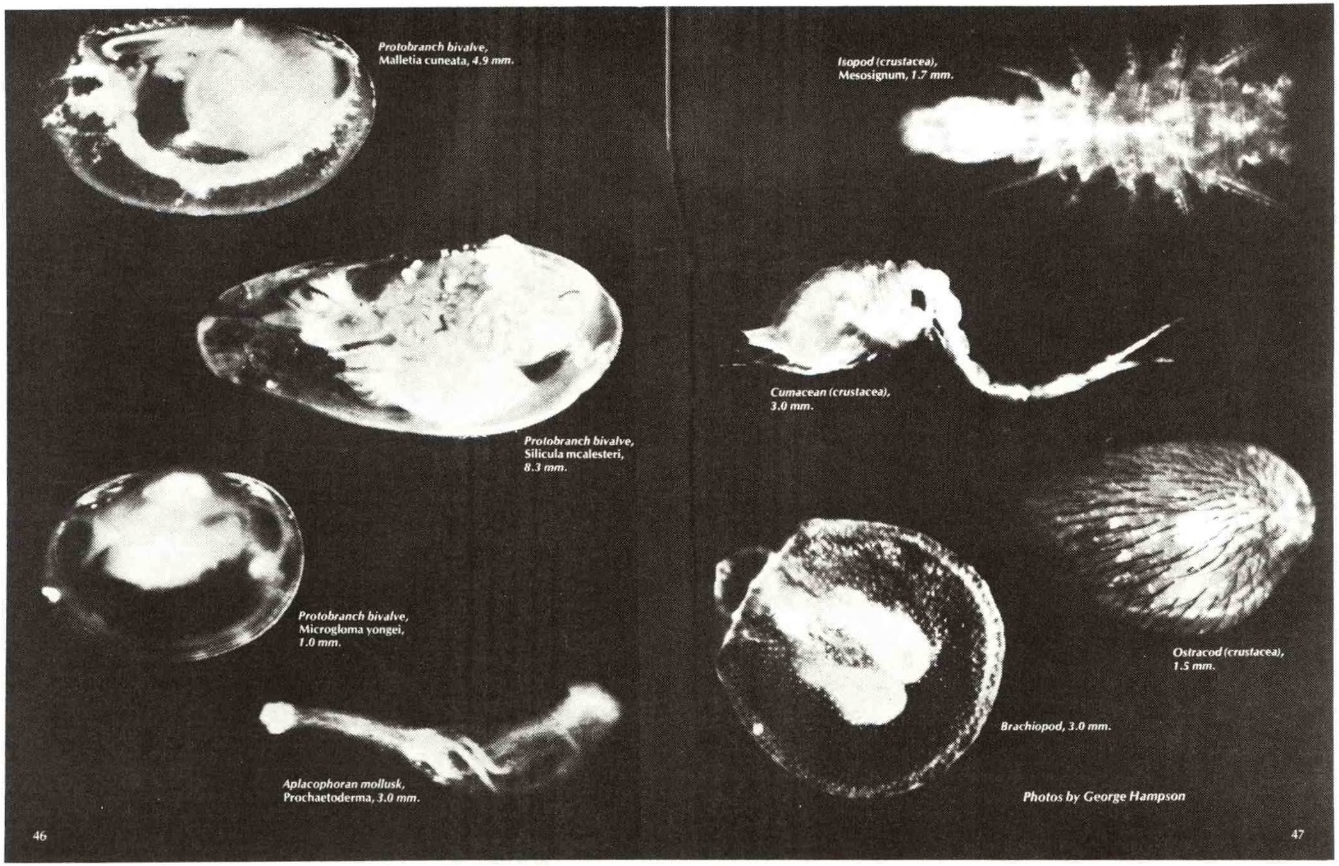

Figure 9.--Abyssal mud-dwelling animals that are representative of the phyla inhabiting the DOMES area (Grassle, OCEANUS, Winter 1978).

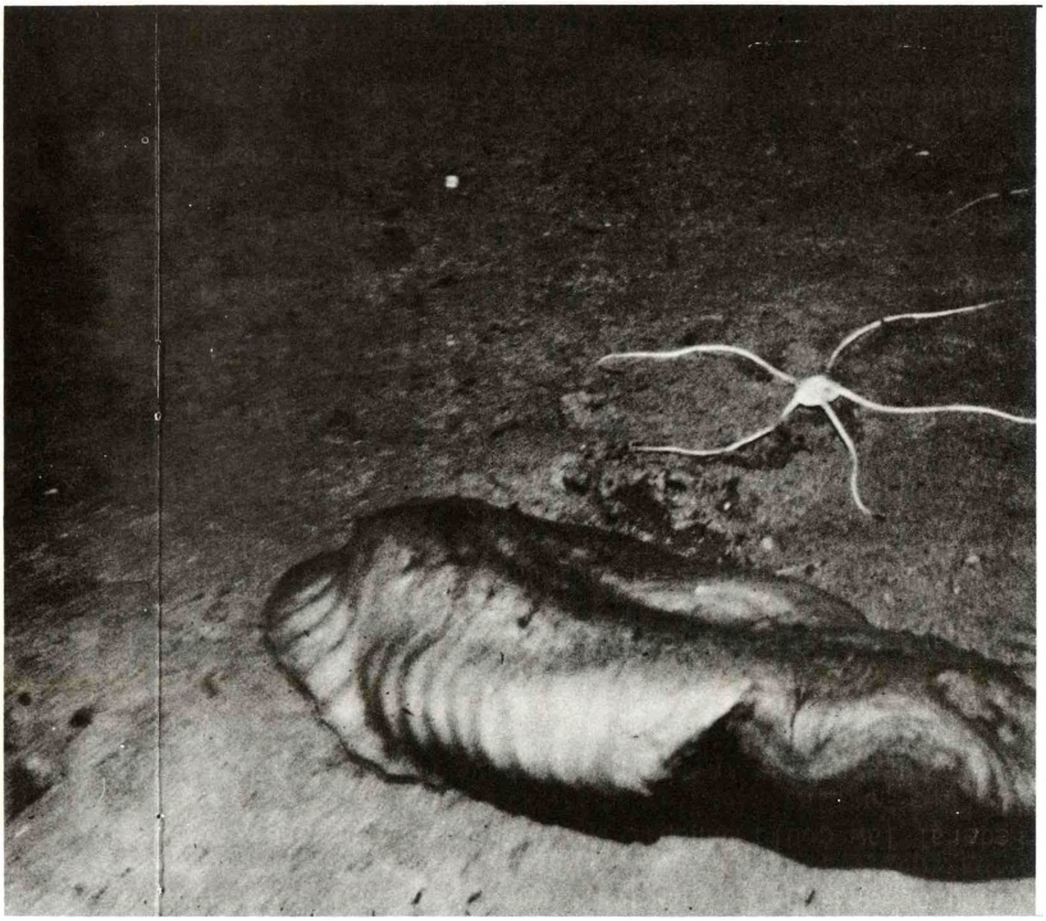

Figure 10.--Deep sea photo of sea cucumber, urchin, and brittle stars lying on sediment (Grassle, OCEANUS, Winter 1978).

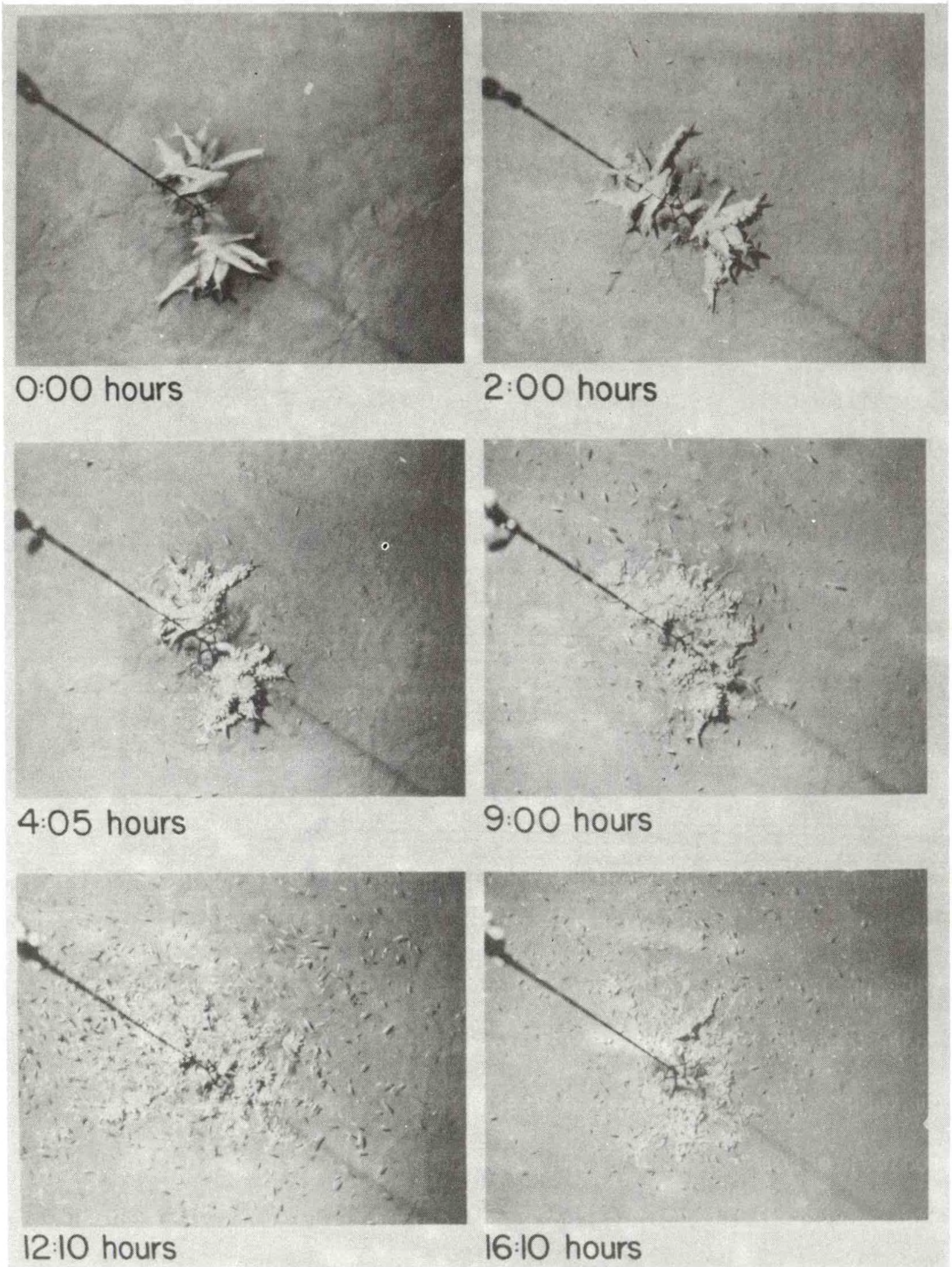

Figure 11.--Deep sea scavengers (rat-tail fish and amphipods) attracted to bait (Hessler, Scripps Institute of Oceanography, under contract to Sandia National Laboratories).

true abundance of the benthos, reveal that at least 90 percent of the larger, observable epibenthic organisms are SEA STARS, BRITTLE STARS, SEA ANEMONES, SEA CUCUMBERS, and sponges (Tables 5 and 6). Box cores analyzed for the organisms that comprise the majority of the benthos, i.e., the infauna, revealed that the "larger" organisms (average wet weight of 1.6 mg or 0.000056 oz) are found in the average densities of from 92 to 152 individuals per m^2 (8.5 to 14.1 per ft^2). The majority of the infauna are minute (less than 1 mm) and live in the upper 1 cm of sediments. Forty percent of the macrobenthos collected were POLYCHAETE WORMS (underestimated due to sampling problems), 19 percent TANAIDS, and 11 percent ISOPODS; sponges, BRYOZOANS, GASTROPODS, sea cucumbers, SEA URCHINS, BIVALVES, sea anemones, brittle stars, BRACHIPODS, and miscellaneous non-polychaete worms comprised the majority of the remaining organisms (Tables 7 and 8). Some of the organisms collected apparently live on the surface of the manganese nodules, including FORAMINIFERA, bryozoans, COELENTERATES, and SERPULID WORMS. The faunal characteristics of the three sites (including the weight of the large epifauna) varied in terms of average biomass, average density of MACROFAUNA and MEIOFAUNA, and the percentage of SUSPENSION FEEDERS (Table 9). The statistics for the DOMES area are comparable to similar statistics for the abyssal benthos elsewhere in the oceans.

In the mid-1960's, marine ecologists were surprised by their discovery of the very high diversity of the fauna in the deep sea. The 80 box core samples from the DOMES sites illustrated this high diversity with 2,422 individuals of 381 macrofaunal species. Nearly three-fourths of the species were represented by four individuals or less; 131 species were represented by only one individual, with an average density of less than one individual

Table 5. Number and percentage of taxa observed in bottom photographs at each site (Ozturgut *et al.* 1978)

	Site A		Site B		Site C	
Taxon	Number	Percentage	Number	Percentage	Number	Percentage
Echinoidea	19	3	55	13	261	32
Ophiuroidea	60	11	37	9	155	19
Actiniaria	40	7	136	33	133	16
Holothuroidea	42	61	122	29	131	16
Porifera	28	5	8	2	28	3
Pennatula	11	2	14	3	26	3
Gorgonacea	8	1	7	2	21	2
Asteroidea	22	4	8	2	20	2
Crustacea	17	3	14	3	13	1
Ascidacea	3	--	2	--	3	--
Polyplacophora	0		2	--	3	--
Pycnogonida	0		0		4	--
Echiuroidea	0		0		1	--
Gastropoda	0		0		3	--
Bivalvia	1	--	0		0	
Bryozoa	2	--	4	--	8	--
Crinoidea	0		1	--	2	--
Polychaeta	1	--	2	--	0	
Enteropneusta	1	--	0		0	
Chimaeridae	1	--	3	--	16	2
Total Number of Individuals	556		415		828	
Density (Organisms/m^2)	0.014		0.030		0.031	
Total Visible Bottom Area (m^2) in Photographs	40,175		13,997		27,183	

Table 6. The common names, feeding, and mobility classes (functional groups) of taxa observed by deep-sea photography (Ringold, 1981, personal communication)

TAXON	COMMON NAME or DESCRIPTION	Functional classifications: FEEDING	MOBILITY
Echinoidea	sea urchins	D	M1
Ophiuroidea	brittle stars	D,F,Sc	M2
Actiniaria	sea anemones	F,P	Sd,Ss
Holothuroidea	sea cucumbers	D	M1,Sd,Ss
Porifera	sponges	F	Ss
Pennatula	sea pansies, sea pens	F	Sd
Gorgonacea	soft corals	F	Ss
Asteroidea	starfish, sea stars	P,D	M1
Crustacea	amphipods, crabs, shrimps, etc.	Sc,D	M2
Ascidacea	sea squirts, tunicates	F,D,P	Ss,Sd
Polyplacophora	chitons	D	Sd
Pycnogonida	sea spiders	Sd,D	M2
Echiuroidea	spoon worms	D,F	Sd
Gastropoda	snails	P,Sc,D,F	M1
Bivalvia	clams	F	Sd,Ss
Bryozoa	moss animals	F	Ss
Crinoidea	sea lillies, feather stars	F	Ss
Polychaeta	segmented worms	F	Ss
Enteropneusta	acorn worms	D,F	Sd
Chimaeridae	fishes	P,Sc	M2

Organisms listed here were observed via bottom photography (see Table 5) and are therefore assumed to be epifauna. Note that each taxon is represented by many species, some of which may be in different functional groups. These descriptions constitute the best assessment available. The key to the functional groups follows:

Feeding

D Deposit feeder
F Filter feeder/suspension feeder
P Predator
Pa Parasite
Sc Scavenger

Mobility

Ss Sessile, attached
Sd Sedentary, unattached but moving little, includes many burrow dwellers
M1 Mobile
M2 Highly mobile

Table 7. Faunal composition by number of individuals and their percentage as obtained from box cores (Hecker and Paul, 1979)

Macrofaunal taxa	Site A #	Site A %	Site B #	Site B %	Site C #	Site C %	Total #	Total %
Polychaeta	189	38.6	239	46.4	542	38.2	970	40.1
Tanaidacea	121	24.7	77	15.0	274	19.3	472	19.5
Isopoda	57	11.6	30	5.8	197	13.9	284	11.7
Bivalvia	40	8.2	73	14.2	90	6.4	203	8.4
Gastropoda	13	2.7	25	4.9	23	1.6	61	2.5
Ectoprocta	25	5.1	8	1.6	97	6.8	130	5.4
Porifera	4	0.8	16	3.1	55	3.9	74	3.1
Hydrozoa	3	0.6	2	0.4	3	0.2	8	0.3
Stephanoscyphus	1	0.2	10	1.9	2	0.1	13	0.5
Actiniaria	3	0.6	-	-	15	1.1	18	0.7
Brachiopoda	10	2.0	9	1.7	31	2.2	50	2.1
Hemichordata	-	-	1	0.2	1	0.1	2	0.1
Sipunculoidea	3	0.6	4	0.8	14	1.0	22	0.9
Echiuroidea	-	-	-	-	3	0.2	3	0.1
Ophiuroidea	9	1.8	-	-	10	0.7	19	0.8
Echinoidea	-	-	3	0.6	1	0.1	4	0.2
Crinoidea	1	0.2	-	-	7	0.5	8	0.3
Holothuroidea	1	0.2	-	-	2	0.1	3	0.1
Aplacophora	2	0.4	2	0.4	2	0.1	6	0.2
Polyplacophora	1	0.2	-	-	5	0.4	6	0.2
Monoplacophora	1	0.2	-	-	-	-	1	-
Scaphopoda	1	0.2	-	-	1	0.1	2	0.1
Oligochaeta	-	-	-	-	8	0.6	8	0.3
Pycnogonida	-	-	-	-	3	0.2	3	0.1
Cumacea	-	-	4	0.8	3	0.2	7	0.3
Amphipoda	2	0.4	5	1.0	14	1.0	21	0.9
Cirripedia	-	-	-	-	3	0.2	3	0.1
Ascidacea	3	0.6	7	1.4	7	0.5	17	0.7
Unknown	-	-	-	-	4	0.3	4	0.2
Total	490	99.9	515	100.2	1417	100.0	2422	99.9
Total per core	22		25		37			
Meiofaunal taxa								
Nematoda	1116	87.3	1486	87.0	709	69.1	3311	82.5
Ostracoda	77	6.0	82	4.8	226	22.0	385	9.6
Copepoda	84	6.6	138	8.1	81	7.9	303	7.5
Acarina	-	-	2	0.1	8	0.8	10	0.2
Turbellaria	2	0.2	-	-	1	0.1	3	0.1
Kinorhyncha	-	-	1	0.1	1	0.1	2	-
Total	1279	100.1	1709	100.1	1026	100.0	4014	99.9
Total per core	58		85		27			

Table 8. The common names, mobility, feeding (functional groups), and infaunal classes of taxa obtained from box cores (Ringold, 1981, personal communication)

		Functional classifications:		
TAXON	COMMON NAME or DESCRIPTION	FEEDING	MOBILITY	INFAUNA or EPIFAUNA
Polychaeta	segmented worms	D,F,Sc,P	Ss to M2	I,E*
Tanaidacea	crustaceans	D,Sc,P	Sd	I,E*
Isopoda	crustaceans	D,Sc,Pa	Sd to M2	I,E
Bivalvia	clams	D,F,P	Sd,Ss	I,E*
Gastropoda	snails	P,Sc,D,F	M1	E,I
Ectoprocta	bryozoans, moss animals	F,D	Ss	E*
Porifera	sponges	F	Ss	E*
Hydrozoa	coelenterates	F	Ss	E*
Stephanoscyphus	a coelenterate	F	Ss	E*
Actiniaria	sea anemones	F,P	Sd	E*
Brachiopoda	lamp shells	F	Sd	E*
Hemichordata	acorn worms and others	D,F	Sd,Ss	I
Sipunculoidea	peanut worms	D,F	Sd,M1	I
Echiuroidea	spoon worms	D,F	Sd	I
Ophiuroidea	brittle stars	D,F,Sc	M2	E,I
Echinoidea	sea urchins	D	M1	E,I
Crinoidea	sea lilies, feather stars	F	Ss	E*
Holothuroidea	sea cucumbers	D	M1	E*,I
Aplacophora	solenogaters, molluscs	D,P	Sd	E,I
Polyplacophora	chitons	D	Sd	E*
Monoplacophora	chitonlike mollusc	D	Sd	E*
Scaphopoda	tusk shells	D,P	Sd	I
Oligochaeta	segmented worms	D	M1	I
Pycnogonida	sea spiders	Sc,D	M2	E
Cumacea	crustaceans	F,D	M2	I
Amphipoda	crustaceans	D,Sc	M2,Sd	E,I
Cirripedia	barnacles	F,P	Ss	E*
Ascidacea	sea squirts	F,D,P	Ss	E*

*All or some attached to nodules

Note that each taxon is represented by many species, some of which may be in different functional groups. These descriptions constitute the best assessment available. The key to the functional groups follows:

Feeding
D Deposit feeder
F Filter feeder/suspension feeder
P Predator
Pa Parasite
Sc Scavenger

Mobility
Ss Sessile, attached
Sd Sedentary, unattached but moving little, includes many burrow dwellers
M1 Mobile
M2 Highly mobile

Infauna or Epifauna
I Infauna, living below the sediment surface
E Epifauna, living on or above the sediment surface

Table 9. Descriptive statistics for benthic biota of three DOMES study sites

	DOMES Site A	DOMES Site B	DOMES Site C
From 0.25 m^2 cores*			
Average Biomass (grams per m^2)	0.14	0.19	0.64
Average Density of Macrofauna (no. individuals per m^2)	99	114	152
Average Density of Meiofauna (no. of individuals per m^2)	258	378	110
Percent Macrofauna as Suspension Feeders (by number)	14	18	22
From Bottom Photos**			
Average Density of Visible Fauna (no. individuals per m^2)	0.014	0.030	0.031

*Hecker and Paul, 1979
Note that Hecker and Paul lost approximately 45 percent of the polychaetes that were actually in the sample. Correcting for this loss would increase macrofauna density to 116, 138, and 179 individuals per m^2 at sites A, B, and C respectively. Hecker and Paul (1979) also note that their methods allowed most of the meiofauna to escape uncounted; the extent of the meiofauna underestimate is unknown.

**Ozturgut *et al.* 1978

per 20 m^2 (218 ft^2). The diversity of this habitat is so high that even with 80 samples, the number of species versus number of samples curve has not leveled off. In other words, if more samples were taken one would expect to find more species. A familiar land analogy of this diversity is not readily available, but one can imagine a 20 m^2 field (one about 15 ft on a side) with over 2,000 stalks of grass representing more than 350 species.

In trying to explain the function and importance of these organisms to those not familiar with the marine environment, a land/sea analogy that shows a rough comparison of the DOMES area benthos with their approximate land equivalents may prove helpful. Table 10 shows both a very general comparison of some DOMES area benthic organisms with their approximate land or freshwater benthic equivalents and the general ecological functions played in both environments. A more detailed comparison is not possible because of our incomplete knowledge of the deep-sea environment. Since the majority of the deep-sea benthos are detritus feeders, much of our knowledge about the structure of their ecosystem is inferred from the study of more accessible detrital systems such as mangrove swamps and the forest litter ecosystem (Figure 12a and 12b). The same detrital principles apply to leaves that fall into a freshwater stream, onto the forest floor, and to the organic detritus that reaches the ocean floor; small organisms ingest the detritus, eat the bacteria, and recycle the nutrients back into the water or soil. The source of energy of the abyssal benthos is the "rain" of organics provided by dead plant and animal material. The major marine food chains in the ocean vary by location and depth, with most of the chains involving a "rain of organic detritus" from dead upper water organisms to deeper waters (Figure 13). Bacteria, which break down the detritus, are in turn fed upon

Table 10. Comparison of ecological functions of DOMES area benthos and their approximate land equivalents (Jumars, 1980, personal communication)

Ecological Function	DOMES Benthos	Forest Litter Ecosystem	Freshwater Benthos
Remineralize refractory organic matter	Bacteria (Fungi?)	Fungi Bacteria	Bacteria Fungi
Digest bacteria, cause physical breakdown of organic matter, aerate soil or sediments	Polychaetes Crustaceans Bivalves	Earthworms Pillbugs Insects	Oligochaetes Larval insects
Low-order predators	Other polychaetes Crustaceans Bivalves	Other insects Lizards	Other insects Salamanders
High-order predators	Fishes	Mammals, Birds	Fishes
Scavengers	Amphipods Rat-tail fishes	Other insects Crows	Catfishes Carp
Supply of organic matter	"Rain" of organics and carcasses	Leaf and other litter fall	Terrestrial runoff

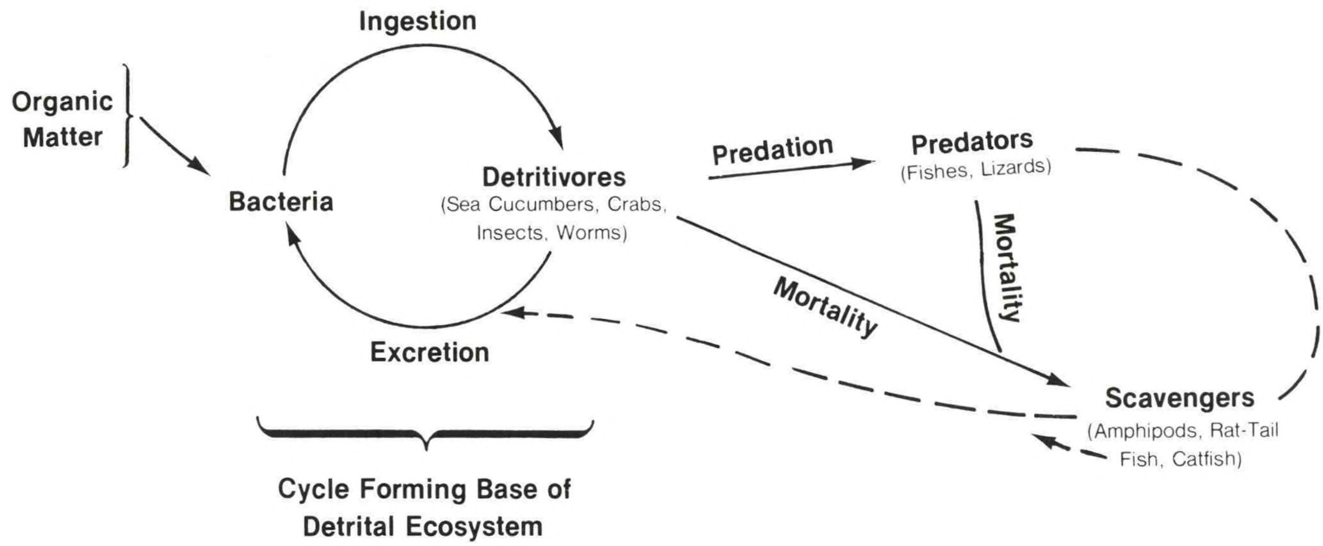

Figure 12a.--Generalized detrital food chain (Jumars, 1980, personal communication).

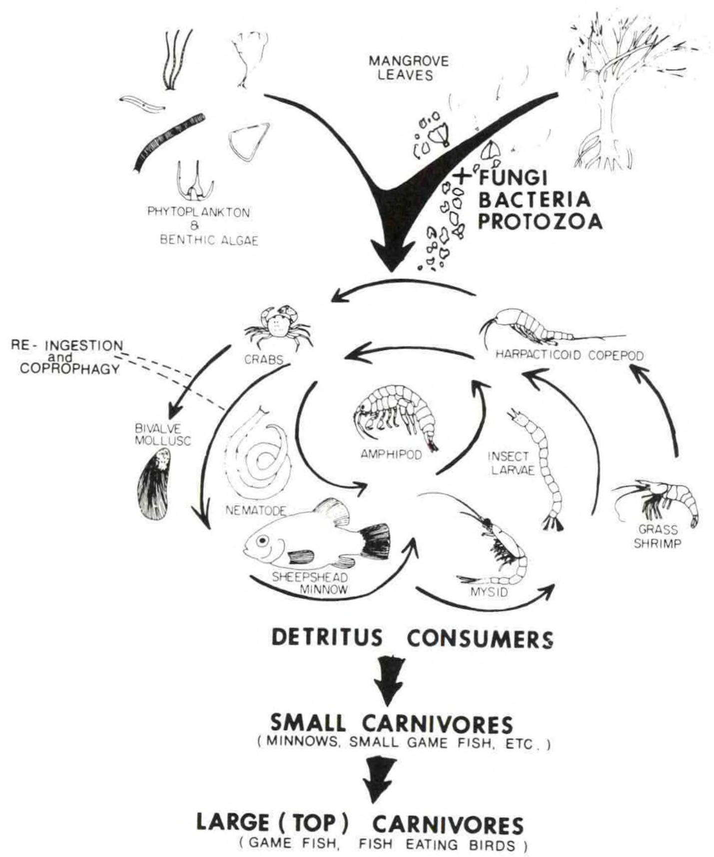

Figure 12b.--A "picture model" of a detritus food chain based on mangrove leaves which fall into shallow estuarine waters of south Florida. Leaf fragments acted on by saprotrophs and colonized by algae are eaten and re-eaten (coprophagy) by a key group of small detritus consumers which, in turn, provide the main food for game fish, herons, storks, and ibis. (Odum, 1971).

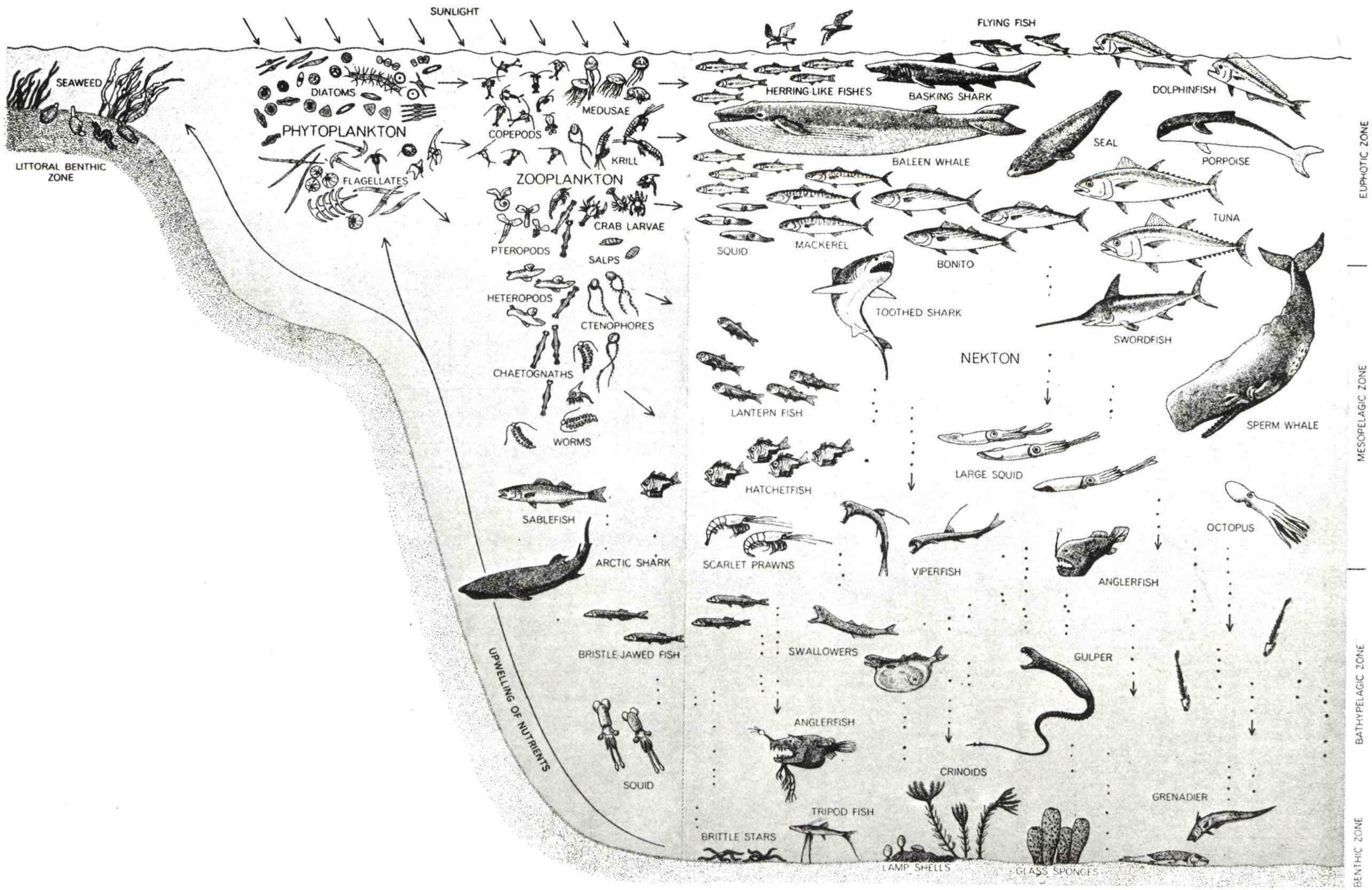

Figure 13.--Marine biota and depth relationships that comprise the major food chain of the oceanic ecosystem. The minute animals (infauna) that comprise the majority of the benthic organisms in the DOMES area are not shown because of the scale. The dots and arrows depict the "rain of organic detritus" (Isaacs, The Nature of Oceanic Life, copyright © 1969 by Scientific American, Inc. Used by permission).

by DEPOSIT FEEDERS and suspension feeders. Deposit and suspension feeders physically and chemically break up the organic detritus and its associated bacteria, and thus by the processes of digestion, metabolism, and excretion serve to recycle the basic nutrients back into the ecosystem. Predators feed on these living animals, other predators, or scavengers. Scavengers feed on dead animals of any trophic level (Tables 6 and 8 list the trophic status of the taxa listed in Tables 5 and 7). One of the important features of any detritus-based system is the continuous recycling of materials (Figure 12a). In the abyssal benthos, neither the rates at which important processes occur, the factors that control the trophic directions of energy flow, nor the factors that control the taxonomic directions of the energy flow are understood. Preliminary indications, however, are that these processes occur relatively slowly in the deep sea.

Present knowledge indicates that nutrients in the bottom water can be returned to the surface waters by two mechanisms: the long-term (about 2000 years) movement of bottom waters to the surface and the vertical migration of bottom-dwelling animals which are consumed by predators occurring higher in the water column. Rat-tail fish and amphipods are two benthopelagic organisms found in the DOMES area that are known to migrate vertically to shallower depths. Rat-tails have been caught from 50 to 730 m (164 to 2,395 feet) and amphipods up to 400 m (1,320 feet) above the abyssal floor of the North Pacific Ocean (Smith _et al._ 1979). In the deep sea, the organic detritus that is not utilized by the benthos, bacteria, or other bottom microorganisms is lost forever to the ecosystem by burial in the sedimentary column.

The destruction of detritus feeders during mining could thus interrupt a small portion of the natural mechanism for the regeneration of nutrients in the deep sea. The fact that only about one percent of the DOMES area will be affected by first generation mining over a 20-year period, the dispersing effects of natural horizontal water currents, and the limited linkage between benthic and water column food webs should make the loss of nutrients undetectable. This interruption in nutrient recycling should thus be rendered insignificant with no adverse effect on the food chain of the upper waters. Nevertheless, the concern will be addressed during future research (see Section II.C.2.1).

II.A.1.3 Existing human activities

Major human activities occurring in the DOMES area are commercial fishing, marine transportation, oceanographic research, and, because of the proximity of the area to the U.S. naval base in the Hawaiian Islands, perhaps naval maneuvers. These activities, plus recreational activities and oil and gas operations, could also occur in transportation corridors to and from shore facilities. NOAA does not expect any significant effect on these activities from deep seabed mining.

II.A.1.3.1 Commercial fishing

Commercial fishing includes five United States and Japanese tuna and billfish industries: Japanese longline fishery; purse-seine and LIVE-BAIT FISHERIES in the eastern Pacific dominated by U.S.; Hawaiian-based LONG-LINE FISHERY; and Japanese live-bait fishery (Figure 14). Shomura's (1980, Personal communication) data on estimated catch and EX-VESSEL VALUE from several of these DOMES area fisheries from 1974 to 1978 show that these industries are quite sizeable, amounting to approximately 15,550 MT (17,105 tons) and $36,129,000 in 1977 alone. Longlined bigeye tuna caught by the Japanese account for 49 percent of the weight and 61 percent of the value. Only 4,932 MT (5,425 tons) worth $7,152,000 was caught by the United States.

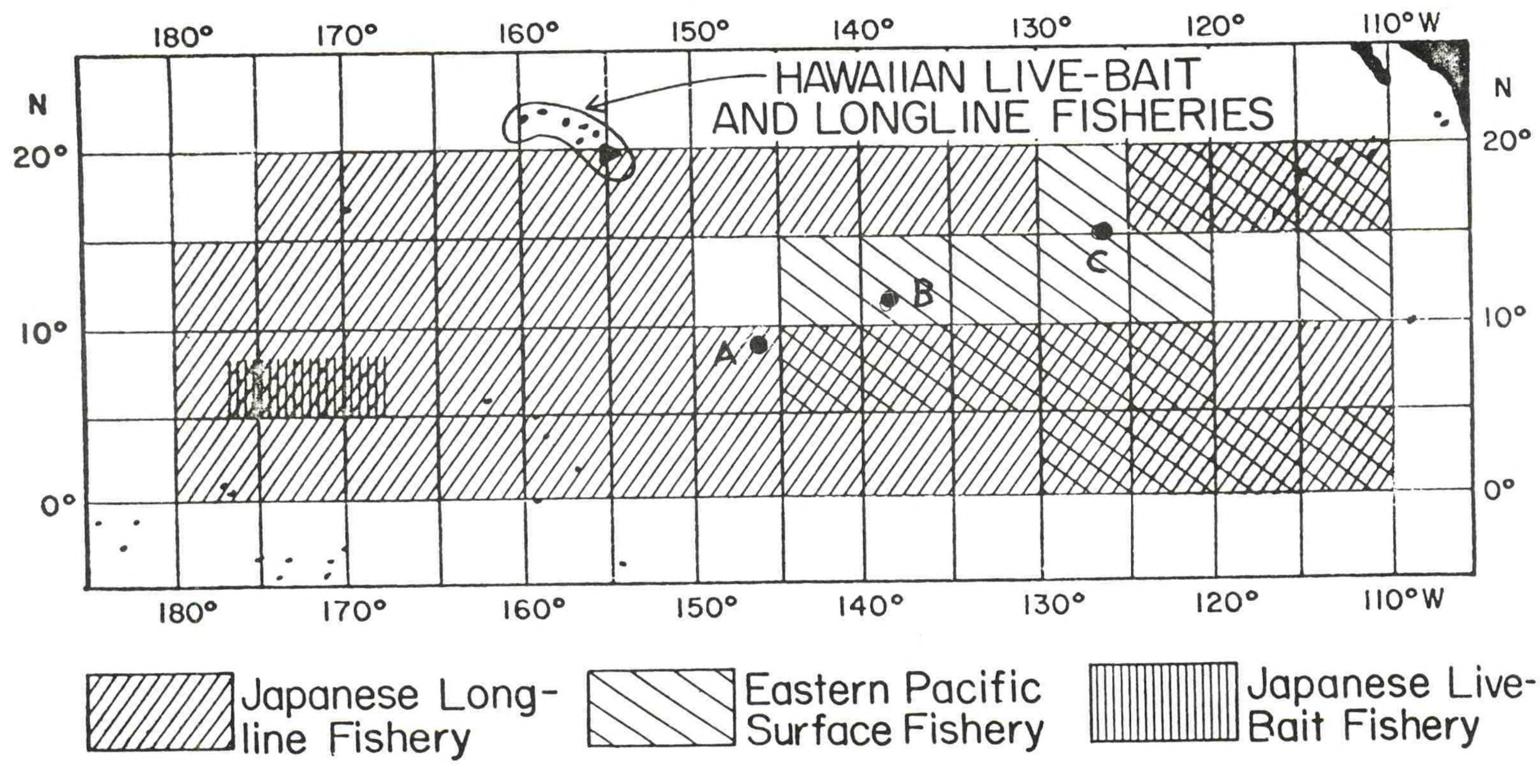

Figure 14.--Areas and types of commercial fishing, with DOMES Sites A, B, and C (Blackburn, 1976).

II.A.1.3.2 Research

Oceanographic and meteorologic research cruises have passed through or been on station in the DOMES area since the voyage of HMS CHALLENGER in 1872-76. Since then, hundreds of cruises by private and government vessels of the U.S. and foreign nations have traversed and/or obtained data in the area (Documentation Associates, 1977). Ships from Sweden, Japan, Russia, Denmark, Canada, Germany, and South Korea have also conducted research in the DOMES area.

A large portion of the most recent private, government (DOMES I and II), and industry research has addressed the origin and distribution of manganese nodules, environmental effects of commercial mining, equatorial current systems, the Intertropical Convergence Zone, the Clarion and Clipperton fracture zones, and tropical/subtropical marine biology and geology. Seabed mining will not interfere with these activities; on the contrary, mining and monitoring will provide a significant opportunity for greater research in the area.

II.A.1.3.3 Marine transportation

The DOMES area is criss-crossed by several major shipping lanes of U.S. and foreign nations (Figure 15). Frequency of transit data are not available.

II.A.1.3.4 Naval operations

U.S. Navy operations could occur in the DOMES area. The Defense Mapping Agency's Hydrographic Center is responsible for issuing a warning to shipping in the form of a Notice to Mariners in case of naval maneuvers or any other hazard to vessel operations. Special submarine operation areas exist in the areas around the Hawaiian Islands and are clearly marked on navigation charts.

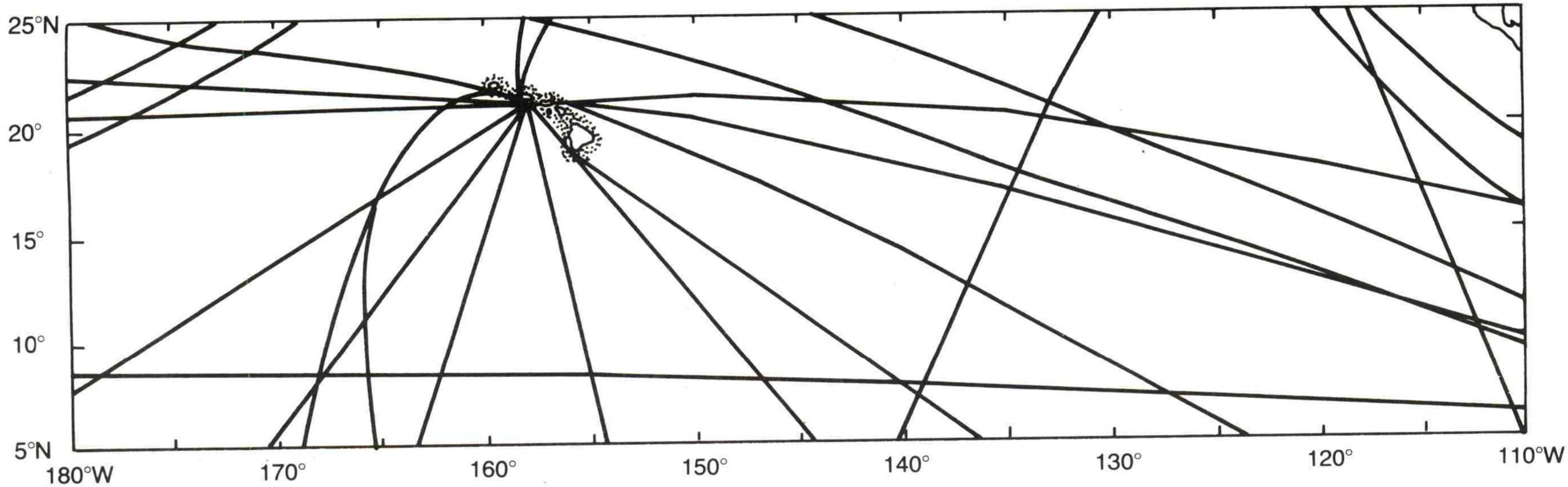

Figure 15.--Major U.S. and foreign shipping lanes in DOMES area (U.S. Department of Commerce, Maritime Administration and Defense Mapping Agency Hydrographic Center, 1979).

II.A.2 Transportation corridors

The area of the ocean in which nodule transport vessels could travel from a mine site to a marine terminal processing plant is enormous (Figure 16). The environmental characteristics of the precise transportation corridor will be examined by NOAA during preparation of the site-specific EIS required for each commercial recovery permit. Special consideration should be given to natural resources (see Appendix 8 for endangered and threatened species) and human activities that exist in corridors but not in the DOMES area.

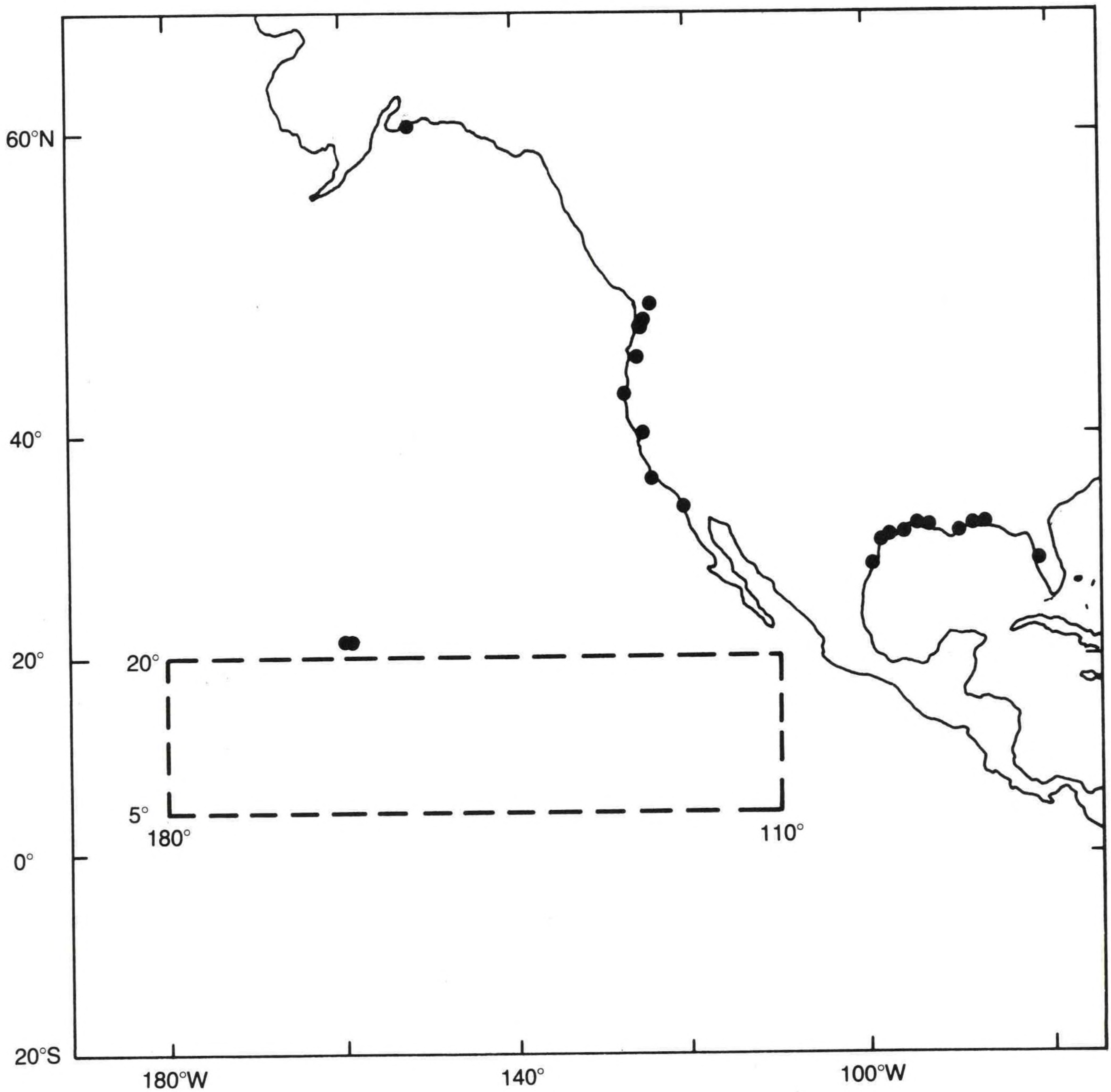

Figure 16.--Geographic relationship between DOMES area and representative potential U.S. processing sites.

II.B Mining Activity Impingement on Environment

This section summarizes how first generation mining activities (Appendix 3) could affect the DOMES area and the transportation corridors that lead to processing plant marine terminals. Section II.C, Environmental Consequences and Mitigation Measures, discusses the effects of each facet of impingement.

II.B.1 DOMES Area

Within the DOMES area, five types of activities could be carried out: mining; nodule transfer; offshore processing; offshore waste disposal; and offshore support activities. Each is briefly discussed below, with emphasis on mining.

II.B.1.1 Mining

Although some of the environmental concerns associated with mining (Section II.C) are caused by the actual contact of the collector as it sweeps the seafloor in nearly abutting swaths (Section II.C.2.1), most of the concerns relate either to bottom or surface discharge plumes as characterized in this section. The design and operation of a hydraulic deep seabed mining system (Appendix 3) can be visualized as a "black box" that collects materials from the seafloor, transports them to the surface, and reintroduces all but the nodules to the environment in two different locations -- just above the seafloor and into surface waters. The net result is direct collector disturbance on the seafloor and two sediment plumes (Figure 17).

The operating characteristics associated with mining were discussed with industry during a public meeting (DOMES Project, 1976) where agreements were reached on likely ranges of operational factors such as depth of collector cut. Quantities of material were then evaluated and used as one basis for developing the DOMES program strategy (National Oceanic and Atmospheric Administration, 1976).

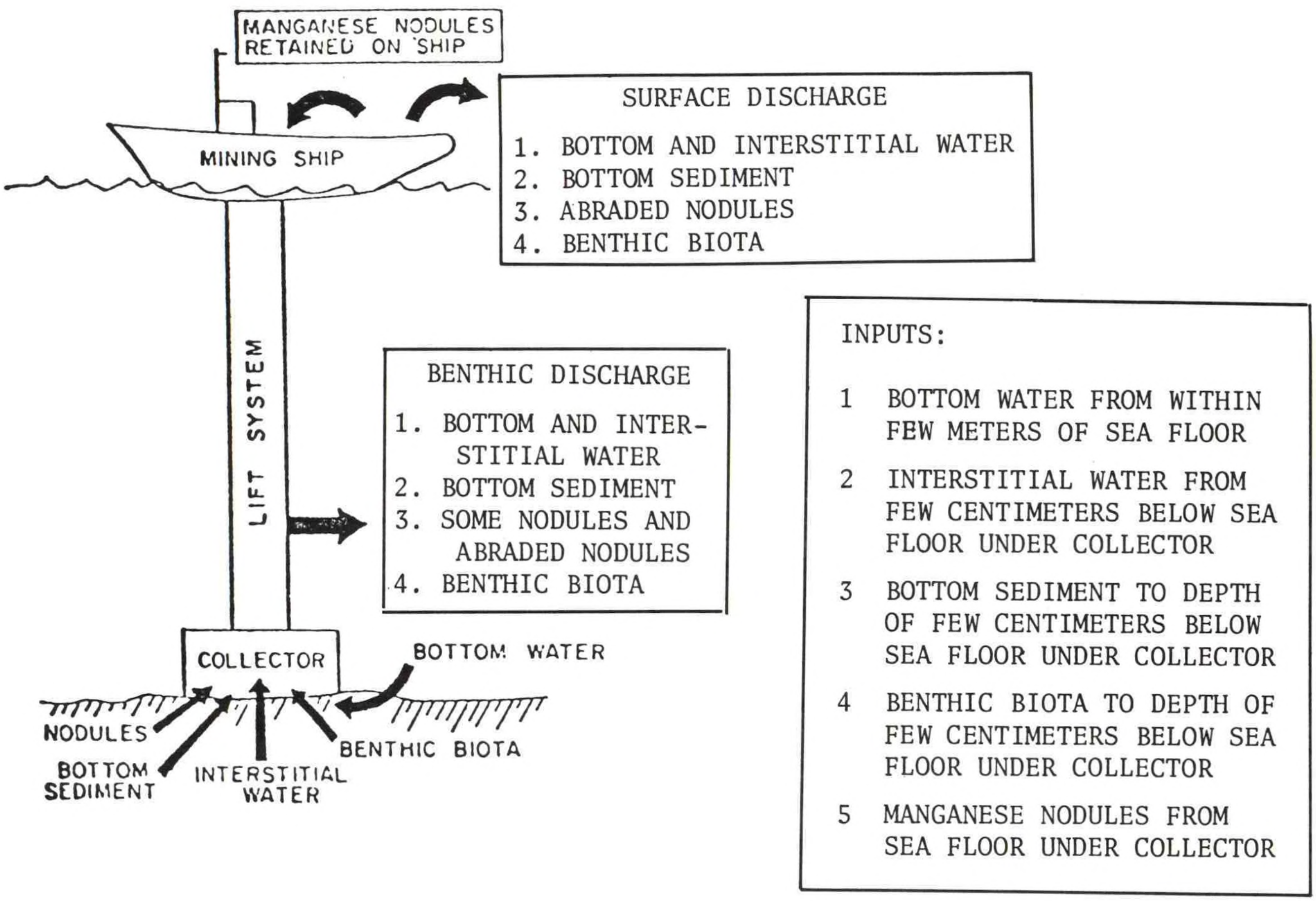

Figure 17.--Schematic diagram showing input and output of a hydraulic mining system (Ozturgut et al. 1978).

Many possible significant mining effects were addressed in the latter report; however, subsequent evaluation of the DOMES I findings led to a focused attention on fewer but more probable effects for research during DOMES II. For example, the change in water characteristics from the surface plume was predicted as a basis for developing a monitoring strategy for the pilot-scale industrial mining tests.

NOAA monitored the tests of two consortia in 1978, Ocean Management, Inc. (OMI) (Burns _et al._ 1980) and Ocean Mining Associates (OMA) (Ozturgut _et al._ 1980). Monitoring operations were carried out on the mining ships by NOAA personnel, and on the NOAA research vessel OCEANOGRAPHER. Because of the technical difficulties associated with the development of new technology, actual test mining totaled only five days, with two days being the longest period of continuous pumping of nodules.

Mining operations were conducted at Site A (Figure 1, Executive Summary) from March to May 1978 and at Site C from October to November 1978. Surface effects were examined at both sites (see also Lavelle _et al._ 1980); benthic effects at Site A only. Two types of pumping were tested at Site A -- hydraulic and air lift; the Site C test involved air lift only.

The monitoring strategy entailed observations made before, during, and after the pilot mining tests. Benthic biota were sampled before and after mining. Bottom-mounted instrument arrays were moored near the test site to detect the presence of a benthic plume.

In discussing the results of the DOMES study, it is useful to categorize the mining effects in terms of NEAR-FIELD or far-field and SHORT-TERM and long-term. Industry tests at sea lasted several days. Equipment was only one-fifth of commercial scale, and production averaged 1/14 of commercial scale. Resulting limitations in the data base must be acknowledged. Adverse effects of a potentially catastrophic nature were not detected in these DOMES II tests. The monitoring of the far-field and long-term effects will be accomplished during future tests as well as during commercial operations (Sections II.C.2, 3, 4).

II.B.1.1.1 Surface discharge

In both mining tests, discharge was over the side of the mining vessel onto the sea surface, a drop of 3 to 5 m (Figure 18). The plume that developed in the surface mixed layer following discharge was long and slender (see Appendix 9). By the time the plume had travelled for about 5 hours, the concentration of suspended particulate matter near the ocean surface was so close to ambient that the plume could no longer be detected with a NEPHELOMETER. By then the plume was about 1 km (0.55 mi) wide and 4 km (2.2 mi) long (Figure 19).

The plume appeared to sink quickly to a depth of about 20 m (66 ft) before beginning to spread out and drift with the current. The fine particles seemed to settle more rapidly than had been expected, suggesting either incomplete disaggregation of the particles during mining or else flocculation after discharge (Ozturgut et al. 1981a). It was not clear whether the plume passed through the pycnocline or spread out on it. These uncertainties will be addressed during the future monitoring of industrial demonstration scale mining tests (Section II.C.3.2.2).

During a commercial mining operation, it is estimated that the solid fraction of the mining effluent, consisting mainly of bottom sediments and some abraded nodule material, will be discharged at the rate shown in Table 11. The liquid fraction of the surface discharge will be bottom water with a salinity of 34.7 o/oo and a temperature of 7°C (44.6°F); the bulk density of the surface discharge will be approximately 1.06 g/cm^3 (0.04 lbs/in^3).

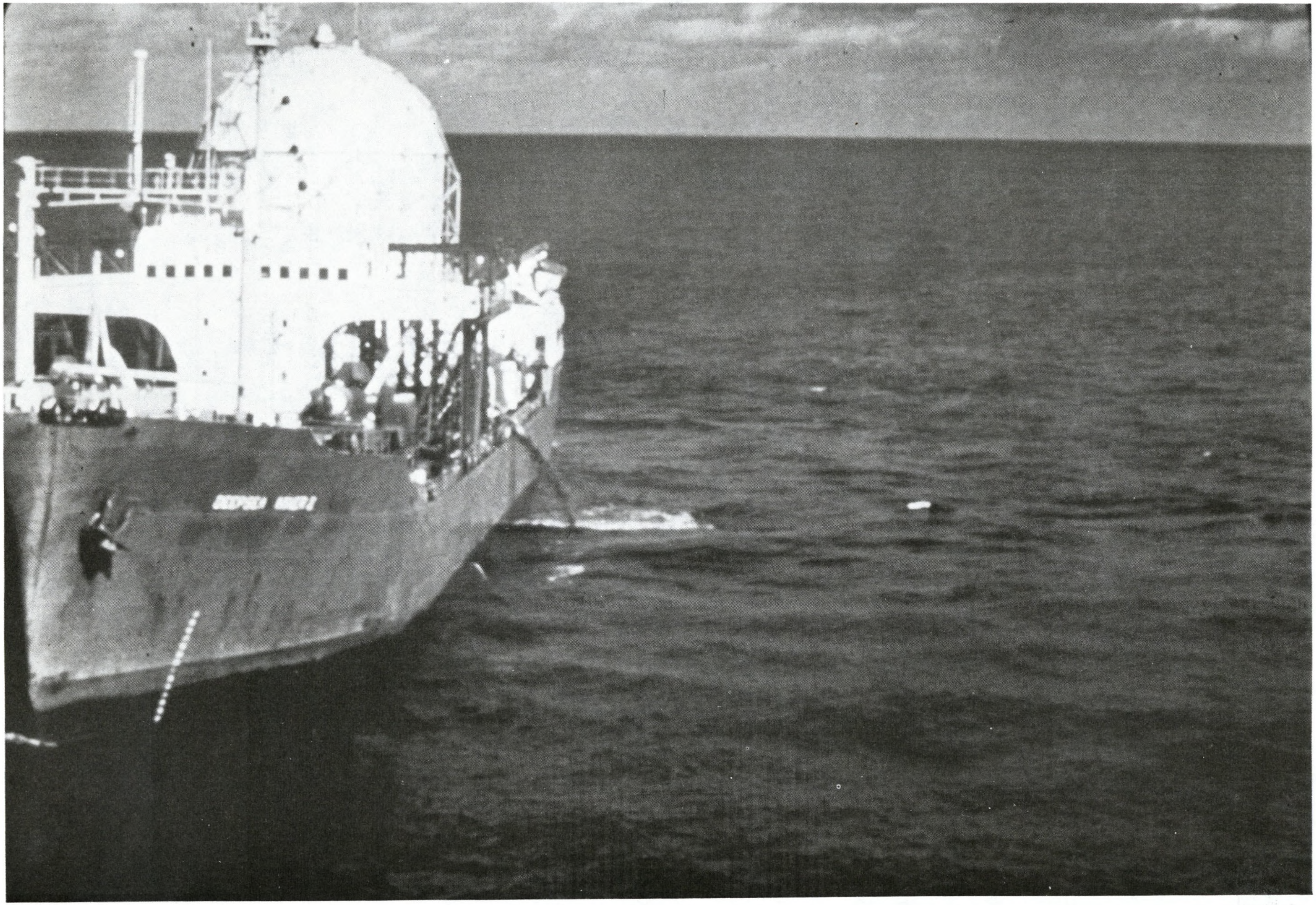

Figure 18.--This photo, taken during test mining, shows the mining vessel Deepsea Miner II and the discharge pipe over the side.

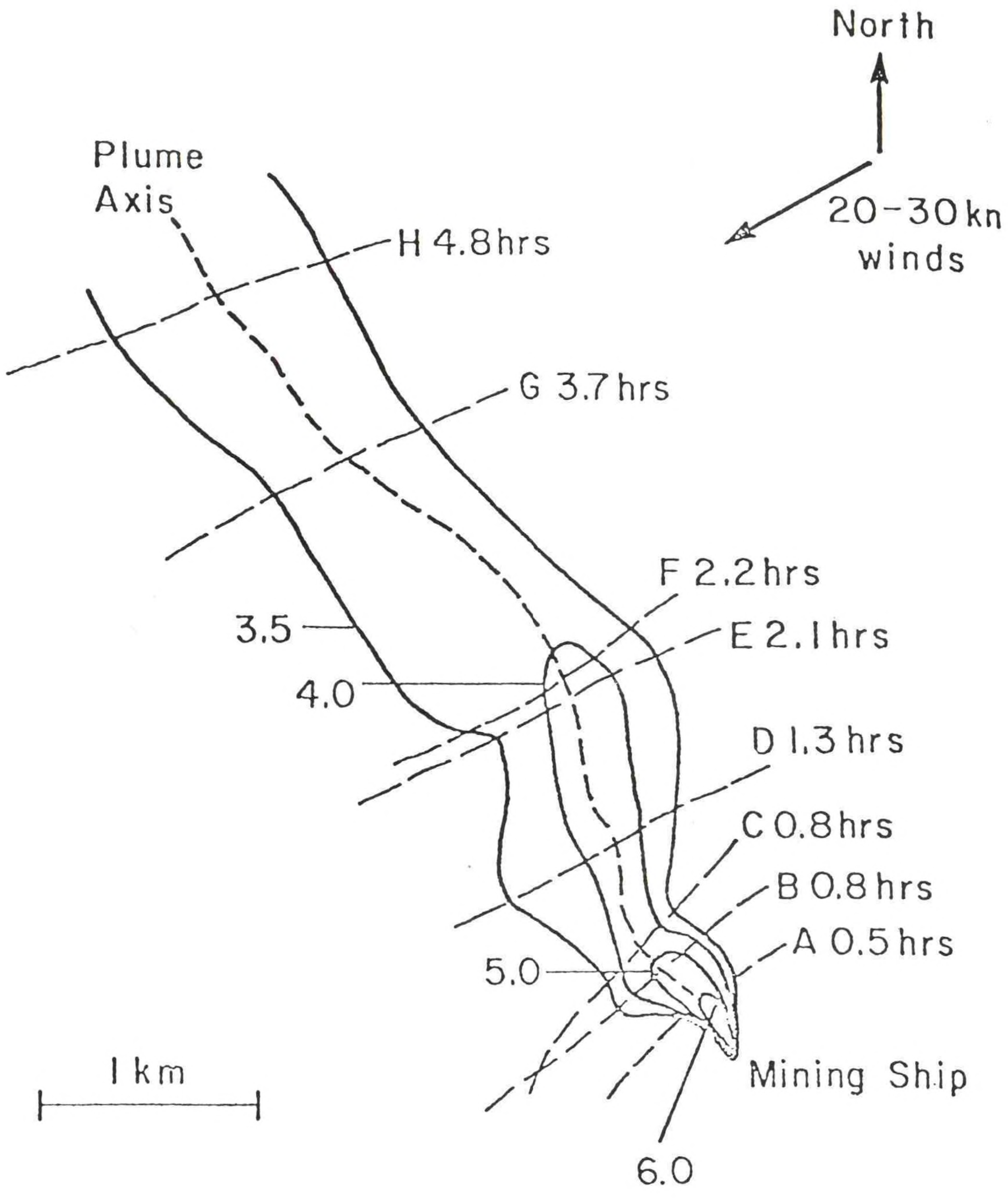

Figure 19.--Planar view of the plume reconstructed from transects through the test mining plume. Contour levels are nephelometer voltages. Background voltage is approximately 3.3 (Burns et al. 1980).

Table 11. Daily discharges from a 5,000 dry MT/day mining ship (Ozturgut et al. 1981b.)

	Surface Discharge	Bottom Discharge
Water	2.5×10^4 m^3	8×10^4 m^3*
Sediment	1.6×10^3 MT (dry)	5.2×10^4 MT (dry)
Abraded Nodules	2.5×10^2 MT (dry)	2.5×10^2 MT (dry)

* National Oceanic and Atmospheric Administration, 1976

The ratio of nodule material to sediments in the mining discharge will be dependent upon the nodule-sediment separation system employed on the mining ship (Ozturgut et al. 1981b).

The dispersion models for commercial mining operations predict length scales of 85 km (46.8 nmi) and widths of 10 to 20 km (5.5 to 11 nmi) for the surface plume, as defined by an increase in particulate concentration at the surface of lug/l over ambient. Along the plume axis, at the average mixed layer depth of 50 m (165 ft), particulate concentrations are expected to be less than 1,000 ug/l; at a 100 m (330 ft) depth, concentrations are not expected to exceed 300 ug/l (Lavelle and Ozturgut, 1981).

II.B.1.1.2 Bottom discharge

Although it was not possible to track and sample the benthic plume as directly as the surface plume, assembled observations and data permit some conclusions concerning the character and behavior of the benthic plume. The collector disturbance consists of both a track (several cm deep, several m wide) and associated heavy redepositions; the commercial scale tracks will be around 20 m or 66 ft wide. Observations at site A revealed an extremely localized area where bottom material was reworked and pushed aside by the collector. This phenomenon is suggested in a photograph (Figure 20) donated by Deepsea Ventures, Inc. Heavy redeposition is closely associated with the collector track and rapid resettling of most of the material initially stirred up by the collector.

The benthic plume, after it leaves the vicinity of the collector, is principally composed of resuspended particulates fine enough to remain in suspension after the initial redeposition and which are moved away by local bottom currents. This portion of the plume is called a "rain of fines," in the PEIS.

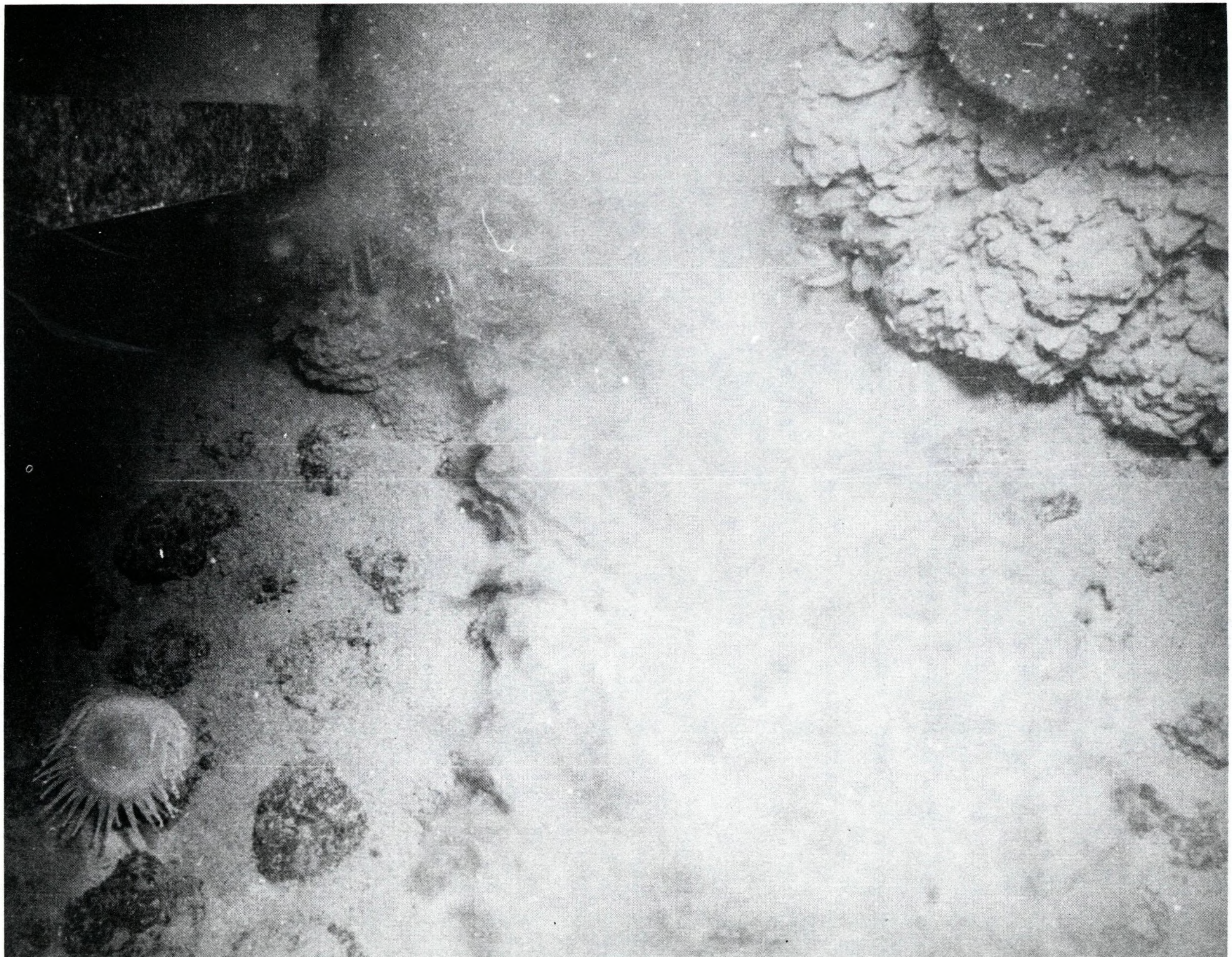

Figure 20.--Photo of benthic plume and benthic organism taken during testing of mining equipment (Courtesy of Deepsea Ventures, Inc.).

Plume dimensions observed during the Site A test were of the order of tens of meters thick with some evidence of an increasing thickness and width with age. The test plume persisted for an order of days and was observed by bottom-mounted nephelometers to have moved distances of at least 10 km (5.5 nmi) away from the source. Particulate concentrations were greater than ambient up to 50 m (165 ft) above the seafloor.

Additional information on the general character of the benthic plume has been inferred from closed circuit television and photographs. Determination of the ultimate distance traveled by the plume and its persistence were not possible due to the limitations of monitoring technology and the limited resources available. However, it was determined that the plume is chemically detectable far beyond the point of visibility to humans or detectable impacts to marine life.

The benthic plume consists of sediments disturbed by the collector and redeposited over a matter of days to weeks. The magnitude of this discharge, given furrow depth of 10 cm (4 in) and collection speed of 1 m/s (3.3 ft/s) was shown earlier on Table 11. The thickness of the plume can be expected to be several times the height of the collector and will extend perhaps more than 100 km (55 nmi) in continuous mining operations (Lavelle et al. 1981). In at least its initial stage, the plume will also contain an estimated 400 kg (880 lbs) of macerated benthos trapped daily by the collector.

During commercial mining operations, it is envisioned that a mining vessel will annually mine in a small area (perhaps 30 km by 30 km or 16.5 nmi by 16.5 nmi) that has been sampled in detail. Increased suspended loads will likely be detectable to distances up to at least 100 km (55 nmi) from the mining region (Figure 21). Benthic areas of 3,000 to 5,000 km^2 (875 to 1,458 nmi^2) per vessel may have elevated suspended loads over the mining period of one year (Lavelle et al. 1981).

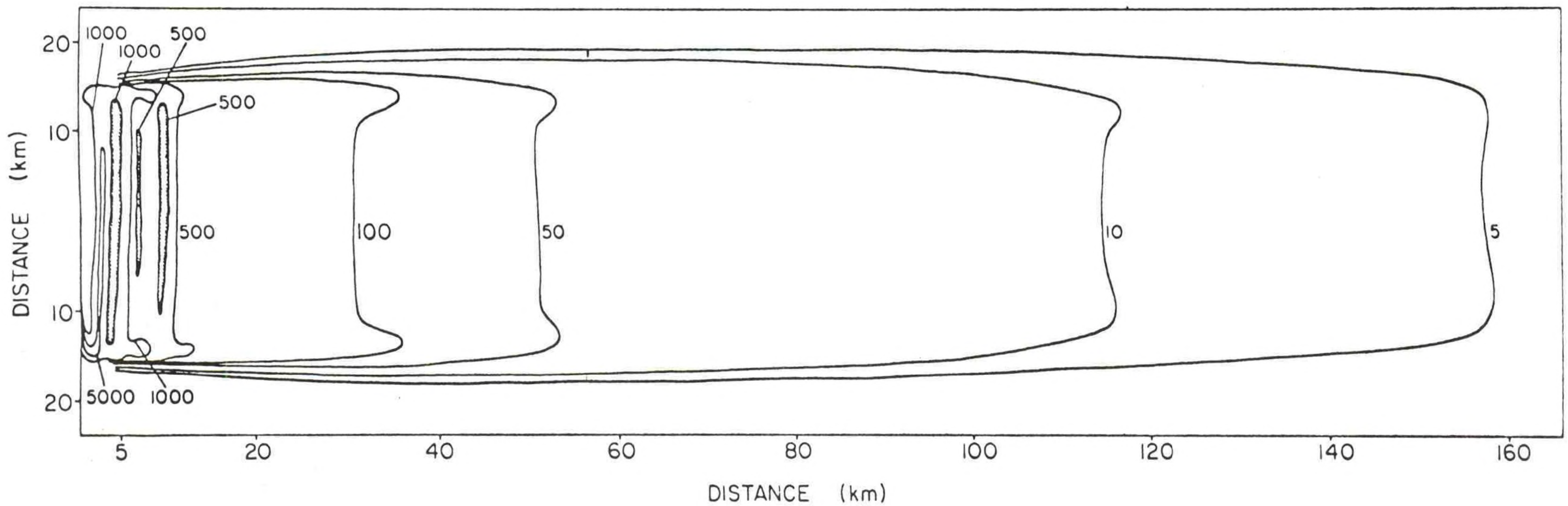

Figure 21.--Estimated concentration of particulates above ambient in suspension in commercial scale benthic plume (μg/1). Collector is assumed to be travelling in a rectangular pattern (top to bottom); bottom current (left to right) assumed to be 4 cm/s (Lavelle et al., 1981).

II.B.1.2 Nodule transfer

Nodules could be transferred from mine ship to transport carrier either through a slurry hose, conveyor, or pneumatic hose (see Appendix 3.2.3 for related discussion). The slurry system appears to be preferred by industry at this time.

II.B.1.3 Offshore processing

At-sea processing of nodules would require the development of such new technology that it is considered not likely for first generation mining; partial processing is a possibility. This subject is discussed in Appendix 3, Sec. 3.1.2. If at-sea processing of either type is proposed, a supplement to this PEIS will be prepared.

II.B.1.4 Ocean waste disposal

Ocean disposal technology is available but would have to be adapted to handle the particular types and quantities of waste that will be produced. The main questions relating to ocean dumping of nodule processing wastes are legal and technical. Under the Marine Protection, Research, and Sanctuaries Act, a permit is required to transport material from the U.S. to sea for dumping. In order to receive such a permit, the applicant would have to demonstrate that no unreasonable degradation or endangerment to human health would result from the ocean dumping operation and that there are no other reasonable alternatives if the material is hazardous or toxic. Given all the unknowns concerning the characteristics of the nodule processing wastes, it is not possible to say at this time whether or not ocean dumping would be allowed.

The use of an ocean outfall pipe as a means of nearshore ocean disposal is also a possibility. This method is presently being used for the disposal of copper processing tailings at the Utah International Island Copper Project on Vancouver Island, Canada (Western Miner, 1974). Such a point source disposal method requires a National Pollutant Discharge Elimination System (NPDES) permit from the EPA under the Clean Water Act. The wastes must meet the ocean discharge criteria established by EPA under that Act, a fact that will depend on the determination of the exact nature of the process wastes.

Because of climatic and economic factors and the problem of locating suitable land disposal sites, the nodule mining industry is likely to seriously consider ocean disposal as a potential waste disposal method. (see Appendix 3.3.4.3.3 and 3.3.4.3.4).

Ocean disposal of processing wastes would essentially preclude future access to the wastes. Wastes from so-called three-metal processes would contain manganese which could become valuable in the future. This subject is discussed in Section II.D.1.1 as "Resource Conservation Issue" number 3.

II.B.1.5 Offshore support activities

The annual operations by one consortium in each mine site are likely to involve one or two mine ships and two to eight nodule transport carriers, one on-site exploration vessel, and perhaps one fast service vessel for logistics and personnel transfer. The nodule transports would haul less than 2,000 MT or 2,200 tons of fuel per carrier to the mine ships on their return trips from port.

II.B.2 <u>Transportation</u>

An average of one nodule transport ship per day will travel between port and the mine site during first generation mining. NOAA has determined that this level of vessel traffic should not have a significant effect on the environment. Nonetheless, this issue will be addressed in site-specific EISs.

Offshore waste disposal, discussed above in Section II.B.1.4, also applies to the transportation corridors linking onshore marine terminals and mine sites. A different approach could involve an ocean outfall, especially in deep water nearshore locations.

II.C Environmental Consequences and Mitigation Measures

II.C.1 Effects Without Potential for Adverse or Significant Impacts

Since 1972, NOAA research in the DOMES area has investigated a number of natural resource and human activity issues which could be affected by deep seabed mining. Most of these effects do not appear to have the potential for significant or adverse impact. NOAA environmental documents on license/permit applications will refer to the following analysis on which this conclusion is based, rather than repeat it in site-specific EISs. Findings of no potential significant impact may be extended to other impacts as research continues. On the other hand, monitoring may result in certain low probability effects becoming potentially significant. This event would trigger the analysis discussed in Section II.C.4.

II.C.1.1 Transportation corridors to and from shore facilities

It is anticipated that an average of one nodule transport ship per day could cross these corridors during first generation mining.

II.C.1.1.1 Vessel pollution

Because the ore carriers may haul fuel to the mining ship on their return trips, the possibility exists that fuel such as diesel oil could be spilled on occasion.

Bulk carrying ships, especially those built in the U.S. and flying the U.S. flag, are subject to extensive safety and pollution abatement regulations administered by the U.S. Coast Guard (USCG), the American Bureau of Shipping (ABS), the Environmental Protection Agency (EPA), and the Intergovernmental Maritime Consultative Organization (IMCO). In addition, the Maritime Administration (Mar Ad) of the U.S. Department of Commerce has its own requirements for safe operation and pollution control for ships built in the United States with a Construction Differential Subsidy (CDS), though nothing is at present directed specifically toward nodule transporters.

The USCG is the primary domestic agency responsible for the implementation and enforcement of Federal laws pertaining to maritime safety and control of vessel source marine pollution. The USCG maintains aids to navigation; establishes and enforces rules of the road and vessel traffic separation schemes within United States waters; ensures proper manning, enforces observance of required safety standards, including design and construction standards, on U.S. flag vessels; enforces regulations relating to the intentional and accidental discharge of oil and other hazardous substances from vessels; responds to marine casualties; coordinates efforts to control and clean up oil and other hazardous substance spills; and denies access to U.S. ports by foreign flag vessels which fail to comply with approved standards on navigation, discharges of oil or hazardous substances, and manning requirements.

Foreign flag vessels may be used under a U.S. license or permit for exploration and transport of nodules. Mining vessels, processing vessels, and at least one ore transport per operation must be U.S. flag. The Act imposes no restriction on the nationality of non-U.S. flag vessels.

The rules of the American Bureau of Shipping (ABS) prescribe standards for the design and construction of the hull structure, main propulsion machinery, and vital auxiliary equipment for all types of merchant vessels. Where there is sufficient need, specific rules are developed for specialized vessels, such as dry and liquid bulk cargo carriers, ore carriers, etc. Most of the basic requirements will apply to nodule transports.

The need for international agreement on measures curbing the growing volume of pollution from ships is reflected in various agreements reached over the last several decades. Foremost among these are the conventions and standards developed and adopted by the Intergovernmental Maritime Consultative Organization (IMCO). IMCO is a specialized agency of the United Nations whose purpose is to achieve the highest practicable standards of maritime safety and efficient navigation by facilitating cooperation among governments in technical maritime matters relating to shipping.

Most maritime nations are members of IMCO and are parties to the principal safety and pollution conventions for which IMCO is depository. These include the Safety of Life at Sea Convention (SOLOS '74, and its 1978 Protocol), Collision Regulations, and Load Lines Convention. In addition, a new Treaty, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, was signed in 1978. Because IMCO is only a consultative organization, the various conventions must be adopted and enforced by the member governments. Accepted and properly enforced, these conventions would constitute a level of safety regulations comparable to that of the United States. The IMCO conventions do not establish as rigorous an environmental regime as that of the U.S. under the Clean Water Act, Clean Air Act, and certain discharge limits established and enforced by the USCG. However, potential seabed mining countries generally have safety regimes comparable to that of the United States and environmental laws that are less strict. Problems, if any, are likely to arise with "flag of convenience" countries which, although they often are parties to the major IMCO conventions, frequently have a poor record of enforcement.

Enforcement against a foreign flag vessel used in conjunction with a U.S. license or permit may be difficult. International law prohibits a nation from boarding foreign flag vessels on the high seas without expressed permission of the flag state. The appropriate sanction to ensure compliance by a foreign flag vessel would be to proceed against the licensee or permittee in the event of non-compliance or to prohibit their use of U.S. ports. The Act gives NOAA the authority to impose regulations and terms, conditions, and restrictions on licensees and permittees that would require them to conform their safety and environmental measures aboard a foreign flag vessel to U.S. recognized standards. Failure to comply would constitute a breach of the terms of the license. The only apparent difficulty that may arise would be a conflict between U.S. requirements and those of the flag state.

II.C.1.1.2 Effects on marine mammals and endangered species

In transportation corridors, especially nearshore, vessels associated with the mining operation could pass by or cross through migration routes, feeding grounds, HAUL OUTS, breeding areas, or other habitats of marine mammals or sea turtles. The major determinants of impact severity include frequency of vessel transit, species involved, and time of year. For example, off the California coast, vessel traffic into San Francisco Bay or through Santa Barbara Channel could affect California gray whales during certain months of the year when they are migrating (National Oceanic and Atmospheric Administration, 1980 a and b). For the most part, the amount of vessel traffic necessary to affect mammal or turtle activities is unknown.

Although quite unlikely, it is possible that even one vessel could alter normal activities of these species, e.g., frightening hauled-out mammals or scaring migrating whales. The cumulative effects of all vessels should be innocuous unless the traffic becomes concentrated in a critical portion of a species' habitat. The prospects of these impacts will be addressed in detail in the site-specific EIS that must accompany any application for a license or permit.

II.C.1.1.3 Processing waste disposal offshore

The amount of land required for onshore disposal of process wastes is about 140 ha (360a) and 800 ha (2000a) for the estimated 20 year lifetime of the plant for four- and three-metal plants (utilizing tailings ponds) respectively. The potential for spills, leachate seepage, and dusting extends over a larger area (Appendix 3.3.4.3). These potential hazards and the need for large amounts of land would be eliminated by ocean disposal of process wastes. However, many questions must be answered before an applicant could expect to receive the required permits.

If the waste is to be generated onshore and transported to sea for dumping, Title I of the Marine Protection, Research, and Sanctuaries Act (the "Ocean Dumping Act") would apply. If onshore wastes are to be discharged into deep water nearshore areas through an ocean outfall, the Clean Water Act would apply.

The research plan (National Oceanic and Atmospheric Administration, 1981a) developed in response to the Deep Seabed Hard Mineral Resources Act recognizes the need for information on the character of the wastes as well as the physical and chemical effects to be expected when the wastes are discharged into seawater. The nodule as mined is considered inert (although it has not yet been established that trace metals from nodule fines do not enter zooplankton tissue) but the metallurgical processes that remove the value metals may render the wastes chemically active.

Research to test the toxicity of discharged wastes may involve limited at-sea test dumping of wastes generated during small scale onshore processing tests. Results of the research program will be incorporated into an amendment to this PEIS, if appropriate.

II.C.1.2 DOMES area

II.C.1.2.1 Existing human activities

The major human activities in the DOMES area are commercial fishing, marine transportation, oceanographic research, and naval operations (see Section II.A.1.3). The main concern of mining on commercial fishing involves the unresolved effect of the surface plume on fish larvae [Section II.C.2

below and the Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a)]. NOAA does not expect any significant effect on the remaining activities to result from deep seabed mining.

II.C.1.2.2 Proposed deep seabed mining activities

II.C.1.2.2.1 Nodule transfer

The primary environmental effect associated with the at-sea transportation segment of the mining cycle (see Appendix 3.2) will involve the transfer of nodules from the mining ship to the ore carriers. This is likely to entail nodules being pumped in a sea water slurry until the carriers' holds are filled; the cargo will then be dewatered. These periodic, short duration events will in effect return sea surface water to the surface; however, the character of the water will have been changed. For example, any entrained fine particles released during dewatering will contribute slightly to the particles already being introduced via surface discharge (Section II.B.1.1). These periodic, short duration events could be eliminated by requiring the use of a closed cycle system that retains water draining from the hold and returns it to a holding tank for reuse.

Accidental rupture of the slurry hose would dump nodules and fine particles into the sea surface; transfer pumps would immediately be stopped and the amount of loss should be negligible.

II.C.1.2.2.2 Processing offshore

Processing at-sea is not expected to be practicable during first generation mining (Appendix 3.1.2). Should an applicant's request for a permit include such a plan, a supplement to this PEIS will be prepared.

II.C.1.2.2.3 Processing waste disposal offshore

This subject, as disscused above in Section II.C.1.1.3, is applicable here as well.

II.C.1.2.2.4 Offshore support activities

Offshore support operations (Appendix 3.1.3) are not expected to generate any environmental effects and are not discussed further in this PEIS. The slight prospects of vessel accidents involving spills of hazardous materials should be adequately covered by regulations pertaining to the mining vessel. Possible impacts to human activities (Section II.C.1.2.1) are also considered negligible.

II.C.1.2.2.5 Mining effects

As a result of the DOMES mining tests, many mining concerns raised initially have been determined to have a very low probability of creating a negative environmental impact; other concerns appear certain while others are not yet resolved (Table 12). Because the tests were pilot-scale and brief, it is essential that the important findings be validated, as discussed in NOAA's Five-Year Research Plan (National Oceanic & Atmospheric Administration, 1981a) and Deep Seabed Mining Technical Guidance Document (National Oceanic & Atmospheric Administration, 1981b), during the mining system endurance tests industry will conduct prior to embarking on commercial mining. The status of concerns in Table 12 is discussed below in terms of what the concern means, how it was examined during DOMES, and the outlook.

-- Low Probability of Biological Impacts

1. Light From Collector

Concern:

Light associated with the collector could affect organisms that have a natural behavioral response to light.

Investigation:

There is very little natural light below 1,000 m (3,300 ft). Hence many deep sea organisms have developed bioluminescent capabilities. Bioluminescence

Table 12. Deep seabed mining perturbations and environmental impact concerns

MINING PERTURBATIONS

	STATUS OF CONCERNS*	BENTHIC IMPACT: COLLECTOR CONTACT	BENTHIC IMPACT: BENTHIC PLUME	SURFACE DISCHARGE: PARTICULATES	SURFACE DISCHARGE: DISSOLVED SUBSTANCES
CONCERNS WITHOUT POTENTIAL FOR SIGNIFICANT OR ADVERSE IMPACTS	Low Probability of Impacts	Light from collector	Nutrient or trace metal increase Oxygen demand	Bacteria growth deplete oxygen Alter phytoplankton species composition Affect fish Zooplankton mortality and species composition and abundance changes in plume Trace metals entry into food web	Trace metals effects on phytoplankton Nutrient increase cause phytoplankton blooms Airlift caused embolisms
	Impacts Not Yet Resolved	Not Applicable	Not applicable	Pycnocline accumulation	Not applicable
	Potentially Beneficial Effects	Additional food supply for bottom scavengers	Not applicable	Bacteria increase food supply for zooplankton Filterfeeding zooplankton fecal pellets clean up plume	Not applicable
	Certain Impact Without Significant Adverse Effects	Not applicable	Not applicable	Increased turbidity reduce productivity	Not applicable
CONCERNS WITH POTENTIAL FOR SIGNIFICANT OR ADVERSE IMPACTS	Certain Impacts	Destroy benthos in and near track	Not applicable	Not applicable	Not applicable
	Unresolved Impacts	Not applicable	Blanket benthos; dilute food supply away from mine-site sub-areas	Affect fish larvae	Not applicable

*NOTE: Status of concerns is to be verified during demonstration-scale mining system tests, prior to commercial mining serves as a lure for prey, a defense against predators, an aid in species recognition, and an aid in illuminating potential food sources.

Observations from submersibles indicate that fish exposed to bright artificial light may be temporarily mesmerized.

Outlook:

Collector light may affect the reaction of species to the collector. Motile species in the naturally dark benthic environment may move away from the collector while other species may be attracted. The exact impact of this light has not yet been determined but its effect is expected to be temporary and localized. Accordingly, the issue is not addressed either in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) or in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b).

2. Nutrient or Trace Metal Increases from Benthic Plume

Concern:

Mining will release small amounts of INTERSTITIAL WATER from seafloor sediments. Interstitial water may be chemically different (nutrients and trace metals) from bottom water.

Investigation:

Laboratory analysis shows that interstitial water within the upper 20 cm (8 in) of sediment differs little in chemical composition from bottom water (Richards *et al.* 1976). This similarity indicates that the sediments are not undergoing significant and rapid DIAGENESIS. The only significant exception is a 13-fold increase in the ammonium ion concentration which is produced through bacterial decomposition of organic matter in the sediment (Ozturgut *et al.* 1978).

Outlook:

The amount of interstitial water released by collector disturbance of bottom sediments should be very small, the ammonium ion being quickly diluted or transformed in the bottom water, with no significant chemical nutrient or trace metal increase resulting from the mining disturbance. This issue is not addressed either in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) or in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b).

3. Oxygen Demand from the Benthic Plume

Concern:

Oxygen demand in the lower water column will increase after mining increases particulate organic matter concentrations and attached bacteria. Inorganic particles also will stimulate bacterial growth and oxygen consumption by acting as attachment sites. This increase in oxygen demand could lower dissolved oxygen concentrations in bottom waters.

Investigation:

If the 17 kg c/d (37.4 lbs c/d) of animals macerated or smothered in the mining process were completely oxidized, a BIOCHEMICAL OXYGEN DEMAND of 3,200 l (847 gal) of oxygen would result. This is equivalent to the oxygen dissolved in the bottom 4.4 mm (0.2 in) of the water column and so should have no measurable impact on the dissolved oxygen content of the bottom water (Ozretich, 1981a).

Organic carbon of the sediment is relatively resistant to bacterial attacks (Ozretich, 1981a).

Outlook:

Bottom waters are well oxygenated and should not be affected by increases in oxygen demand due to biodegradation of dead benthic biota. No increased oxygen demand is expected to result from organic carbon in the sediments put into suspension from passage of the collector. This issue is not addressed either in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) or in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b).

4. Bacteria Growth that Depletes Oxygen Concentrations in Surface Waters

Concern:

Increased concentrations of fine particles in the upper waters could also spur bacterial growth and lead to decreased oxygen concentrations. The fine particles can stimulate bacterial growth and oxygen consumption by providing sites for attachment and by accumulating on their surfaces dissolved organic matter which provides nourishment for the bacteria. A decrease in oxygen concentrations in the oxygen minimum zone could lead to anaerobic conditions and the production of hydrogen sulfide.

Investigation:

Estimates of commercial-scale mining operations show that the mining discharge is expected to contain about 76 g/l (0.63 lb/gal) of solids. However, the discharge will be diluted by a factor of 10,000 one hour after discharge and would consume 140 cm^3 O_2/l (32.3 in^3 O_2/gal) of discharge. Laboratory investigations show that if all particulate organic matter were oxidized during the first hour, the oxygen consumed would be less than one percent of that contained in the diluting volume of water. The change in oxygen concentration would be undetectable (Ozretich, 1981b). Experiments conducted with water from the tropical North Pacific indicate that with incubation periods up to one month, nitrate and nitrite are reduced to molecular nitrogen but hydrogen sulfide is never formed (Ozretich and Ozretich, 1978). From theoretical computations, Anderson (1978) concludes that it is unlikely that hydrogen sulfide will ever be produced.

Outlook:

Bacterial growth and increased oxygen demand in the mixed layer is not likely to cause oxygen depletion because of the small amount of oxygen required and the high concentration of oxygen in the upper water layers. A beneficial effect of increased bacterial growth will be its availability for consumption by zooplankton. Hydrogen sulfide is not likely to be produced in the oxygen minimum zone. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Section 3.4.1.6.

5. Alter Phytoplankton Species Composition from Surface Discharge

Concern:

There has been a concern that the surface discharge could affect phytoplankton species composition by a) changing the nutrient content of the surface waters or b) by introducing deep-sea microbes or resting SPORES. Previously dominant species could be replaced by more adaptable species if a permanent, long-term change were to occur in the environment. The long-term introduction of silicate-rich bottom water into the silicate-poor surface waters could lead to an increase in the diatom population in relation to other phytoplankton.

Investigation:

Incubation experiments were conducted using bottom sediments from DOMES Sites A, B, and C at the concentrations estimated for surface discharge points (10 mg/l or 0.0013 oz/gal) during the tests. After 72 hours, species composition was similar in both initial and control samples, and cells that could be identified as having other origins did not contribute significantly to the STANDING STOCK of the phytoplankton. No statistically significant differences were found between the silicate concentration in ambient surface water and the concentration within the surface water of a 1-hour old plume (Chan and Anderson, 1981). No longer term studies have yet been initiated.

Outlook:

Resting spores found in the deep sea were from shallower-dwelling microbes whose settling in deep ocean sediments and re-introduction to surface waters pose no threat. Oceanographers have handled deep-sea samples for over a century without any apparent harm. Generally, deep-sea organisms are very poorly adapted for life in surface waters.

No significant changes in species composition of phytoplankton due to the surface discharge are anticipated during commercial mining. Permanent or long-term changes in the environment should not occur since the nutrient concentration levels should return to ambient levels very near the mining ship. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.1.1 and 3.4.1.1.

6. Affect Fish from Surface Discharge

Concern:

The surface discharge of mining particulates and consequent turbidity in the upper layer could affect the health of fish, by, e.g., altering feeding behavior or affecting respiration by clogging the gills. The discharge can also indirectly affect fish by bringing about changes in the light regime and in lower trophic levels. Several commercially valuable species of tuna and billfish have feeding and spawning grounds in the DOMES area and may be affected by mining particulates (Ozturgut *et al.* 1978).

Investigation:

Laboratory experiments in which two species of tuna were placed in a tank with a continuous flow of seawater showed no ill effects in the tuna during short-term exposures to fine particulate concentrations of 1,000 to 10,000 ug/l (Ozturgut *et al.* 1978). Behavioral responses varied; tuna sometimes avoided turbid areas and sometimes would feed within turbid areas. The turbidity avoidance seemed to be visually controlled.

Outlook:

The mining tests results showed that because the mining introduced solids settled faster than was expected, the surface plume was small and predicted solid concentration levels in the mixed layer to decrease from about 1,000 ug/l to about 10 ug/l above ambient in about four days. Because these concentrations are so low and experiments show no ill effects, such a short-term exposure of fish to these suspended solid concentration levels is not expected to have any effect on fish health.

This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Section 3.4.1.6.

7. Zooplankton Mortality and Species Composition and Abundance Changes in Surface Plume

Concern:

Direct mortality during the one or two days zooplankton might be in the plume could result from ingesting or adsorbing plume particulates. This could modify metabolic activity, clog respiratory surfaces and feeding appendages, or increase energy expended to capture and assimilate food. Because of these stresses, changes could occur in the abundance and/or taxonomic composition of surface zooplankton due to unequal susceptibility of different species.

Investigation:

During a series of laboratory experiments, 12 species of oceanic copepods and one coastal mysid were exposed from one to two days to clay suspensions at concentrations representative of those observed during test mining. Plankton survival data over a broad range of suspended particulate matter concentrations showed no increased mortality at concentrations up to about 10 ppm (Hirota, 1981).

Field studies during DOMES II revealed no increase in plankton mortality within the discharge plume (Hirota, 1981). Statistical analysis of selected zooplankton species in the plume and in control samples suggested that no major changes in species composition or abundance had occurred during exposure to the plume.

Outlook:

Field and laboratory studies provide no evidence suggesting major toxic effects of mining discharge during short exposure times. Because the discharge will be rapidly diluted during commercial mining, no significant adverse effect is expected to occur. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 3.4.1.6, 3.4.1.7, and 3.4.1.8.

8. Potential entry of trace metals into the food web via surface discharge

Concern:

At this time it is not known if trace metals associated with abraded nodule fragments in the surface plume might enter the food web most readily through ingestion by filter feeding zooplankton. Hirota (1981) hypothesizes that absorption of trace metals from nodule fragments ingested by zooplankton could occur and result in food web accumulation. In the latter case, there is a possibility that commercial fish and eventually humans could be affected.

Investigation:

Although incorporation of trace metals into zooplankton from ingestion of abraded nodule fragments was to have been investigated during DOMES, technical difficulties associated with the culture of successive generations of zooplankton for laboratory experiments precluded these investigations.

Outlook:

Although experimental studies show that mining discharges are ingested and defecated by filter feeding macrozooplankton (Hu 1981), no data yet exist on the incorporation of trace metals into body tissues from ingestion of these particles or on long-term effects on zooplankton and their predators. Accordingly, NOAA is examining this concern (National Oceanic and Atmospheric Administration, 1981a) as well as preparing an interpretive report on this subject. Indications based on a National Marine Fisheries Service preliminary review, however, are that the likelihood of zooplankton accumulating trace metals substantially above natural concentrations is low because of the relatively low bioavailability of trace metals associated with inorganic particulate material. If substantial accumulation did occur, however, adverse consequences would tend to be mitigated by (1) the relatively short time (1-3 days) that particles are available for ingestion, (2) the fact that the trace metals associated with nodule fragments (e.g., Fe, Mn, Ni, Cu, Co, Pb and Zn) tend not to be BIOMAGNIFIED in the food web, and (3) the tendency of metals to be excreted by normal biological processes once these organisms were no longer in the discharge plume. For these reasons, it is difficult to conceive that long-term elevated body burdens of trace metals would occur in fish after ingestion of zooplankton. If NOAA's planned research is inconclusive (National Oceanic and Atmospheric Administration, 1981a), mining tests will provide the opportunity by which questions or hypotheses identified in NOAA's research can be addressed. Actually, a combination of monitoring and shipboard and laboratory experimentation may be necessary to assess the potential for food web accumulation of trace metals. Should the test findings reveal a potential problem, NOAA could require that, insofar as practicable and necessary, nodule fines be retained on the mining ship or discharged below the photic zone.

Accordingly, NOAA has tentatively determined that the probability for trace metal assimilation from ingestion of abraded fragments by zooplankton and subsequent food chain transfer leading to an adverse ecological impact is low.

This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.1.4, 3.4.1.4, 3.4.1.6, 3.4.1.7, and 3.4.1.8 and the research plan (National Oceanic and Atmospheric Administration, 1981a).

9. Trace Metal Effects on Phytoplankton in Surface Plume

Concern:

Dissolved trace metals could be introduced into the surface mixed layer by sediments, nodule fragments, or bottom water found in the surface discharge. Such contaminants could be taken up by phytoplankton, thereby inhibiting primary productivity, affecting species composition, and providing entry of toxic metals with subsequent bioaccumulation into higher levels of the marine food chain.

Cobalt, which is a required trace element, could be removed from solution by adsorption onto nodule fragments and thus be unavailable to the microorganisms in the vicinity of the mining discharge.

Investigation:

In laboratory studies, DOMES bottom sediments were resuspended in oxygenated seawater (Ozturgut *et al.*, 1978). Concentrations of nickel, zinc, chromium, iron, copper, manganese, and aluminum could not be detected above ambient. Subsequently, Benjamin (1981) determined the amounts of copper, cadmium, and cobalt released from crushed nodules as a function of time, pH, and nodule concentration. In the pH range of seawater, the amounts of cobalt, copper, and cadmium released were below the analytical detection limit even in the highest nodule concentration (20 g/l). Benjamin (1981) also determined that cobalt is more likely to be removed from seawater by adsorption onto nodule surfaces than to remain in solution.

Outlook:

Since the release of trace metals from surface discharges has not been detected, effects on phytoplankton from uptake are not expected to occur.

Due to the rapid dilution of the discharge and the resultant low concentrations of nodule fragments, cobalt deficiency, if it occurred, would be expected to be confined to the plume area and be short-lived. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Section 3.4.1.6.

10. Nutrient Increase Cause Phytoplankton Blooms in Surface Plume

Concern:

Introduction of nutrient-rich bottom waters and sediment interstitial water into the nutrient-poor mixed layer could produce an increase in primary productivity, possibly causing blooms of single species.

Investigation:

The mixing of the discharge with the surface waters is expected to increase the amount of nitrate enrichment of the ambient water to no more than 0.03 ug-at/l within the first few minutes and 0.003 ug-at/l within an hour. These values are so low that they are below analytical detectability and so are expected not to have an appreciable immediate effect on the rates of nitrate uptake and primary productivity (Chan and Anderson, 1981). On a long term basis, nitrogen introduced into the photic zone could support production of 50 MT (55 tons) per year of plant carbon, only one ten-millionth the production of the Pacific central gyre. At this rate, primary production induced by the mining activity of even a dozen vessels would be many orders of magnitude below natural production (Chan and Anderson, 1981).

No statistically significant differences were found between nitrate and silicate concentrations in ambient surface water and those within the surface water of a one hour old plume (Chan and Anderson, 1981).

Outlook:

No short-term or long-term changes in surface water nutrient concentrations and consequent phytoplankton population levels are expected. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.1.1 and 3.4.1.1.

11. Air-Lift Caused Embolisms in Surface Plume

Concern:

The discharge from the air-lift mining system is supersaturated with dissolved gases. Exposure of fish to this discharge could cause fatal nitrogen embolisms.

Investigation:

Research has shown that exposure of fish to supersaturated waters can cause fatalities. However, measurements of oxygen profiles taken during both mining tests showed that the profiles in the plume resembled those in ambient water. Because nitrogen profiles parallel those of oxygen, this potential effect is judged to be unlikely.

Outlook:

The small discharge flow rates, the subsequent rapid mixing, and the exposure of the discharge to air prior to its release prevents supersaturation of gases outside the volume of initial plume penetration. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Section 3.4.1.10.

-- Impacts Not Yet Resolved

1. Pycnocline Accumulation from Surface Discharge

Concern:

Fine mining particulates may spread and accumulate at the pycnocline as a result of depressed settling velocity. Such a layer, or layers, would cause a reduction in light penetration that could affect biota dependent upon specific levels of light. Since a phytoplankton maximum exists just above the pycnocline, a reduction could shift the optimum light levels into the nutrient-poor waters above, thus potentially reducing primary productivity. In addition, such a layer has the potential to inhibit the vertical migration of certain species of mid-water organisms that occur below the mixed layer and utilize light levels to stimulate vertical migration.

Investigation:

Data taken during test mining were inconclusive about discharge particles accumulating near the top of or in the pycnocline. Mathematical models of settling phenomena indicate that the larger particles will readily pass through the pycnocline while the smaller particles will be held homogeneously within the mixed layer (Lavelle and Ozturgut, 1981). Particle concentration and thus the amount of light diminution has not been examined.

Outlook:

Because test-mining data yield inconclusive evidence on the accumulation of particulates at depth, it is not clear whether particulates accumulate to significantly increased concentrations in the pycnocline. Future research and monitoring of industry test mining will be conducted to determine if this phenomenon occurs and significantly affects light levels. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.1.3, 2.3.1.4, 3.4.1.3, 3.4.1.4, 3.4.1.6, 3.4.1.7, and 3.4.2.5, as well as NOAA's Research Plan (National Oceanic and Atmospheric Administration, 1981a).

-- Potentially Beneficial Effects

Although the long-term aspects of this category of effects may prove otherwise, each of the following effects appears to have a potentially beneficial aspect to it.

1. Additional Food Supply for Bottom Scavengers

Concern:

The collector will uncover, injure, or kill large numbers of benthic organisms. This increase in available organic matter will provide an additional, temporary food supply for scavengers. Collector noise could serve as a stimulus to attract scavengers, especially species like the rat-tail fish that communicate by sound.

Investigation:

Photographs show that bottom disturbances can attract large numbers of deep-sea scavengers. During DOMES I, samples obtained with baited traps indicated that a large population of scavengers exist in the bottom waters.

Outlook:

Although this temporary food supply will provide scavengers with additional nutritional input, its effect on community size and structure is unknown. The effect would probably depend on several parameters such as the rate of reproductive responses to this temporary food increase. The impact of terminating this added food source is likewise unknown. This concern is not addressed either in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) or in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b).

2. Bacteria Increased Food Supply for Zooplankton

Concern:

Growth of bacteria is stimulated by increases in substrates and organic matter. Particles from the surface and bottom discharges could provide an increase in surface area with resultant increases in bacterial biomass and other levels in the food chain.

Investigation:

Shipboard measurements taken during DOMES in the surface plume showed that a higher bacterial biomass was present near the bottom of the mixed layer than in ambient water from the same depth zone. This biomass increase either means that bacterial growth occurred or that zooplankton grazing pressure was reduced in the plume.

Outlook:

Ingestion by zooplankton of particles laden with bacteria could enhance productivity in the upper waters. The concentration of total particulates should return to ambient levels within a few days after mining ends. The temporary increase in bacterial biomass is therefore not expected to have any long-term effects in the mining area. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 3.4.1.6 and 3.4.2.5.

3. Filter Feeding Zooplankton Clean Up Surface Plume

Concern:

The clay and silt fine fraction of the surface discharge that remains in suspension and disperses over a large area is more likely to be ingested by filter feeding plankton. One result could be the aggregation of many small particles into fecal pellets which because of their size would sink more rapidly.

Investigation:

Laboratory examination of the elemental composition of oceanic copepod fecal pellets revealed that copepods ingest particles the size of the mining discharge particulates (Hirota, 1981). Those experiments showed that pellet production rates and mean fecal pellet size are not greatly affected by the presence of mining discharge. The sinking rates for the pellets produced in the presence of a mixture of ambient seawater and mining particulates did show an increase over the rates reported for pellets produced by copepods feeding on natural suspended particulate matter. The sinking speeds for the pellets produced in the presence of mining discharge range from about 50 to 150 m/day (165 to 495 ft/day) depending on pellet volume (Chan and Anderson, 1981).

Outlook:

Pellet formation, while not significant on a short-term, near-field basis, could become an important long-term mechanism for clearing the upper layer of fine mining particulates. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 3.4.1.6 and 3.4.2.5.

-- Certain Impact Without Significant Adverse Effects

1. Increased Turbidity from Surface Plume that Reduces Productivity

Concern:

Mining particulates affect the primary productivity by decreasing the depth of light penetration. In the DOMES region, most phytoplankton are concentrated just below the mixed layer where more nutrients are available. This zone corresponds to where light is 10 to 20 percent of surface intensity. Reduced light levels from the surface plume would shift the optimum light level upwards into the nutrient-poor waters and thereby reduce total production.

Investigation

Results of incubation experiments and light profiles in the plume showed that the reduction in productivity from ambient levels in the euphotic zone amounted to 50 percent. This change is the same order of magnitude as the natural variability caused by day-to-day variation in cloud cover.

Outlook:

The DOMES results showed that the local reduction in primary productivity due to increased light attenuation inside the surface plume was significant. In a commercial mining operation, a 50 percent reduction in the primary production rate in the water column may occur over an area approximately 20 km long and 2 km wide (10.8 nmi by 1.1 nmi) (Chan and Anderson, 1981). The mining ship will continually generate a plume and there will always be a zone where there is a 50 percent reduction. However, the plume will age as it advects and disperses so that a given mass of plume will start at 100 percent reduction, pass quickly through 50 percent, and then approach zero in a matter of days. Plankton in the mixed layers might be expected to encounter reduced light over an 80 to 100 hour period; however, this effect is similar to exposure to several days of cloudy skies. It should be noted however, that, light attenuation values used to calculate the reduction in primary productivity are based on only a few measurements; their accuracy must be evaluated in future field or laboratory tests (Lavelle and Ozturgut, 1981).

One mining ship's "cloud" would be 20 km by 2 km or 40 km^2 (11.7 nmi^2). As a percent of the DOMES area this equals:

$$40\ km^2 \div 13 \times 10^6\ km^2 = 3 \times 10^{-6}$$

$$= 0.0003 \text{ percent}$$

If each mine site is served by two mining ships and there are about five mining sites being simultaneously mined during the first generation (Appendix 5), this area increases by a factor of 10 to become 0.003 percent of the DOMES area. This amount is also deemed insignificant. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Section 3.4.1.6.

II.C.1.2.2.6 Endangered species

The potential impact that mining may have on endangered marine mammals and sea turtles was not addressed as a separate investigative category during DOMES. Section II.C.1.1.2 addresses the effect that activity in transportation corridors may have on these animals and emphasizes that the prospects for impacts will be addressed in site-specific EISs.

The Hawaiian monk seal is the only marine mammal listed as endangered (Appendix 8) that has been sighted in the DOMES area. One yearling male monk seal was sighted and identified on Johnston Island, in the northwest portion of the DOMES area, in 1968 (Documentation Associates, 1977). The Hawaiian monk seal breeds in the northwestern Hawaiian Islands and normally ranges only within the Hawaiian Archipelago. An occurrence outside of its normal range is extremely rare. A literature survey by Documentation Associates (as part of the DOMES program) of the available scientific information in the DOMES area showed that the occurrence of marine mammals and sea turtles is infrequent. Several species of porpoise, none of which is listed as endangered, have been sighted in the DOMES area. Whale marking and recovery studies conducted from 1954 through 1966 indicate that whales rarely range within the DOMES area (Documentation Associates, 1977). At the mine site existing knowledge, therefore, implies that marine mammals and sea turtle occurrences are infrequent and unlikely to be affected by mining. This concern is addressed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.1.2 and 3.4.1.2.

II.C.1.2.2.7 Effect of noise on marine mammals

The noise in the water column associated with first generation deep seabed mining technology should be similar to the noise associated with oil and gas drillships. Literature reviews by the Department of the Interior's Bureau of Land Management on possible noise impacts from continental shelf oil and gas activities indicate that exploration and drilling sounds and associated service vessel traffic could alter normal whale and dolphin activities such as feeding behavior and use of migration routes (Bureau of Land Management, 1981). The noise associated with collector action on the seafloor was previously mentioned (II.C.1.2.2.5) as possibly serving as a stimulus to attract deep-sea scavengers. Although the exact effect of operational noise on marine mammals is unknown at this time, the infrequent occurrence of these animals in the DOMES area should preclude any significant adverse effects. Nevertheless, observations will be made of the behavior of whales and porpoises during test mining as discussed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Section 3.4.1.10.

II.C.2 Effects With Potential for Significant or Adverse Impacts

NOAA research has shown that there are three potentially adverse effects of deep seabed mining. They occur in license phase tests of mining systems as well as permit phase commercial operations (they do not apply to the license phase pre-test activities discussed in Section 3.4.1). Should future investigations reveal any of them to be significant, NOAA licenses and permits would then require the use of efforts to mitigate the impacts (Section II.C.4). The need for mitigation will be determined in the coming years, mainly in the license phase during which the industry will be conducting reliability tests of commercial recovery equipment as discussed in the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b).

For potentially significant impacts, NOAA has set forth in this section possible mitigation measures (mainly for commercial operations under a NOAA permit) which might be considered in the context of a site-specific environmental statement for the terms, conditions, and restrictions (TCR) of a license or permit. In the event mitigation of a significant impact is necessary, NOAA will establish the appropriate performance standard(s) and then encourage the applicant to suggest measures and technology to meet the goal of mitigation of specific consequences. Monitoring of future commercial operations, as well as tests, will verify whether or not the standards are being met (Section II.C.4).

The Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) and monitoring of license and permit activities (see Section II.C.4 and National Oceanic & Atmospheric Administration, 1981b) provide for investigation concerning the significance of the potentially adverse effects discussed here. If necessary, NOAA will prepare a supplemental environmental document to incorporate research and monitoring findings into this PEIS. Effects found to be insignificant will not be considered in site-specific environmental statements. Research will also investigate other possible means for mitigating effects so that significant adverse impacts can be avoided and mining can proceed as intended by Congress and NOAA.

The following discussion highlights the concerns, research, outlook, and possible mitigation techniques for each of the three potentially significant adverse effects. These effects were determined to have no potential for significant environmental impact during exploration activities of the license phase. Thus each subsection discusses a concern in terms of mining system testing activities in the license phase as well as subsequent permit phase commercial mining using first generation technology.

II.C.2.1 Destruction of benthos in and near collector track in mine site subareas

Concern:

The mining collector will disturb sediment in and adjacent to its track. It is assumed that all organisms living in this track of perhaps 20 m (66 ft) width will be destroyed. Those organisms living in between the tracks, which industry hopes will be nearly abutting, will most likely be smothered by the sediment wake of the collector. The width of this inter-track zone could be on the order of the width of the collector track, but could vary depending on the type of operation employed, the topography, or the possible use of strips or islands to accelerate recolonization (see Section II.D.1.1).

Investigation:

Macerated biota were, on occasion, observed in the surface discharge during DOMES II research. Many more animals are assumed to have been killed and culled from the seafloor by the collector. The potential for death by smothering in between tracks can be inferred from studies in another deep-sea area that showed substantial mortality resulting from accidental burial of a deep-sea community at 1,200 m (3,960 ft) (Thiel and Hessler, 1974; Jumars, 1981). Although the DOMES area is generally much deeper, these findings are probably applicable.

Outlook:

During a commercial operation, the area impacted by the collector each year, both by its track and windrow (assuming a 20m track width where benthos are destroyed), will be about 1,800 km^2 (525 nmi^2) [two ships at 900 km^2 (or 262 nmi^2) each] for a 3 million MT (3.3 million tons) per year three-metal operation (Ozturgut et al. 1981b) and about one-third that area for a four-metal operation. The resultant mortality of benthic biomass, at an approximate density of 0.3g/m^2 (0.001 oz/ft^2), will be about 540 MT (594 tons) per year. If it is assumed that five (three 3-metal and two 4-metal) first generation miners will operate for 20 years in the mining area, the total area of benthic destruction would be:

$$\left(1800\ \text{km}^2/\text{yr.} \times 3\ \text{mines} + \frac{1800\ \text{km}^2/\text{yr.}}{3} \times 2\ \text{mines}\right) 20\ \text{years}$$

$$= 130{,}000\ \text{km}^2 \text{ or } 37{,}900\ \text{nmi}^2$$

Therefore, the amount of seafloor expected to be directly affected by the collectors in first generation mining (operating for 20 years) is about one percent of the DOMES area.

According to McKelvey et al. (1979), the initial mine sites may not be randomly distributed throughout the DOMES area. Rather, they may be located within a 2.5 million km^2 (729,000 nmi^2) area thought to contain the richest nodule deposits. If this is the case, the impacted area will represent nearly five percent of that area of richest concentration.

NOAA is unable to conclude that this scale of impact is significant to benthic populations, although it is clearly adverse. Factors which will be studied include the rate of recolonization, type of species that recolonize, and the resulting linkage between benthic and water column food webs. Present knowledge indicates that this linkage is very limited and not likely to be significantly affected (Section II.A.1.2.2). Future research will address these factors (National Oceanic and Atmospheric Administration, 1981a and b).

NOAA anticipates the impact during the mining system testing phase to be extremely small. For example, five mine ships each conducting two months of commercial scale test-mining could impact an area of:

$$\frac{900\ \text{km}^2}{\text{year}} \times \frac{2\ \text{mo.}}{12\ \text{mo.}} \times 5\ \text{ships} = 750\ \text{km}^2 \text{ or } 219\ \text{nmi}^2$$

or less than 0.01 percent of the DOMES area. Even with expanded exploration activities or potential long-term effects, this impact appears to be insignificant.

Mitigation:

License Phase

During the license phase, research will involve the collection of essential environmental information and controlled experimentation in the DOMES area (National Oceanic and Atmospheric Administration, 1981a and b; Jumars, 1981). In addition, mining system tests will be monitored to examine recolonization patterns.

This information will help NOAA determine if TCR for mitigation during commercial operations are appropriate. Based on the best available information at this time, no mitigation measures are appropriate during the license phase.

Permit Phase

Understanding completely the nature and implications of the benthic impact will not be possible until full-scale mining has occurred for a few years. To attain this understanding, it is necessary to develop both theories and monitoring schemes keyed to the initial commercial operations. As information on the effects and potential significance of this disturbance develops, the importance of other factors, such as shape and spacing of mine sites, will become more evident and be taken into account in further NOAA regulatory actions.

In addition, if situations arise during exploration that could cause significant adverse impacts, mitigation in the form of equipment and/or operational changes may be required and a new monitoring plan devised before proceeding with additional commercial operations. Examples of mitigation could involve requirements to insure that:

- o special habitat areas are avoided;
- o nodules are raked loose by small tines, rather than larger blades; and/or,
- o rejected sediments be guided back into the collector track immediately behind the collector.

At this stage of knowledge, it is premature to require any measures such as these; there is no evidence to indicate that any of these potential regulations would be necessary or beneficial. Thus, it is not appropriate at this time to require mitigation measures for commercial operations. If at a later date, NOAA determines the impacts of collector contact to be significant, based on monitoring and research, mitigation strategies would be implemented.

This concern is addressed in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) as well as the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.2.3 and 3.4.2.4.

II.C.2.2 Blanketing of benthic fauna and dilution of food supply away from mine site subareas

<u>Concern:</u>

Possibly of greater concern than direct collector impact is the large area affected by the fine sedimentary particulates (called "fines") that move in response to bottom currents and then settle very slowly. The infauna have no burrowing ability and thus may be smothered. Farther away the thin blanket of fines from the benthic plume may cover and thus dilute the food supply of bottom feeders. Food descending through the water column settles as a thin layer on the sediment where it is consumed by deposit feeders and bacteria. Most deep-water benthic animals are small (less than 0.5 mm or .02 in length), live in the upper 1 cm (0.4 in) of the seafloor, and may have adapted to this scarcity of food by developing acute chemosensory capabilities (smell). Thus, even slight alterations from this pattern might significantly change natural conditions and diminish an already meager source of food. According to Jumars (1981, page 6), "For animals adapted to feeding at the sediment-water interface, it is conceivable that burial of their normal food resources under 1 mm (0.04 in) or less may be critical depending on the time scale over which these food resources recover."

The impacts on the various species of benthos will be dependent upon the guild to which they belong (Section II.A.1.2.2, Tables 6 and 8). Scavengers will receive a temporarily increased food supply, and are unlikely to suffer from mortality due to burial. Subsurface deposit feeders are also unlikely to be affected because of their relative isolation from resedimentation effects. Suspension feeders, another important component of the deep-water benthic community, could be adversely affected. These animals filter their food from the water. An increase in suspended sediments of a few ug/l, a level practically undetectable to the human eye, could render their feeding apparatus less efficient or could dilute their food supply with organic-poor clays. Surface deposit feeders could be affected if the net food value of the surface deposits is altered (Jumars, 1981).

Mining particulates may interfere with the chemical communication systems of marine invertebrates. Chemicals released into the water by invertebrates may act as a stimulus for reproduction, for the detection of food and prey, and for influencing spacing behavior. This concern was not examined during DOMES.

Investigation:

Field measurements suggest that fines in the benthic plume, with particulate concentrations about twice that of the ambient, may remain suspended for a week or longer after the cessation of mining operations and be carried tens of kilometers by bottom currents (Lavelle *et al.* 1981).

Outlook:

These fines could cause mortalities far beyond the zone of mortalities caused by mechanical disturbance. NOAA has predicted that the annual commercial mining of a 900 km^2 (262 nmi^2) sub-area (roughly the size of the area expected to be mined each year by one mining ship) will result in a rain of fines on an area of 3,000 to 5,000 km^2 (875 to 1,458 nmi^2) (Lavelle *et al.* 1981). Given that bottom currents are not completely unidirectional, it seems reasonable to assume that during the 20 years or more of operation of each mine site (which could include dozens of sub-areas), the entire site as well as surrounding areas will be subject to a rain of fines considerably higher than ambient.

The impact of increased sedimentation rates and particulate loads on benthic fauna is not known at this time. However, monitoring of the brief period of test mining conducted by Ocean Management, Inc. (OMI) in 1978 revealed no repercussions from this impact. Therefore, an unsubstantiated worst case assumption would involve the destruction of less than 100 percent of the benthic fauna in the complete mine site, plus a strip around the site that could average, for example, 20 km (11 nmi) in width if the site were circular in shape [based upon the difference in radii between the 900 and 4,000 km^2 (262 and 1,166 nmi^2) circles].

The greater the increase in site perimeter in relation to site area, the greater will be the area of the strip around the site receiving the rain of mining fines. For example, the area of a 20 km (11 nmi) wide strip around a circular 40,000 km^2 (11,662 nmi^2) mine site involves an area 39 percent that of the site proper. A similar strip around a 40,000 km^2 square site involves a comparable area 44 percent that of the site. Similarly, a 20 km (11 nmi) wide strip around a rectangular site of 400 km by 100 km (220 by 55 nmi) involves an area 54 percent that of the site.

During exploration, our worst case estimate of impact is the destruction of a fraction of the benthic fauna in strips surrounding the test areas estimated above to comprise about 750 km^2 (219 nmi^2). For example, the collector of a single mining test of two months duration will directly impact an area of 150 km^2 (44 nmi^2) (750 km^2 divided by 5 ships). Assuming that a test occurs in a reasonably compact test area (if not, the test could conceivably involve a spreadout collector path that could, in turn, expose a large area to a rain of fines depending on current direction), one can apply the same ratio of that area to its predicted rain of fines impact area:

$$\frac{900\ km^2}{4,000\ km^2} = \frac{150\ km^2}{X} \quad \text{then } X = 667\ km^2 \text{ or } 194\ nmi^2.$$

The impact of the particulates on the chemical communication systems of invertebrates is not known. Although NOAA will investigate benthic plume effects, it may not be able to discern chemical from physical impacts.

As discussed in the outlook for direct collector impact, the rain of fines also appears to be insignificant.

Mitigation:

License Phase

Monitoring of mining system tests will be aimed at understanding the long-term fate of that portion of the benthic plume that travels well away from the collector. Although the impact is currently unknown, damage could be irrevocable. Specifically, information is needed on particulate settling rates and patterns (Lavelle *et al.* 1981). A compact pattern of area for mining system testing would concentrate the effect of the benthic plume. A less compact pattern of testing operation would disperse it, potentially over an area one hundred times the size of a compact pattern. NOAA does not, at this time, know which mining configuration would cause the least environmental effects. Monitoring will focus on the benthic plume to determine the significance of its effect and what mining patterns might reduce any observed problems. In the event monitoring leads to the conclusion that there is a preferred approach that can signficantly mitigate adverse impacts, terms, conditions, and restrictions (TCR) for the license may be modified. If it is necessary to limit the area affected by the benthic plume, the TCR can provide that test mining should be reasonably compact, taking into account topography and efficiency of mining operations. Until further information is collected, no mitigation measures will be considered.

<u>Permit Phase</u>

The rationale noted above for direct destruction of benthos is also applicable here. Because this category of concern has the potential to affect an area larger than the mining subareas or even the mine sites and because repopulation rates are unknown but likely to be on the order of decades or longer (Jumars, 1981), possible mitigation measures include:

- collector design features to minimize the size of the benthic plume;
- reasonably compact mine site shapes to minimize impact area taking into account the conservation aspects of such a requirement; or,
- controlling the dispersion of suspended sediments resulting from mining, either by restricting the areal extent of their spread or by dispersing them.

Applicants for mining permits would be required to discuss in their commercial recovery mining plans how they intend to attain any of the measures that may be required; the site specific EIS's will assess the likelihood of success and recommend monitoring procedures for the permits' TCR.

This concern is addressed in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) as well as the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.2.1, 2.3.2.2, 2.3.2.3, 2.3.2.4, 2.3.2.5, 3.4.2.1, 3.4.2.2, 3.4.2.3, and 3.4.2.5.

II.C.2.3 Surface plume effect on fish larvae

Concern:

Tuna are epipelagic fish which live and spawn in the open ocean. They have been shown to be attracted to discontinuities in the ocean. The plumes from the mining operations could be considered examples of this sort of discontinuity. Should the spawning period or location be altered by this attraction and the chemical and physical characteristics of the plume prove lethal to larval forms, the effect on the local populations may prove to be considerably more serious than if the larvae were evenly distributed over the DOMES area. (Personal communication - Andrew Dizon, National Marine Fisheries (NMFS), Southwest Fisheries Center, Honolulu, HI.)

Investigation

This concern was not examined during DOMES I or II research.

Outlook

During commercial mining, a steady-state surface plume, defined by a 1 ug/l concentration over ambient at the sea-surface, will cover an area about 85 km by 10 to 20 km (45 nmi by 5 to 11 nmi) (Lavelle and Ozturgut, 1981). First generation mining may involve eight ships (Appendix 5). Thus, the area of the sea surface covered by the plumes could be around 10,000 km^2 or 0.1 percent of the DOMES area.

During license phase mining system tests, each ship could generate a plume that may cover about 1,300 km^2 (360 nmi^2), or 0.01 percent of the DOMES area for two months. Based on the level of activity, the potential for a significant effect during tests is judged to be remote.

Mitigation:

License Phase

Because the effects of mining tests are projected to be minimal, no mitigation measures are appropriate.

Permit Phase

If no significant detrimental effects are discovered prior to commercial operations, no mitigation measures will be necessary. However, if NOAA determines this impact to be significant, it could require that the point of discharge be below, whichever is the deepest, the pycnocline, the lower level of the euphotic zone, or the oxygen minimum zone. According to Hirota (1981), discharge of this type "....would seem to be the most effective manner to minimize the effects of increased loading of fine particulates."

The financial implications of such a possible requirement were examined by Flipse (1980) and found not to be excessive. However, fish larvae are known to occur throughout the water column; hence, this often-discussed potential mitigation measure would have to be examined in detail prior to becoming a requirement. For example, if flocculation is found to be enhanced in the mixed layer, compared to the level at which sub-surface discharge might occur, the resultant decreased residence time in the water column could offset some impact on larvae in the mixed layer. Such tradeoffs would be assessed before imposing a requirement for sub-surface discharge.

This concern is addressed in NOAA's Five-Year Research Plan (National Oceanic and Atmospheric Administration, 1981a) and the Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b), Sections 2.3.1.3, 2.3.1.4, 3.4.1.3, 3.4.1.4, 3.4.1.6, 3.4.1.7, 3.4.1.9, and 3.4.1.10.

II.C.3 Information to be Required from Industry

The Act requires that NOAA prepare a site-specific environmental impact statement (EIS) on the issuance of a license and permit and that the applicant apply to EPA for a National Pollutant Discharge Elimination System permit (See Section II.C.5). It is assumed the site will lie in the general DOMES area; if not, a new PEIS will be prepared, as required by the Act, as well as or including a site-specific EIS based on environmental information prepared by the applicant. Also, if new mining technologies are to be used, a supplement to the PEIS may be required. The magnitude of the effort will be worked out with the applicant on a case-by-case basis.

II.C.3.1 License phase activities

These issues are covered in NOAA's Technical Guidance Document for Deep Seabed Mining (National Oceanic & Atmospheric Administration, 1981b) and in Section 970.204 of the Deep Seabed Mining Regulations.

II.C.3.2 Permit phase activities

When an applicant applies for a permit, certain additional information should be provided. At that time a supplement to the site-specific EIS may be prepared. Decisions now on requirements are premature; nevertheless, NOAA's present views on necessary information beyond what was provided at the license stage include:

II.C.3.2.1 Environmental information

It is possible that certain data submitted during the license phase will need to be supplemented. This will be determined on a case-by-case basis.

II.C.3.2.2 Operational information (examples)

o Mitigation plans (if applicable at that time)

o Mining pattern planned

o Selective-mining plan

- o Contingency plans for recovery of wastes generated from processing, such as manganese tailings (applicable to the Resource Conservation and Recovery Act).
- o Transportation corridor(s) to be used by nodule carriers
- o Processing plant location and details (see Section III).
- o Procedures designed to prevent unwarranted generation of waste (applicable to the Resource Conservation and Recovery Act).

II.C.4 Monitoring Strategy

Although specific parameters will be monitored (Section II.C.3), at this time NOAA sees no basis for prescribing specific standards. If the applicant's work plan for either a license or a permit is judged acceptable, a monitoring plan will be devised by the licensee or permittee in accordance with a set of initial terms, conditions, and restrictions (TCR) imposed on the applicant. The TCR applicable to the surface discharge will be developed in consultation with EPA since the Act requires that a discharge permit be obtained under terms of the Clean Water Act. Monitoring will involve dockside inspection of equipment as well as at-sea inspection and sampling. This monitoring strategy will be devised to insure that the mining equipment and operation do not deviate significantly from the approved plan, and verify NOAA's assessment of plan acceptability.

The general logic of the monitoring plan is shown in Figure 22. The "monitor and learn" step is designed to answer the questions, "Are environmental effects consistent with the PEIS and EIS estimates?" Precisely what is meant by consistency is discussed in Sections II.C.1 and II.C.2.

Basically, the license phase is viewed as an opportunity to verify the low probability predictions (see Section II.C.1) and to further examine the effects of remaining concerns (see Section II.C.2). Consequently, monitoring and accompanying research will be focused on the magnitude of mortality of benthic fauna in and near collector tracks in mine-site subareas; blanketing of benthic fauna and dilution of food supply away from mine-site subareas; recovery of the benthos following mining; and the effect of the surface plume on fish larvae.

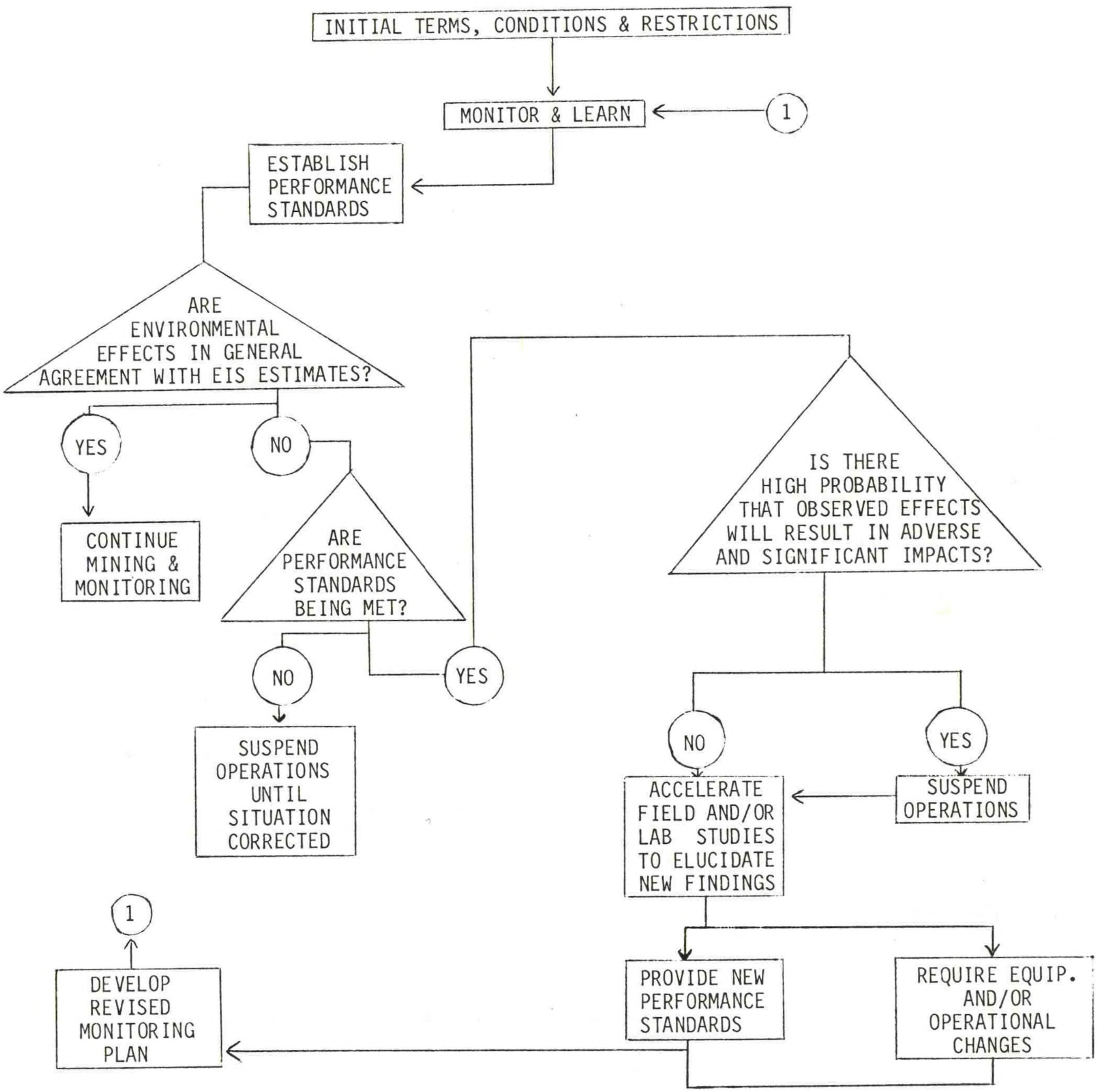

Figure 22.--Monitoring Strategy Flow Chart

During monitoring, new information will be gathered on a wide range of issues. At this time, NOAA can make five general statements on the effects of monitoring results for license and permit operations:

1. If effects are in line with current estimates (see Sections II.C.1 and II.C.2) and no significant adverse effect is found, operations would be allowed to continue. Monitoring would continue until it was determined, e.g., after several tests or after one year of commercial mining, that requirements could be reduced in scope -- either for the applicant, NOAA, or both.

2. If effects are not consistent with estimates and performance standards (should they become required in the future, e.g., limiting the abraded nodule discharge to X-percent of total solids discharged at the sea surface) are not being met, NOAA has authority to: (1) enforce compliance with the performance standards; (2) change the performance standards by amending regulations or modifying license terms, conditions and restrictions; and (3) require immediate suspension of the license, or immediate suspension or modification of activities under the license, if necessary to prevent a significant adverse effect on the environment.

3. If, on the other hand, effects are not consistent with estimates but performance standards are being met, NOAA could take the latter two types of action described in the preceeding paragraph.

4. If there are unexpected effects which are adverse but not significant (e.g., gas embolisms in fish very close to the mine ship), operations probably would be allowed to continue while research is accelerated to figure out the unanticipated findings.

5. If the unexpected effects are adverse and significant (e.g., massive attraction of adult tuna to surface plume and large scale mortality due to gas embolisms), NOAA could require immediate suspension of the license, or immediate suspension or modification of activities under the license. Research would be rapidly accelerated to learn how best to respond to this unexpected situation. Equipment, operational activities, and/or performance standards could be changed as a result of the new findings and a new monitoring plan developed before proceeding with mining.

II.C.5 National Pollutant Discharge Elimination System Permit Considerations

The Act requires that applicants for a license or permit also apply to EPA for a National Pollutant Discharge Elimination System (NPDES) permit under Section 402 of the Clean Water Act. The NPDES permit applies to surface and benthic discharges from mining ships either as a result of mining (see Section II.B.1.1 in this PEIS) or process waste disposal (see Section II.B.1.4). This discussion deals solely with surface and benthic discharges from mining system tests to be conducted under NOAA exploration licenses. Specific guidance to industry is included in NOAA's Technical Guidance Document (National Oceanic and Atmospheric Administration, 1981b).

In deciding whether or not an NPDES permit will be issued, EPA under its Ocean Discharge Criteria regulations (40 CFR 125.122) must first determine whether or not a discharge will cause unreasonable degradation of the marine environment. In making this determination, EPA must consider 10 important factors. Although this PEIS is not organized around those factors, the subject matter of each is discussed in one or more sections of this PEIS. In the following paragraphs, each factor is listed, discussed briefly, and cross-referenced. In so doing, NOAA hopes to assist EPA by providing information for EPA review of site-specific applications for NPDES permits. Providing the generic data should make the NPDES process far simpler since data to be considered for issuing the permits will be included in this document.

> Factor 1 - The quantities, composition, potential for bioaccumulation, and persistence of the pollutants to be discharged.

During exploration and demonstration-scale mining tests, mining ships will be licensed to mine at a commercial rate of production for up to two months.

This could involve a rate of mining of about 5,000 MT (5,500 tons) of nodules (dry weight) daily (Appendix 3). The nodules would be accompanied up the riser pipe by water from near the seafloor, interstitial water from bottom sediments, bottom sediments, abraded nodule fragments, small quantities of macerated benthic biota, and possibly air from air-lift pumping (see Section II.B.1.1). For each 5,000 MT operation, the volumes of the primary materials expected to be discharged daily at the seafloor by collector action and to the sea surface, following recovery of nodules, are about:

	SEAFLOOR		SURFACE	
	m^3	ft^3	m^3	ft^3
Water	80,000	3,000,000	25,000	900,000
Bottom sediment	19,000	700,000	600	22,000
Nodule fines	180	6,500	180	6,500

Initial mixing in the surface waters within one second after discharge to the sea surface is predicted to result in a rapid dilution of 1:1000 (see Section II.B.1.1). Use of EPA's mixing zone of extending laterally 100 m (330 ft) in all directions from the discharge point would result in an even greater dilution factor.

The characteristics of bottom and interstitial waters are described in Section II.A.1.2.2. The composition of seafloor sediments and manganese nodules are shown on Tables 13 and 14, respectively. The environmental effects implication of the introduction of these materials into the surface and bottom waters of the ocean are discussed below in terms of the specific concerns addressed during preparation of this PEIS. Discharge will be monitored in accordance with the Technical Guidance Document (National Oceanic & Atmospheric Administration, 1981b).

Table 13. Average chemical composition (one standard deviation in parentheses) of sediments from DOMES Sites A, B, and C and average Pacific pelagic sediment (Bischoff *et al.* 1979)

Weight Percent

	Site A n=20	Site B n=20	Site C n=78	Pacific Pelagic Clay
SiO_2	48.3 (5)	51.5 (1.8)	50.7 (5)	54.9
Al_2O_3	11.3 (1)	12.5 (1.3)	14.5 (2)	16.6
Fe_2O_3	5.4 (.6)	5.4 (.8)	7.6 (1)	7.7
MgO	3.0 (.2)	3.0 (.1)	3.2 (.2)	3.4
CaO	4.7 (6)	1.5 (.6)	2.3 (3.6)	.7
Na_2O	5.5 (.7)	5.7 (.5)	2.9 (.8)	1.3
K_2O	2.9 (.3)	3.3 (.7)	3.2 (.3)	2.7
TiO_2	.55 (.1)	.59 (.1)	.72 (.1)	.78
P_2O_5	.54 (.2)	.51 (.3)	.42 (.1)	.25
MnO	.50 (.4)	.53 (.4)	1.2 (1.7)	.56
l.o.i. *	14.5 (3.5)	11.2 (.8)	12.4 (4)	-
SUM	97.2 (5)	95.9 (3)	99.3 (2)	-
C_{org}	.11 (.2)	.15 (.3)	.2 (.15)	.27
CO_2	3.4 (4.5)	1.2 (.5)	1.05 (2.8)	-

Parts Per Million

	Site A	Site B	Site C	Pacific Pelagic Clay
B	178 (30)	167 (31)	145 (30)	100
Ba	2835 (650)	1505 (1373)	3926 (2015)	3900
Be	3 (.7)	3 (1)	3.5 (1)	-
Co	83 (31)	62 (27)	116 (90)	113
Cr	57 (12)	50 (20)	53 (16)	64
Cu	440 (160)	222 (70)	595 (1000)	230
Mo	12 (16)	8 (5)	24 (60)	10
Ni	183 (76)	112 (66)	341 (660)	210
Pb	34 (6)	26 (8)	61 (40)	34
Sc	33 (6)	30 (3)	21 (6)	25
Sr	175 (100)	343 (100)	317 (180)	710
V	89 (22)	99 (20)	102 (26)	117
Zn	243 (100)	95 (13)	160 (64)	165
Y	171 (90)	124 (60)	97 (32)	150

* Ignition losses - water and other volatiles not analyzed

																	He
Li	Be											B 0.024	C 0.08	N	O	F	Ne
Na 1.76	Mg 1.12	Al 2.16											Si 5.44	P 0.12	S ~0.08	Cl 0.64	Ar
K 0.8	Ca 1.28	Sc 0.0008	Ti 0.36	V 0.032	Cr 0.0008	Mn 20.0	Fe 6.8	Co 0.16	Ni 1.04	Cu 0.88	Zn 0.10	Ga 0.0008	Ge	As 0.004	Se	Br	K
Rb	Sr 0.064	Y 0.024	Zr 0.048	Nb 0.0024	Mo 0.04	Tc	Ru	Rh	Pd	Ag 0.0002	Cd 0.0016	In	Sn 0.024	Sb 0.0024	Te	I	X
Cs	Ba 0.32	La 0.13	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl 0.016	Pb 0.04	Bi 0.0024	Po	At	Rn
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm								

Table 14. Assumed composition (weight percent) of major categories of elements in manganese nodules (Dames & Moore and EIC Corp. 1977).

The single known possibility for bioaccumulation relates to the ingestion by zooplankton of abraded nodule fine particles (see Factor 3).

Factor 2 - The potential transport of such pollutants by biological, physical, or chemical processes.

Characteristics of the surface and benthic plumes are discussed under "Surface Discharge" and "Bottom Discharge" respectively, in Section II.B.1.1. The characteristics of each plume are based on observations made by NOAA in 1978 during two pilot-scale mining tests in DOMES II. Extrapolation to commercial scale operations (mining tests could operate at commercial rates) is based upon assumptions explained by Lavelle _et al._ 1981).

One uncertainty in the extrapolation is whether or not the fine particles in the surface discharge accumulate at and along the pycnocline as a result of retardation of particle settling velocities. Although particles settled faster than predicted, suggesting the occurrence of flocculation following surface discharge, the brief periods of mining (total 5 days) did not permit resolution of this possibility. This is discussed under "Impacts Not Yet Resolved" in Section II.C.1.2.2.5 and is not believed to be of concern. Nevertheless, this is one of the aspects of the test monitoring program described in Section II.C.3.1. and II.C.4. The effect that the transport of the benthic plume will have on the blanketing of the benthic fauna and the dilution of their food supply is discussed under "Effects with Potential for Significant or Adverse Impacts" in Section II.C.2.

> Factor 3 - The composition and vulnerability of the biological communities which may be exposed to such pollutants, including the presence of unique species or communities of species, the presence of species identified as endangered or threatened pursuant to the Endangered Species Act, or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain.

Potential effects of the surface plume on phytoplankton were evaluated and each was judged to have either a low probability of impact or impact with no significant adverse effects (see Section II.C.1.2.5): alteration of species composition (low probability concern 5); dissolved trace metals uptake (low probability concern 9); and phytoplankton blooms (low probability concern 10). The reduction in primary productivity resulting from the reduction in light within and beneath the plume could be equivalent to that resulting from a couple of extra days of cloudy skies (see Section II.C.1.2.2.5, page 95).

Potential effects on zooplankton resulted in a wide spectrum of probable outcomes. Laboratory experiments showed that simulated plume conditions neither increased mortality nor caused major changes in either species composition or abundance (see Section II.C.1.2.2.5, low probablity concern 7). Although zooplankton were found to ingest fine particles in the plume which could lead to a rapid "clean-up" of plumes (see Section II.C.1.2.2.5, potentially beneficial effect 3), it is unknown whether or not trace metals in the abraded nodule fines enter tissue (Section II.C.1.2.2.5, low probability concern 8). NOAA believes that the chance of this phenomenon occurring is very low and that, if it did, there is little chance for significant impact.

Surface discharge could affect the survival and growth rate of upper water-column fish larvae (see Section II.C.2.3), which is more of a concern than the potential effects on older fish. Three concerns for adult fish have been judged low probability: effects on feeding or respiration (see Section II.C.1.2.2.5, low probability concern 6); depletion of oxygen in surface waters as a result of increased growth of bacteria (see Section II.C.1.2.2.5, low probability concern 4); and, embolisms caused by the use of air-lift mining (see Section II.C.1.2.2.5, low probability concern 11).

The effects of the benthic plume on the blanketing of the benthos and the dilution of their food supply, were judged to have the potential for significant or adverse impacts (Section II.C.2.2). Two potential effects associated with the benthic discharge were judged to have a low probability of impact: a nutrient or trace metal increase from the benthic plume (Section II.C.1.2.2.5, low probability concern 2); and, an increase in oxygen demand from the benthic plume (Section II.C.1.2.2.5, low probability concern 3).

With respect to endangered, threatened, depleted, or unique species, marine mammals and sea turtles are believed to be most relevant to this area. They are judged unlikely to be affected by recovery operations (see Section II.C.1.2.2.6).

Because the mining tests on which the above probability estimates are based were pilot scale and brief, the findings will be validated by monitoring during the demonstration-scale mining tests (see Sections II.C.3.1 and II.C.4).

> Factor 4 - The importance of the receiving water area to the surrounding biological community, including the presence of spawning sites, nursery/forage areas, migratory pathways, or areas necessary for other functions or critical stages in the life cycle of an organism.

During a mining test, a mine ship's discharge should create a plume that will cover an area about 85 km by 10 to 20 km (46 nmi by 5 to 11 nmi) for up to two months (see Section II.C.2.4). This area is defined by a 1 ug/1 concentration of particulates above ambient at the sea surface. Any effects to be experienced are likely to be detected in a much smaller areal extent of higher concentration. Nevertheless, even this 1,300 km^2 (380 nmi^2) area is only 0.01 percent of the DOMES area (which in turn is about eight percent of the total area of the Pacific Ocean).

> Factor 5 - The existence of special aquatic sites including, but not limited to marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, and coral reefs.

There are no such sites in the DOMES area, although the Deep Seabed Hard Mineral Resources Act calls for international negotiations aimed at setting aside Stable Reference Areas as control sites against which the effects of mining can be documented.

> Factor 6 - The potential impacts on human health through direct and indirect pathways.

At this time, the only conceived mechanism by which humans could be affected is the possibility that trace metals present in the mining discharge could be accumulated by zooplankton (as discussed in Factor 3) and passed up the food chain through commercial fish (tuna and billfish) to humans. The brief duration of the mining tests, the apparent low probability for food chain transfer, and the migratory nature of tuna and billfish should preclude the opportunity for this to occur during mining system tests (see Section II.C.2.3). NOAA studies should provide more information on this subject prior to initiation of mining tests.

> Factor 7 - Existing or potential recreational and commercial fishing, including finfishing and shellfishing.

Commercial fishing in the area includes five United States and Japanese tuna and billfish industries (see Section II.A.1.3.1). The activities are not expected to be affected by the mining tests.

Factor 8 - Any applicable requirements of an approved Coastal Zone Management plan.

This consideration is not applicable to mine ship discharges in the DOMES area.

Factor 9 - Such other factors relating to the effects of the discharge as may be appropriate.

All factors of a generic nature are discussed in the PEIS and noted above; additional factors may arise during evaluation of site-specific test plans.

Factor 10 - Marine water quality criteria developed pursuant to Section 304(a)(1).

EPA and NOAA will work together to identify the conventional, non-conventional, and toxic pollutants in the discharges and establish that the numeric limits in applicable marine water quality criteria will be met. They will then compare concentrations to be expected in the mixing zone discussed in Factor 1. Applicable marine water quality criteria are contained in the EPA publication, <u>Quality Criteria for Water</u> (the "Red Book"), and in the water quality criteria for toxic pollutants published November 28, 1980 at 45 <u>FR</u> 79318-79370.

In conclusion, it appears that mining ship and collector discharges to the ocean during mining system tests are unlikely to cause unreasonable degradation of the marine environment.

II.C.6 Summary of Marine Environmental Consequences

Table 15 lists the environmental consequence concerns expected to be caused by changes in the physical-chemical environment as a result of mining, comments on the possible significance of potential biological impacts, notes mitigation measures considered for license and permit phases, comments on the thrust of the monitoring role at each phase, and lists the parameters of concern.

INITIAL CONDITIONS[1] / DISTURBANCE	PHYSICO-CHEMICAL EFFECTS	POTENTIAL BIOLOGICAL IMPACTS (REMAINING CONCERNS IN CAPITALS)	POTENTIAL SIGNIFICANCE OF BIOLOGICAL IMPACT: PROBABILITY OF OCCURRENCE	RECOVERY RATE	CONSEQUENCE	OVERALL SIGNIFICANCE
COLLECTOR	o Scour and compact sediments	DESTROY BENTHIC FAUNA IN AND NEAR COLLECTOR TRACK	Certain	Unknown[3] (Probably Slow)	Adverse	Unavoidable * (Uncertain Sig.)
	o Light and Sound	Attraction to new food supply; possible temporary blindness	Unlikely	Unknown (Probably Rapid)	Uncertain	None
BENTHIC PLUME	o Increased sedimentation rate and increased suspended matter ("rain of fines")	o EFFECT ON BENTHOS				
		- Covering of food supply	Likely	Unknown[3] (Probably Slow)	Adverse	Unknown*
		- Clogging of respiratory surfaces of filter feeders	Likely	Unknown[3] (Probably Slow)	Adverse	Unknown*
		- Blanketing	Certain	Unknown[3] (Probably Slow)	Adverse	Unknown*
		o Increased food supply for benthos	Unlikely	Rapid[4]	Possibly Beneficial	None
	o Nutrient/Trace Metal increase	o Trace metals uptake by zooplankton	Unlikely	Rapid	No detectable effect	None
	o Oxygen demand	o Lower dissolved oxygen for organisms to utilize; mortality from anaerobic conditions	Unlikely	Rapid	No detectable effect	None
SURFACE DISCHARGE Particulates	o Increased suspended particulate matter (sediments, nodule fragments and biota debris)	o Effect on Zooplankton				
		- Mortality	Unlikely	Rapid[4]	No detectable effect[2]	None
		- Change in abundance and/ or species composition	Unlikely	Rapid[4]	No detectable effect[2]	None
		- Trace metal uptake	Unlikely	Rapid[4]	Locally Adverse	Low*
		- Increased food supply due to introduction of benthic biotic debris and elevated microbial activity due to increased substrate	Unlikely	Rapid[4]	Possibly Beneficial	None
		o Effect on adult fish	Unlikely	Rapid[4]	No detectable effect[2]	None
		o EFFECT ON FISH LARVAE	Uncertain (Low)	Uncertain (Probably Rapid)	Uncertain	Low*
	o Oxygen Demand	o Lower dissolved oxygen for organisms to utilize	Unlikely	Rapid	No detectable effect	None
	o Pynocline accumulation	o Effect on primary productivity	Unlikely	Uncertain (Probably Rapid)	Unknown (Prob. Undetect)	Low
	o Decreased light due to increased turbidity	o Decrease in primary productivity	Certain	Rapid[4]	Locally Adverse	Low
SURFACE DISCHARGE Dissolved Substances	o Increased nutrients	o Increase in primary productivity	Very Low	Rapid[4]	No detectable effect[2]	None
		o Change in phytoplankton species composition or introduce deep-sea microbes or spores to surface	Very Low	Rapid[4]	No detectable effect[2]	None
	o Increase in dissolved trace metals	o Inhibition of primary productivity	Very Low	Rapid[4]	No detectable effect[2]	None
	o Supersaturation in dissolved gas content	o Embolism	Very Low	Rapid	No detectable effect[2]	None

1. Includes characteristics of the discharge and the mining system.
2. Based on experiments/measurements conducted under DOMES.
3. Years to tens of years, or longer.
4. Days to weeks.

Uncertain = Some knowledge exists; however the validity of extrapolations is tenuous.

Unknown = Very little or no knowledge exists on the subjects; predictions mostly based on conjecture.

*Areas of future research
SPM = Suspended Particulate Matter

LICENSE PHASE		PERMIT PHASE		
MITIGATION	MONITORING	POSSIBLE MITIGATION	MONITORING	PARAMETERS OF CONCERN
None	Study tests	Premature	Study initial operations	Natural history; recolonization; subarea mortality
None	Verify predictions during tests	Premature	Premature	Community size, structure, and population oscillations for scavengers; behavior of benthic organisms
Proximity of sites; Stable Reference Areas	Study tests	Control dispersion; require compact shape of site	Study initial operations	Natural history; recolonization; fate of plume (suspended particulates); mortality away from subarea; mine site shape; proximity of mine sites
None	Verify predictions during tests	Premature	Premature	SPM concentration; dissolved oxygen of bottom water
None	Verify predictions during tests	Premature	Premature	Chemistry of bottom and interstitial waters
None	Verify predictions during tests	Premature	Premature	Dissolved oxygen for bottom water
None	Verify predictions during tests	Premature	Premature	SPM concentration and zooplankton mortality
None	Verify predictions during tests	Premature	Premature	Nutrient content of surface waters; SPM concentration; zooplankton mortality and species changes
None	Surface discharge and zooplankton in and around plume	Premature (could retain nodule fines on ship if necessary or discharge beneath surface	Surface discharge	Nodule fines in discharge; uptake in zooplankton tissues; trace metal concentrations in surface water
None	Verify predictions during tests	Premature	Premature	SPM concentration; dissolved oxygen in surface waters
None	Verify predictions during tests	Premature	Premature	SPM concentration; effects on feeding and spawning of tunas
None	Fish larvae in and around plume	Premature (could discharge at depth if necessary)	Premature	Fish larvae mortality; dissolved metal content of discharge
None	Verify predictions during tests	Premature	Premature	Dissolved oxygen of surface waters, SPM concentration
None	Verify predictions during tests	Premature	Premature	SPM concentration and settling velocities
None	Verify predictions during tests	Premature	Premature	SPM concentration; light attenuation values; particles setting rates
None	Verify predictions during tests	Premature	Premature	Nutrient content of discharge
None	Verify predictions during tests	Premature	Premature	Nutrient content of discharge; changes in species composition; rate of silicate uptake by phytoplankton
None	Verify predictions during tests	Premature	Premature	Dissolved trace metals in discharge; SPM concentration
None	Verify predictions during tests	Premature	Premature	Fish mortality; dissolved O_2 content of plume and ambient waters

TABLE 15 SUMMARY OF INITIAL ENVIRONMENTAL CONCERNS AND POTENTIAL SIGNIFICANT IMPACTS OF MINING

II.D Marine Alternatives, Including Proposed Actions

Legal alternatives under mining as regulated by the Act are discussed below including both environmental and resource conservation issues. Alternatives are treated as either license or permit phase issues. Approaches to issues having little or no environmental consequences are also identified. Finally, certain approaches precluded by the Act are noted: a laissez-faire approach involving little or no Federal involvement; delaying the initiation of commercial recovery beyond 1988; or prohibiting deep seabed mining in favor of a continued reliance on land sources of metals.

II.D.1 Alternatives Under Regulated Mining

In passing the Act, Congress adopted a program of regulated deep seabed mining wherein the Administrator of NOAA will develop regulations to govern issuance of licenses for exploration and permits for commercial recovery. Before issuing a license or permit, NOAA will determine among other things that the proposed activities cannot reasonably be expected to result in a significant adverse impact on the environment. Thus, NOAA may impose terms, conditions, and restrictions (TCR), including those relating to conservation of natural resources, protection of the environment, or safety of life and property at sea, on licenses and permits. Through NOAA's powers to grant licenses and permits and impose TCR, environmental quality will be preserved. Industry is aware of possible adverse environmental impacts and will be expected to take environmental protection into account in their design and operating practices.

The Act involves NOAA in mining through reviewing and approving applications, imposing necessary environmental requirements, preparing technical and financial reports, and implementing other requirements of the law. TCR for particular site-specific licenses and permits will consider mitigation (see Section II.C.2) and conservation measures in light of the potential impacts in a particular application.

Any potentially significant environmental impacts will be set forth in site-specific EISs, together with pertinent mitigation measures (which may include those listed as possible mitigation measures in Section II.C.2) and appropriate TCR. Through this mechanism and appropriate environmental reviews, measures to protect the environment will be incorporated into licenses and permits. This approach is specifically authorized by current law, and can be negotiated as part of RSA and LOS. Through these requirements, Congress has adopted an environmentally protective approach which also protects industry's rights to mine an area and facilitates continued development of the deep seabed mining industry.

Regulated deep seabed mining requires an administrative framework to expeditiously evaluate and grant licenses and permits. Such processing will most likely delay industry action compared to what would happen in the absence of Federal regulation. Nonetheless, Congress has mandated Federal license and permit processes for the legal and environmental protection they will provide during seabed development.

Under regulated mining, NOAA is prohibited from issuing a license or permit if it finds that mining will result in a significant adverse impact on the environment that cannot be mitigated through appropriate measures. The Act further provides for NOAA to require in permits the use of best available technologies (BAT) to protect the environment where significant effects are found unless the incremental benefits are clearly insufficient to justify the incremental costs of using such technologies. Monitoring of mining systems tests plus a modest Government-sponsored research effort (National Oceanic & Atmospheric Administration, 1981a) will assist applicants in the identification of technological alternatives to mitigate potential significant environmental impacts.

The regulatory deep seabed mining alternative will lead to competition with nations who are greatly dependent on land based mining, thus impacting our relations with those nations, e.g., Zaire for cobalt.

II.D.1.1 Issues where alternatives have environmental consequences

Within the framework of the above comments on a regulated approach to deep seabed mining, NOAA has identified nine issues (three License Phase, six Permit Phase) relevant to this PEIS, each of which has several alternative approaches; the following discussion is organized accordingly.

- License Phase Issues

1. <u>Environmental Monitoring</u>

During exploration, a miner will be required to conduct certain types of environmental monitoring. The results of the monitoring will be used to verify NOAA's estimates of effects not likely to be significant (see Section II.C.1), our general understanding of the DOMES area, and the three potentially significant concerns discussed in Section II.C.2.

- o Alternative 1 - Let explorer show capability to decide what to monitor
- o Alternative 2 - NOAA define monitoring requirements (see Section II.D.3 and II.D.4)
- o Alternative 3 - NOAA define environmental parameters on which NOAA will need information; industry show capability of "how to do it", subject to NOAA review
- • Environmentally preferred and NOAA preference - Alternative 3

o Discussion - Under Alternative 1, industry would be free to decide what to monitor and how. Even assuming a good faith effort on the part of companies, it is unlikely that the resultant data would be compatible with the DOMES data. Unless otherwise directed, a great variety of instruments, techniques, and sampling strategies would likely be used. If monitoring data are not compatible, it will be impossible to verify probability predictions (see Sections II.C.1 and II.C.2) without considerable government sponsored research, an effort that is more properly directed at the three effects with potential for significant impact (see Section II.C.2).

In Alternative 2, NOAA would specify parameters to be monitored, for what purpose, and with what techniques. A technical guidance document (National Oceanic & Atmospheric Administration, 1981b) would help insure a correlation between DOMES research findings, NOAA's (1981a) Five-Year Research Plan, and new results. The data requirements (see Section II.C.3) and findings from monitoring (see Section II.C.4) would be studied by NOAA to determine TCR during commercial mining (see Sections II.C.2, II.C.3, and II.C.4).

Alternative 3 is a sensible compromise in that NOAA builds on the PEIS by defining, in its technical guidance document, the environmental parameters of relevance and encouraging industry to devise methods of sampling that satisfy or surpass those used in the mid-1970's in DOMES.

This requirement is incorporated into Section 970.203(b)(7) and 970.522 of the regulations.

2. <u>Proximity of Mining Sites</u>

The spacing of sites is related to both the impact of the rain of fines from the benthic plume on bottom communities and the nature and rate of post-mining recolonization. Although this is largely a permit phase concern, whether or not commercial recovery sites proposed by industry will be too close to one another should be reviewed at the license phase to ensure that alternatives at the permit phase are not precluded.

o Alternative 1 - Laissez-faire approach; sites would be issued without any spacing requirements except that they be located within the DOMES area.

o Alternative 2 - Encourage clustering of sites; concentrate the rain of fines in as small an area of the seafloor as practicable.

o Alternative 3 - Avoid a linear alignment of commercial mining sites which could form a barrier to recolonization or provide for "bridges" at a spacing to be estimated, if possible.

o Alternative 4 - Avoid a long swath of sites at the license phase.

• Environmentally preferred and NOAA preference - Alternative 3

o Discussion - Under Alternative 1, it is possible that several sites could be located such that they comprise a long swath of mined out areas. Such a swath is one pattern of sites that seems to have the most potential for significant adverse impact. Jumars (1981) describes such a swath as acting as a potential barrier to recolonization by isolating one part of a benthic population from another.

Alternative 2 would obviate the concern noted above. However, there is no basis for determining at this time if clustering is better than dispersing sites. Therefore, there is no environmental reason for placing such constraint on site locations.

Alternative 3 takes a laissez-faire approach with the single constraint that NOAA would review applications at both the license phase and the permit phase so a swath of commercial mining sites would not occur. Research would be conducted to estimate minimum safe spacing. Intra-mine site buffer zones might be just as effective as the inter-site buffers created by well separated sites.

Alternative 4 appears to be premature and unnecessary at the license phase. NOAA does not have data on what, if any, safe spacing between sites is necessary for recolonization. Areas subject to testing at the exploration phase will be small. Further, the relationship between areas actually affected by mining and the size of commercial recovery sites is not yet clear. Thus, NOAA expects that any potential problem regarding a "swath" will not come up until the commercial recovery stage.

3. Stable Reference Areas

The Act requires the U.S. to negotiate internationally for the purpose of establishing "stable reference areas" (SRA) in the DOMES area in which no mining will occur. These areas are intended to serve as research reference or control areas. The SRA concept is not to be construed as an authority to withdraw substantial portions of the DOMES area.

o Alternative 1 - Establish sites at random

o Alternative 2 - Determine criteria for site selection, in cooperation with reciprocating states

• Environmentally preferred and NOAA preference - Alternative 2

o Discussion - Establishing stable reference areas at random could result in the withdrawal of areas from mining that are poor control areas, are very rich in nodules, or both. Jumars (1981) has speculated that, after mining, sites will be recolonized by species having high larval dispersal abilities as well as relatively rapid reproductive rates. Thus, there is reason to suspect that abandoned mine sites will be initially recolonized by a substantially different benthic community structure. Randomly selected control areas may serve as a poor reference standard against which such mining-induced changes can be documented.

Alternative 2 would focus on a determination of criteria for site selection. For example, one well-selected, large area may be sufficient as a control area.

- Permit Phase Issues

Six issues follow: two deal with environmental effects; three deal with resource conservation; and, one is an international issue.

Environmental Issues

1. Operations

During commercial operations, miners will be expected to mine in harmony with the environment, with due regard for conservation measures, and in accordance with any TCR that may be established.

o Alternative 1 - Assume technological capabilities of applicant

o Alternative 2 - Require detailed design and operating information accompanying applications for permit to include a monitoring plan as well as a description of the miner's ability to monitor environmental effects; selected components of the mine system would be reviewed and evaluated for the site-specific EIS and possible TCR prior to mining (see Section II.C.3).

● Environmentally preferred and NOAA preference - Alternative 2

o Discussion - Alternative 1 assumes that the mining system would operate in a fashion described in this PEIS and that the miner would have the capability to adhere to the TCR established for the permit. Either assumption could prove unfounded in which case unexpected environmental effects e.g., secondary rejection of sediment from riser pipe at mid-depth, could occur and/or selected parameters, e.g., discharge flow rate, could be measured incorrectly.

Alternative 2 rests on the premise that a monitoring strategy is best worked out between the miner and NOAA after examining such details as proposed nodule collection techniques, sediment rejection techniques, pumping methods, and mine ship fines separation plans.

2. Proximity of Mining Sites

See license phase discussion.

- Resource Conservation Issues

1. Mining Pattern

This section deals with the environmental implications of the manner in which the miner endeavors to mine each sub-area in the mine site.

o Alternative 1 - Laissez-faire; this approach assumes that companies should be allowed to mine in any pattern they choose.

o Alternative 2 - Require a pattern of any type desired by the applicant.

o Alternative 3 - Defer decision until demonstration-scale mining tests are observed; this would allow a laissez-faire approach during test mining in exploration but may lead to a requirement that a pattern be selected for subsequent commercial mining. Required pattern mining is inappropriate at the license stage because of the small areas involved for test mining.

• Environmentally preferred and NOAA preference - Alternative 3

o Discussion - A random pattern over the entire permit area might allow the maintenance of a satisfactory production rate over the life of the permit. However, a lack of control over recovery efficiency might obviate the economic viability of future mining because of the patchiness of remainding nodules. Pattern mining may enable later miners to mine nodules missed the first time with more ease that if the initial mining was conducted in a random manner. Second generation mining could postpone the need to mine virgin sites, thereby postponing the need to disrupt additional areas of benthic communities. A decision to require pattern mining would take into account the environmental aspects of such an action.

2. Selective mining

This issue deals with the mining of the richest zones of a mineral deposit first.

o Alternative 1 - Laissez-faire

o Alternative 2 - Identify the logic of selective mining plan; permit only planned operations.

• Environmentally preferred and NOAA preference - Alternative 2

o Discussion - Mining rich areas of sites first very likely will be done to improve cash flow in the early years. If it is part of a long range mine plan, selective mining could proceed. If not, the applicant could mine rich zones until leaner zones are all that remain and then abandon the site.

3. Manganese Utilization

This issue involves the potential waste of manganese on the part of those first generation miners who plan three-metal operations.

o Alternative 1 - Let the market decide. The market for manganese would be the sole criterion in determining the fate of the manganese that comprises about 25 percent of the nodules.

o Alternative 2 - Require four-metal operations; this approach recognizes that manganese will be in short supply for the U.S. by the year 2000, possibly earlier. This could also delay mining until the manganese market opens up or the Federal government becomes financially involved.

o Alternative 3 - Establish a means for manganese tailings to be saved, as necessary for future strategic purposes and as a resource for the future, to the extent practicable.

• Environmentally preferred - Not predictable at the programmatic level; a site-specific analysis would balance less mining on land and more storage space near nodule processing plants.

- NOAA preference - Alternative 3.

o Discussion - Although manganese, which is essential in the manufacture of steel, is in ample supply at present, its continued supply to the U.S. could become a problem by the end of this century. There are relatively few land producers in the world (the USSR and South Africa are the major producers) and there have been no major discoveries in the past 20 years. The U.S. has no known deposits that can be mined, even at substantially higher prices. World demand is forecast to increase at an annual rate of 2.93 percent. In order to meet this demand, South Africa must keep expanding its mines. If capacity does not expand, a shortage could conceivably develop as early as the late 1980's. Continued flow of manganese to the U.S. will depend on a continuing supply flowing from South Africa.

Despite this outlook, the economics of the early first-generation industry and the absence of a manganese market indicate that three-metal operations will dispose of huge quantities of tailings that contain potentially recoverable manganese. Manganese may be disposed of in such a manner that retrieval would be impossible, e.g., ocean disposal, or it may be stored on land for later use.

The retention of manganese from three-metal operation could be assured if manganese tailing are saved at government expense for the National Defense Stockpile; manganese and selected other materials are held for future strategic needs under the authority of the Strategic and Critical Materials Stock Piling Act of 1946, as amended. Such a "resource for the future" should preclude the need for an equivalent amount of mining on land and avoid the associated environmental effects (Appendix 6). It can be argued that manganese tailings need not be saved until a market develops. This argument presupposes that ocean mining can continue to supply manganese and that no stockpile would be useful. However, consideration should be given to the future vulnerability of deep seabed operations. Not only are they vulnerable to sabotage, but they may be subject to production control through the International Seabed Authority if a LOS treaty comes into force.

Within the framework of Section 110 of the Act, a study of the potential for manganese tailings to contribute to the National Defense Stockpile will be proposed in cooperation with the General Services Administration stockpile manager, and the Federal Emergency Management Agency. The extent of the national need for manganese and the potential implications of stock piling manganese tailings from U.S. processing plants will be examined. The implications for the deep seabed mining industry also will be examined, e.g., additional land needs or precluding operations dependent on ocean disposal. This study will be coordinated with the joint NOAA/Bureau of Mines research into the character of the manganese-bearing rejects as well as a research project planned by the U.S. Bureau of Mines aimed at developing techniques to recover manganese in useable form from tailings from nodule processing.

- International Issues

1. Reciprocating States Criteria

This issue deals with both the license and permit stage because the U.S. is authorized by the Act to recognize licenses and permits of other nations whose requirements are compatible with U.S. law and regulations. This section deals with criteria for designation of reciprocating states (RS).

Alternative 1 - No criteria.

Alternative 2 - Criteria for designating RS would be developed. The criteria would identify the major elements of an environmental and regulatory program which could be considered compatible with the United States program. In consideration of whether to designate a RS, the following factors are of the type that will be taken into account in developing a set of applicable criteria:

a. Authority to issue emergency orders for the protection of environment and safety;

b. A process for reviewing the environmental, conservation, and safety aspects of ocean mining and for evaluating alternative measures for addressing them;

c. Authority to impose terms, conditions, and restrictions (TCR) on licenses and permits;

d. Authority to modify terms, conditions, and restrictions (TCR) based on new information, consultations, or proposed modifications of activities;

e. Authority to suspend, revoke, or modify particular activities as needed to ensure compliance and to protect the marine environment, ensure conservation of the resource, and preserve the safety of life at sea;

f. Authority to require monitoring of the activities of licensees and permittees;

g. Authority to require detailed technical operations information from applicants including a description of mine site; the technology to be developed, tested, or employed; the exploration and recovery schedule; the methods to be used for processing and disposal of wastes at sea; and, a description of environmental safeguards and monitoring systems;

h. Authority to require mitigation measures and reporting requirements;

i. Effective enforcement authority;

j. Authority to disapprove applications if significant adverse impacts which cannot be mitigated are found;

k. Specified term for license;

l. Authority to place inspectors onboard ships for observation or enforcement;

m. Encourage public disclosure, participation, comment, notice, and hearings; and,

n. Continue consultations, coordination, and review to assure equivalent environmental protection and compatibility of programs.

These and other appropriate elements of a deep seabed mining environmental and regulatory program would be discussed with potential RS and efforts would be made to harmonize differing national approaches. While national legislative and regulatory schemes will vary, a reciprocating states arrangement (RSA) would be based on the assumption that national programs can reach essentially the same results. Consultations among RS would be a key mechanism for assuring equivalent environmental protection. In particular, RS would consult in cases where there is a finding of significant adverse impact in order to identify appropriate mitigation measures. Additional criteria would be considered as appropriate. Important technical aspects of seabed mining programs also would be coordinated with RS. For example, RS would exchange environmental data and information on a regular basis. In particular, RS would allow joint review of research and monitoring programs and coordinated evaluation and consideration of the need for mitigation measures. Similarly, nations would exchange information on the environmental effects of deep seabed mining activities obtained through monitoring programs. RS also would be requested to enter negotiations to establish internationally recognized stable reference areas.

NOAA would designate other nations as RS. The designations would incorporate the requirement for later consultations to assure development of compatible commercial recovery regulations. In addition, RSA would include a mechanism for systematic review designed to maintain the compatibility of their programs.

- Environmentally preferred and NOAA preference - Alternative 2

o Discussion - Agreements between RS will establish international mechanisms for authorizing deep seabed mining. The development of criteria for the designation of RS will provide benchmarks for judging the adequacy of other nations' regulatory programs in terms of addressing numerous issues including the assessment of environmental impacts and environmental protection. Without such criteria, it would be difficult to provide for systematic uniform evaluations of the adequacy of other nations' regulatory programs. Such a system offers models for use by the Seabed Authority if a LOS treaty enters into force. If a LOS treaty fails to enter into force, these reciprocating agreements will guide the harmonization of commercial recovery as well. Further the Act requires RS proposals to be judged on the basis of U.S. law and regulations. The alternative of "no criteria" would be inconsistent with the Act. NOAA concludes that the criteria cited in Alternative 2 will be used in negotiations with potential reciprocating states.

II.D.1.2 Issues where alternative approaches have little or no environmental consequence

The Act's provisions include many issues where NOAA has broad latitude in implementation. This section lists those issues that NOAA believes to be environmentally neutral, hence not worthy of detailed analysis in this PEIS. Of course, later NOAA evaluations, e.g., of an applicant's technological capability, will include an appraisal of the applicant's ability to meet NOAA's monitoring requirements. An applicant unable to show the technological (and financial) capability to mine and monitor as planned would not receive a license or permit.

1. Technological capability of applicant for license
2. Financial capability of applicant
3. Diligence in exploration
4. Safety of life and property at sea
5. Potential international conflicts
6. Mine site size

Other than the fact that each mine site should be large enough to support about 20 years of mining, size of and by itself does not seem to be an environmental issue. The environmental issue is the size of area to be affected by the sweeping action of the collector. About 1800 km^2 will be swept each year, using first generation mining technology, in a 3 million tons per year operation (see Appendix 3.1.1). Thus, a 20 year first generation mine site is likely to be at least 36,000 km^2 in area. However, the 36,000 km^2 is not likely to be contiguous; this is the sum of the areas of numerous relatively small sub-areas of mineable seafloor. The subareas are very likely to be separated by areas of seafloor that are not mineable due to such limitations as topographic constraints and low density of nodules. A mine site consisting of widely separated mineable sub-areas of necessity will be larger than one of closely spaced sub-areas. Regardless, only about 1800 km^2 will be swept by the collectors annually. Quite apart from environmental considerations, site size will be taken into account by NOAA (as required by the Act) in making findings under §103(a)(2)(D) and (E) relative to "Logical Mining Units."

II.D.2 Other Alternatives That Are Precluded by the Act

II.D.2.1 Laissez-faire approach

With this approach, any miner would be free to mine an area without the need for government intervention, approval, or regulation (except for other laws and treaties that apply to U.S. citizens wherever they go). This alternative would provide maximum flexibility for industry: each miner could mine what it could get. However, the miner would have no legal claim to an area for exploration and processing, no protected rights, and there would be no means to resolve conflicts over claims. This alternative has been rejected by industry and NOAA in favor of a system where legal rights to a particular site are established to guide the seabed mining industry and impose environmental controls, if needed.

Environmental protection through regulations would be precluded by this approach. Accordingly, industry would, under this approach, be free to mine without any legally required regard to the environmental consequences. However, the possibility exists for significant adverse effects over which NOAA would have no control.

Clearly, Alternative 1 has serious environmental, legal, and economic problems. It is not preferred under any criteria.

II.D.2.2 Prohibit deep seabed mining

Prohibiting or delaying deep seabed mining would necessitate continued reliance on land based mines. This approach would preclude or delay the environmental consequences set forth in this statement. However, continued reliance on land based mining will have predictable serious adverse impacts (see Appendices 5 and 6), regarding land and water use, air pollution (particularly sulfur dioxide), human resources, injuries, and socio-economic structures.

NOAA estimates that a delay in initiating deep seabed mining until 2010, for example, would result in over 180 km^2 (52 nmi^2) of land based mines to produce comparable amounts of nickel, copper, cobalt, and manganese. About 30 million MT (33 million tons) of sulfur dioxide may be emitted into the atmosphere (the actual amount would depend on mitigation measures in force in various countries). Over 80,000 disabling injuries would be expected to occur.

Reliance on land based mines will also mean increasingly costly infrastructure (roads, ports, utilities, etc.) to support mining operations. Reliance on land based mines would mean dependence on potentially unreliable foreign sources for the supply of U.S. strategic metals. Sources of these minerals currently involve nations such as South Africa (manganese) and Zaire (cobalt). As has been demonstrated in the case of oil, U.S. dependency on foreign sources for natural resources may have potentially substantial effects on cost and availability.

Delays in proceeding with deep seabed mining would also retard development of domestic technology while foreign competitors proceed. While the U.S. currently is at least the technological equal of other nations in developing mining capacity, this position would likely be lost by prohibiting or delaying seabed mining. Jobs for U.S. citizens involved in deep seabed mining would also be lost to land based mining abroad. This would amount to several hundred jobs at sea and between 350 and 500 jobs per processing plant on land.

Because a prohibition of deep seabed mining would lead to substantial adverse effects resulting from increased land based mining and an increasing dependence on foreign sources of supply of strategic metals, this alternative is not preferred.

II.D.2.3 Delay initiation of deep seabed mining

There are two reasons one might contemplate delaying implementation of the Deep Seabed Hard Mineral Resources Act, thereby effectively delaying the initiation of mining. NOAA could delay involvement in the reciprocating states' agreement (RSA) of Like-Minded Nations until a Law of the Sea (LOS) treaty is in force. Alternatively, NOAA could delay implementation until a greater understanding of likely environmental effects has been reached.

The Administrator is authorized to negotiate with other nations and to designate reciprocating states for the purpose of recognizing mining licenses granted by other nations. As indicated above, the Act requires that other states regulate their industry in a manner compatible with U.S. seabed mining regulations, including adequate provisions for environmental protection and conservation of natural resources, for the U.S. to make a finding that they are eligible for designation as reciprocating states. The U.S., by acting on seabed mining environmental regulations early, can exercise leadership in this area. Many of the key issues in the environmental area would be resolved early in the U.S. domestic context. As a practical matter, however, these technical issues, once resolved, could serve as a base for other nations working toward their own domestic mining regimes but with different priorities.

Delay of implementation will in effect delay U.S. access to seabed minerals and prove costly to U.S. industries already involved in seabed mining development. Further, there is no reason to believe that delay of the RSA might be environmentally beneficial. U.S. environmental requirements are currently among the most stringent in the world. Other ocean mining nations are likely to have a wide range of approaches to environmental issues and would be unlikely to impose standards compatible with U.S. standards outside the context of RSA. This could pose additional risks to the environment and disadvantages to U.S. industry. In the RSA context, NOAA is confident that a compatible environmental regime will be worked out at a relatively early date.

The combination of U.S. domestic environmental standards and the environmental criteria established in RSA will provide a useful model for the international rules and regulations to be drafted by the Preparatory Commission (Prepcom) of LOS. Once the major ocean mining nations have agreed to the environmental requirements they are likely to be adopted first by the Prepcom and then by nations who are on the verge of seabed mining, e.g., USSR, but who would not otherwise accept stringent environmental regulations similar to those of the U.S.

If on the other hand, the United States delays developing environmental standards until the international community addresses them at the Prepcom, the results may be less environmentally sensitive. Less environmentally specific requirements could result because some developing countries and/or land-based producers of manganese, cobalt, nickel, and copper have objectives which conflict with U.S. interests in mineral access. Some wish to see a strong international mining enterprise operating without environmental regulations which they consider to be the exclusive concern of developed countries. Some nations might wish for competitive or ideological reasons to see environmental regulations imposed for the purpose of reducing seabed mining production. A functioning RSA could serve as an affirmative model for the Prepcom and could help to minimize the possibility that international rules and regulations would focus on nonenvironmental objectives. Delay in implementing an RSA, therefore, could reduce U.S. leadership in the development of sound environmental regulations.

Delay would not change the actual impact of mining. Delaying implementation of the Act until a greater understanding of likely environmental effects has been reached would almost certainly preclude acquisition of information that would give us the necessary understanding. Most short-term concerns appear to have a low probability of occurrence (see Section II.C.1.2.2.5). To examine the nature and significance of long-term effects will require the monitoring of demonstration scale mining tests during exploration. Research and monitoring programs will be established while the industry is in the testing and exploration phase (National Oceanic and Atmospheric Administration, 1981a). These programs seek to confirm NOAA's hypothesis, based on DOMES II results, that seabed mining is not likely to result in significantly adverse environmental impacts and thus can proceed to the commercial scale. This process is expected to be underway prior to granting commercial recovery permits and within the time frame necessary to establish or modify appropriate terms, conditions, and restrictions.

Since these exploration tests are necessary to achieve greater understanding of environmental impacts, a delay of deep seabed mining would be counterproductive. Further delay would mean continued total reliance on land based mining with adverse impacts cited above.

All of the above reasons consistently lead us to the conclusion that any delay in implementation of the Act is not an environmentally preferred alternative.

III. IMPACTS OF ONSHORE FACILITIES

Commercial scale nodule recovery and processing have yet to be demonstrated. Consequently, neither the specific sites where processing facilities might be located nor the specific technologies which will be used can presently be identified. These decisions will be unknown until industry groups apply for mining permits for commercial recovery. Locations as diverse as the island of Hawaii; Valdez, Alaska; San Francisco Bay, California; Brownsville, Texas; and Tampa, Florida, have been identified by NOAA as being representative of the onshore areas industry may consider for processing and related activities. These locations vary significantly in terms of their biophysical and economic characteristics, including port water depth, terminal facilities, water availability, and much more. Additionally, the public perception of the potential environmental problems and the associated environmental controls will also vary among these locations. Socio-economic and cultural impacts, and public perceptions as to whether they are positive or negative, will also be site-specific.

Because potential plant locations have not yet been identified by industry and since most impacts are largely site-specific, environmental, socio-economic, and cultural impacts of onshore processing cannot be fully assessed at this time. The types and magnitudes of the environmental, socio-economic, and cultural consequences are dependent on the site-specific characteristics and the processing technology employed. Nonetheless, some general effects of onshore activities are universal or inevitable. Those effects can be described in general terms without reference to a specific site. Mitigation measures, too, can be described generally, although specific application depends on specific locations and technologies.

NOAA has sponsored generic studies of various technologies which might be used for nodule processing and associated activities (Dames & Moore and EIC Corp., 1977; Dames & Moore et al. 1977) and to identify geographic areas (Figure 23) of the U.S. which are representative of where industry may locate processing facilities (Bragg, 1979; Hawaii Department of Planning and Economic Development, 1980; Oregon State University, 1980). The major criteria used to identify the areas were their proximity to the DOMES area, a minimal channel depth of 13 m (40 ft) at low tide (either existing or planned dredging), and an adequate infrastructure for a plant.

While the specific metallurgical processes to be utilized in nodules processing will be different from those used in processing land ores, the facilities and general techniques are quite similar. The most significant differences between land ore and nodule facilities are related to the nature of the ore and the probable coastal location of processing plants. Conventional mineral processing plants are usually found in less densely populated and mountainous interior areas of the country.

Following the format used in Appendix 3, this discussion of environmental impacts is divided into four subsections, each dealing with one of the major onshore processing facilities: (1) marine terminal; (2) port-to-plant transportation; (3) nodule processing plant; and (4) waste disposal. Since the environmental consequences of an industrial facility are different during construction and operation, owing to the relatively short-term nature of the former, the discussion of the environmental impacts of construction and operational considerations are separately described. In addition, it should be pointed out that the extent of most of the potentially adverse onshore environmental impacts of deep seabed mining will be highly dependent

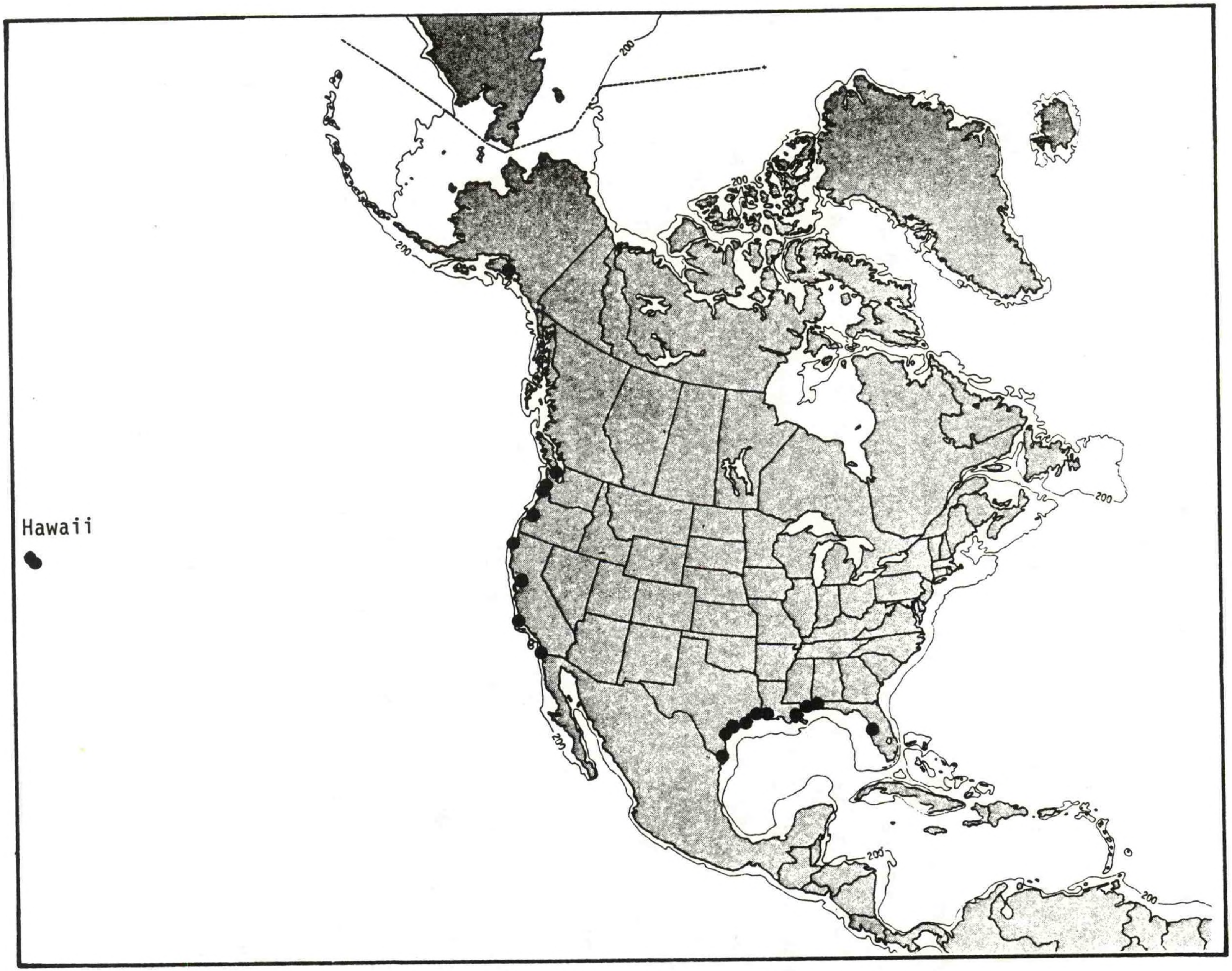

Figure 23.--Representative geographical areas where industry may seek to locate processing facilities.

on the specific location of the onshore facilities. Such site-specific impacts will be addressed in site-specific EISs associated with applications for permits for commercial recovery activities.

III.A <u>Onshore Activities</u>

III.A.1 Port Terminal Facilities

From a shoreline use viewpoint, marine terminal facilities required to unload nodules and provide temporary storage should be relatively small and innocuous compared to most industrialized ports. Moreover, land-use conflicts that might arise from its siting on the commercial waterfront would be typical of those conflicts encountered in expanding commercial ports. The labor skills required to operate the terminal would be the same as those found in most commercial ports; the relatively small labor force needed can probably be drawn from the local labor market without seriously affecting local economy. While terminals designed to unload nodules mechanically or pneumatically are possible, terminals designed to unload nodules in a slurry form are currently considered most likely (see Appendix 3.3.1.1).

III.A.1.1 Construction

The normal construction related environmental impacts, such as those resulting from dredging, noise, dust emissions, rain water run-off, etc., would of course be encountered during port terminal facilities renovation or construction. These impacts, however, are relatively short-term and may be controlled by various mitigation measures imposed on the construction contractor by Federal, State, and local laws and regulations.

In addition to Federal laws, all of the Pacific coastal States and some of the Gulf coast States in which manganese nodule processing plants could be located either have, or may have in the near future, federally-approved coastal management programs. These programs will influence the location, design, and impacts of the port terminal facilities and other onshore nodule processing facilities. Coastal management programs are typically based on performance standards, and include either a State coastal management agency with implementation responsibilities through planning and regulation or State resource management laws tied to State coastal policies. There is no direct Federal regulation involved in NOAA's Office of Coastal Zone Management; however, Federal agencies may not conduct, or issue permits for, activities which are inconsistent with a State's approved coastal management program.

The construction of port and other onshore facilities will generally mean jobs for builders, engineers, and others in the construction process and resultant changes in the local economy and infrastructure. The scope of these effects will depend on the size of the plant and related facilities.

III.A.1.2 Operations

The operation of a slurry-type marine terminal for manganese nodules would not appear to raise serious environmental concerns. Noise generated by pumps and machinery while unloading the nodules from a transport ship and handling them in the temporary storage area would be no greater, if not less, than the noise generated by most other facilities found in commercial ports. Thus, except in ports with comparatively low product volumes, nodule activities would have an insignificant impact on the overall noise level of the area. Salt water used for slurrying the nodules would probably be recycled; only replacement water to counter evaporation or leaks would be drawn from the harbor. Water quantities required should not raise concerns about salt water intrusion in most areas. The placement of structures, such as piers, wharfs, and underwater slurry pipelines, in navigable waters could affect ship navigation; however, the placement of such structures would require Corps of Engineers approval and prior notification of the U.S. Coast Guard so that a "Notice to Mariners" could be issued to warn navigators of the existence of such structures.

Risk of environmental damage resulting from leakage or an accidental spill of nodule slurry is almost nonexistent because the nodules in their natural state do not appear to be environmentally harmful (see Section II.C). While fuel oil for the mining vessel would be carried by the outbound nodule transport ships, the amount of oil involved would be considerably less than the amount carried by even a small oil tanker and not much more than large cargo vessels. Consequently, the risk of spill during oil loading or transporting should be no greater than the risk of a spill from any other type of shipping activity. While it could be argued that increased fuel transfer operations and ship traffic would increase the risk of oil spills from transfers and ship collisions, the increase in transfer operations and in ship traffic near a marine terminal for manganese nodules would be quite small and should have almost no effect on the probability of a spill.

A potential air pollution problem is associated with exhaust emissions from transport ships. The extent of this problem is site specific, being almost entirely dependent on the nature and extent of local air quality problems. If a mechanical or pneumatic terminal were to be proposed, an additional problem of controlling nodule dust would exist.

III.A.2 Port-to-Plant Transportation

The transportation of manganese nodules from a marine terminal to a processing plant does not appear to present any serious long-term environmental consequences, particularly in the likely event that the nodules will be transported by pipeline in slurry form. Because an "above ground" pipeline could be aesthetically displeasing, create a noise nuisance, and impede the movement of people and wildlife, State and local government permitting authorities may require the pipeline to be buried except for crossings of deep ravines, where the pipeline is short, where it is routed through an industrial area, or where the line matches an existing "above ground" pipeline right-of-way. (Even if the pipeline is not required to be buried, it would probably be more economical overall to bury the pipeline rather than to provide additional power to "lift" the slurry over highways, railroads, etc.)

Construction of a slurry pipeline, especially one that is buried, would result in short-term impacts that parallel those from similar construction projects, e.g., sewage pipelines. These effects could be adverse in the short-term but are deemed insignificant in view of the total processing project.

Other methods of nodule transportation, such as truck, railroad, or conveyors are also feasible.

The environmental impacts of transporting nodules by truck or railroad cars would be subject to existing regulations.

Where the plant is in proximity to the port and extant development between the port and plant is suitable, conveyor transportation of nodules is possible.

In some areas, such as Hawaii, it may be possible to locate the port and plant adjacent to or within several miles of each other. Transportation costs and possible environmental effects would then be reduced.

III.A.2.1 Construction

The most significant environmental and social impacts of a buried slurry pipeline would occur during the construction phase. Considerable excavation would be required for about 1.5 ha (3.8 a) per 1 km (1.6 smi) of right-of-way with resultant dust, noise, erosion, and other construction related effects. These effects will be temporary and can be minimized by utilizing environmentally sound excavation and construction practices and by routing the pipeline to avoid both heavily developed areas and environmentally sensitive areas. Indeed, it is highly unlikely that a firm would receive construction approvals for a pipeline through environmentally sensitive areas.

It is assumed that existing railroad mainlines would be used if rail transportation of nodules is proposed, but that new spurs to a marine terminal and to a processing plant may have to be built as part of the construction of those facilities.

Some minor connector roads would have to be built if truck transportation is proposed.

III.A.2.2 Operations

Once the construction of a slurry pipeline is completed, the land above it could be used for other compatible purposes. Noise generated by periodic pumping stations on longer pipelines could be kept to a minimum by enclosing them in sound-proof buildings.

A pipeline failure would result in the release of salt water and nodules to the environment. However, as indicated previously, unprocessed nodules do not appear to be toxic and any damage caused by salt water would probably be temporary and of only relatively minor concern.

The use of rail cars to transport the nodules would not greatly add to railroad traffic, and thus should have only minimal environmental consequences. It is possible that the use of rail cars could have a beneficial effect on the socio-economic environment of the area by strengthening the rail component of an area's transportation network.

The increase in truck traffic that would result from trucking nodules to a processing plant could significantly add to congestion on highways and to vehicle exhaust emissions. Heavy trucks could also increase road bed wear and tear.

III.A.3 Nodule Processing Plant

A manganese nodule processing plant has nodules, energy, reagents, and water as inputs; outputs are value metal products, liquid and solid wastes, and airborne emissions. Operationally, a nodule processing plant will be quite similar to a plant designed to process ores mined on land. In physical size and appearance, it could resemble a relatively small oil refinery except that there could be a storage area for coal instead of oil storage tanks and it could be served by a rail-line to bring coal in and move the products out. On-site nodule storage would probably be in either slurry ponds or specially designed enclosures. Nodules could be clamshelled from the slurry ponds into hoppers over a conveyor belt to a cage mill feed bin. Slurried nodules could also be dewatered by screens as received and stored in a conventional manner to achieve maximum drainage.

In discussing the environmental effects of manganese nodule processing plants, it is important to bear in mind that the potential impacts of the plant will depend to a large degree on the specific processing techniques utilized in extracting value metals from the nodules as well as plant location.

Five different metallurgical processes have been identified and investigated (Dames & Moore and EIC Corp., 197,) as likely alternative methods for extracting and processing value metals from nodules: 1) reduction/ammonia leaching; 2) cuprion ammonia leaching; 3) high temperature sulfuric acid leaching; 4) reduction/hydrochloric acid leaching; and 5) smelting (see Appendix 3.3.3).

Three principal alternative methods of disposing wastes from nodule processing have also been identified and investigated by Dames & Moore <u>et al.</u> (1977) -- containment in tailings ponds, landfilling of dried wastes, or ocean disposal (by either dumping or ocean outfalls). The first two could be either on or off the plant site, the third would be offsite.

The general resource requirements associated with the options for each of these major activities are shown in Table 16. It is important to note that no commercial scale manganese nodule processing facilities have yet been built and operated anywhere in the world. Consequently, the resource requirements shown in Table 16 and the data presented later on pollutant discharges and control measures can only be viewed as the best estimates now available. Generally, the resource requirements for onshore nodule processing are similar to other similar non-ferrous processing operations.

The principal differences in resource requirements for onshore processing are between three-metal and four-metal plants (Table 16). A three-metal plant would be designed to recover copper, nickel, and cobalt as its primary products while a "four-metal" plant would also produce manganese as a primary product. Both plants could produce secondary, market-dependent products.

Resource requirements vary widely between three- and four-metal plants. The latter may require three to four times as much electricity as the former but only approximately one-fifth as much land for onshore waste disposal. This is a function of the different metal recovery processes used and the fact that copper, nickel, and cobalt together make up only three percent of the nodules by dry weight, while the manganese content is about 25 percent. Because of the size of the near-future manganese market, a four-metal plant will probably be designed to process about one-third as many nodules as a three-metal plant.

The decision on whether three or four metals are recovered from the nodules will be determined primarily by the market for the metals. Because of the high percentage of manganese in the nodules, a deep seabed miner would want to weigh potential market trends. A single plant processing 1 million dry MT (1.1 million dry tons) of nodules per year, a size anticipated by NOAA, could supply about one-third of the manganese currently consumed annually in the

TABLE 16. Preliminary Identification of Resource Requirements for Major Activity Alternatives for Onshore Marine Nodule Processing[a]

MAJOR ACTIVITIES	RESOURCE REQUIREMENTS															
	THREE-METAL PROCESSING								FOUR-METAL PROCESSING							
					ENERGY								ENERGY			
						FUELS								FUELS		
	Nodule Input (10^6 t/yr)	Land (Hectares)	Labor (Persons)	Water (10^6 m^3/yr)	Electrical (10^3 kw)	Coal (10^3 t/d)	Gasoline (10^4 l /yr)	Diesel (10^4 l /yr)	Nodule Input (10^6 t/yr)	Land (Hectares)	Labor (Persons)	Water (10^6 m^3/yr)	Electrical (10^3 kw)	Coal (10^3 t/d)	Gasoline (10^4 l /yr)	Diesel (10^4 l /yr)
1. <u>Transshipment From Port to Processing Plant</u>																
•Marine Terminal																
Whole Nodules	-	8.0	58	-[b]	N/A	-	-	-	-	4.8	49	-	N/A	-	-	-
Slurry	-	5.2	33	N/A	N/A	-	-	-	-	2.4	28	N/A	N/A	-	-	-
Dried/Ground	-	4.4	47	-	N/A	-	-	-	-	3.2	39	-	N/A	-	-	-
•Transportation System																
Rail[c]	-	N/A	15	-	N/A	-	-	56.0	-	N/A	12	-	N/A	-	-	19.0
Truck	-	N/A	N/A	-	-	-	N/A	N/A	-	N/A	N/A	-	-	-	N/A	N/A
Slurry[d]	-	4.8 + 3.8/km	6-12	2.70	1.2	-	N/A	N/A	-	2.4 + 3.8/km	6-12	0.81	0.4	-	N/A	N/A
Conveyor[e]	-	4.8 + 3.2/km	N/A	-	0.5	-	N/A	N/A	-	1.6 + 3.2/km	6	-	0.5	-	N/A	N/A
2. <u>Nodule Processing at Onshore Plant</u>																
•Reduction/Ammonia Leaching Plant	3.7	80.0	500	6.00	23.5	2.1	-	-	-	-	-	-	-	-	-	-
•Cuprion/Ammonia Leaching Plant	3.7	80.0	500	7.90	0.0	1.9	-	-	-	-	-	-	-	-	-	-
•High Temperature Sulfuric Acid Plant	3.7	73.0	500	5.40	28.8	1.0	-	-	-	-	-	-	-	-	-	-
•Reduction/HCl Leaching Plant	-	-	-	-	-	-	-	-	1.4	40.0	300	1.40	94.5	1.2	-	-
•Smelting Plant	-	-	-	-	-	-	-	-	1.4	50.0	300	1.40	70.3	0.8	-	-
3. <u>Waste Disposal</u>																
•On-site and/or Off-site Disposal																
Landfill	-	20.0/yr	20	0.09	0.23	1.5	8.7	160.0	-	4.0/yr	5	0.02	0.12	N/A	2.7	27.0
Tailings Pond	-	40.0/yr	4	Neg.	0.66	-	N/A	N/A	-	7.2/yr	3	Neg.	0.06	-	N/A	N/A
Manganese Storage	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
•Off-site Disposal																
Ocean Dumping	-	-	N/A	-	N/A	-	-	N/A	-	-	N/A	-	N/A	-	N/A	N/A

Abbreviations: m^3/yr, cubic meters per year; t/d, tons per day; KW, Kilowatt; N/A, data not available; l/yr, liters per year; km, kilometer; Neg., negligible.

a. All values are rounded; all units are metric.
b. - indicates none.
c. Assumes: 8 km of rail.
d. Assumes: 32 km pipeline.
e. Assumes: 3050 meter length, 24 hour continuous operation.

Source: Computation based on material in Dames & Moore (1977).

United States; any higher production rate could disrupt the domestic market (see Section II.D.1.1, "Resource Conservation Issue" No. 3). A three-metal plant would probably process between 2.5 and 4 million dry MT (2.75 to 4.4 million tons) of nodules per year, a level based largely on the economics of nickel production.

The range of wastewater treatment processes which have been employed in ore processing plants (Table 17) are described by the Environmental Protection Agency (1975). Nodule processing plants should be able to achieve the same levels of pollution control as required of other ore processing plants.

The liquid and solid discharge streams from processing plants include many elements found in small concentrations (Table 18) that, in certain chemical forms, are known to be toxic. Whether the constituents will be in toxic or innocuous forms in the waste stream and the quantities involved can not be fully determined at this time. The constituents in the waste stream will differ between three- and four-metal plants, for each of the processing techniques, and for significant variations within a given technique. Further, processing techniques are still under development by industry and have yet to be tested in a continuous operating mode at a reasonable scale. Small scale plants are likely to be built for testing during the license phase (see Section II.C.3 and Appendix 3.4.2). Because there has been no opportunity to sample and test "representative" wastes, and because of the importance of the subject, NOAA, EPA, the Bureau of Mines, and the Fish and Wildlife Service have embarked on a multi-year research program to determine if a potential major problem could exist.

In the future, EPA will decide if nodule processing facilities can be adequately controlled under existing effluent guidelines or if new rules are required. In any case, the control requirements placed on a nodule processing

Table 17. Wastewater treatment processes used in ore processing industry (U.S. Environmental Protection Agency, 1975)

Impoundment Systems	Chemical Precipitation Processes
tailings ponds	lime precipitation
settling ponds	sulfide precipitation
secondary settling ponds	coprecipitation
Clarifiers and Thickeners	Reduction
Flocculation	Oxidation, Aeration, and Air Stripping
Centrifugation	Adsorption
Filtration	Evaporation and Distillation
Neutralization	

TABLE 18. Preliminary Approximation of Pollutant Discharges from Alternative Nodule Processing Plants[a].

	TYPE OF PROCESSING PLANT	POLLUTANT DISCHARGE STREAMS			IMPORTANT CONSTITUENTS[b] IN LIQUID & SOLID DISCHARGE STREAMS										IMPORTANT CONSTITUENTS[c] IN GASEOUS DISCHARGE STREAMS						
		LIQUID (10^6 m^3/yr)	SOLID (10^6 t/yr)	GASEOUS (10^3 m^3/min)	BARIUM	LANTHANUM	VANADIUM	CHROMIUM	SILVER	ARSENIC	ANTIMONY	THALLIUM	LEAD	CADMIUM	CO	METHANE	WATER VAPOR	HS & SO_2	HCL	NITROGEN	AMMONIA
THREE-METAL PLANTS	1. Reduction/Ammonia Leaching	3.4	2.6	22.0	11.40	4.65	0.57	0.03	-	0.13	0.04	0.06	1.29	<.01	0.99	0.22	9.51	0.07	-	22.10	0.01
	2. Cuprion/Ammonia Leaching	4.3	3.3	9.6	11.40	4.65	1.13	0.03	<.01	0.11	0.08	0.43	1.35	0.01	0.05	-	1.05	0.58	-	8.77	0.01
	3. High Temperature Sulfuric Acid Leaching	4.2	3.8	8.8	11.40	2.33	0.13	0.03	<.01	0.02	0.01	0.29	1.29	<.01	-	-	0.83	-	-	8.25	-
FOUR-METAL PLANTS	4. Reduction/Hydrochloric Acid Leaching	0.8	0.5	18.0	3.3	1.32	0.01	0.01	<.01	<.01	<.01	0.09	0.39	<.01	-	-	1.36	<.01	0.01	8.60	-
	5. Smelting	0.8	0.7	18.0	3.3	1.32	0.01	0.01	<.01	<.01	0.02	0.08	0.22	0.01	0.60	0.04	3.18	0.03	-	25.40	<.01

Abbreviations: m^3, cubic meters; t, metric ton; CO, carbon monoxide; HS, hydrogen sulfide; SO_2, sulfur dioxide; HCL, hydrochloric acid.

a. All values are rounded; all units are metric.
b. 1000 metric tons per year. Constituents are discharged as compounds.
c. Metric tons per minute.

Source: Computations based on material in Dames & Moore, Vol. I (1977).

facility will depend on the types and quantities of pollutants in the discharge stream and the levels of pollution already existing in the area where the facility is proposed.

III.A.3.1 Construction

As with the other onshore processing facilities, the normal construction related environmental impacts will be encountered during construction of the processing plant. Because of their relatively short-term nature and the various mitigation measures imposed by State and local construction laws and regulations, these impacts are unlikely to be a serious threat to the local environment. Moreover, because of the expected size of the plant facilities, the processing plant construction activities could have a significant effect on the local construction industry. The siting of a nodule processing plant will involve environmental impacts similar to those resulting from the siting of any other large industrial facility.

III.A.3.2 Operations

The metal recovery section of the nodule processing plants consumes high levels of electric power; other processing operations require large quantities of steam. Although the energy requirements are comparable to many types of existing industrial plants, supplying the required amounts of energy could present some environmental problems. Because of the emphasis in recent years on the decreased use of oil and gas as sources of industrial power, it is expected that coal will be used wherever possible to generate the steam required for processing and that some of the steam may be used, prior to its use in processing the nodules to generate some of the required electric power on-site. The Power Plant and Industrial Fuel Use Act prohibits the use of oil or natural gas by new industrial plants with boilers exceeding 100 million BTU's per hour capacity, which would include a nodule processing plant, unless a waiver is obtained from the Secretary of Energy. Further influencing the assumption that coal will be the hydrocarbon fuel used in the plant is uncertainty regarding the future availability and cost of oil and gas. Depending on the nodule processing technique being used, this would result in the burning of between 266,000 and 697,000 MT (292,000 to 766,000 tons) of coal per year (derived from Table 16). This use of coal as the primary source of energy for steam generation will necessitate access to a railroad for the delivery of the coal as well as a fairly large coal storage facility on-site. While the environmental consequences of delivering and storing this amount of coal would not appear to be significant, burning coal will impact on air quality emissions such as sulfur and nitrogen oxides and particulates. Mitigation measures designed to minimize air quality impacts will be required to be sufficient to guarantee Reasonable Further Progress (RFP) towards attainment of the National Ambient Air Quality Standards (NAAQS).

Even with some on-site electric power generation, however, it is expected that a three-metal plant will be required to purchase approximately 25 megawatts and a four-metal plant about 75 to 100 megawatts of electricty from the local power grid. Depending on the location of the plant, it is quite likely that high-voltage transmission lines will have to be constructed in order to supply this amount of electricity. In fact, in certain areas, existing power generating facilities may not be capable of providing the required amounts of electricity, in which case the local power company might have to either up-grade its existing facilities or construct new ones.

Although coal is discussed as the primary fuel in this document, as generally applicable, future site-specific cases undoubtedly will provide exceptions. Hawaii and other islands might utilize geothermal or OTEC power in lieu of shipping coal, oil, or gas; processing at sea also might utilize OTEC power in the future.

Nodules processing will require the use of freshwater (not necessarily potable) for steam generation, cooling, and other process uses, including its addition to the waste stream to improve slurry pumping characteristics. The 6 to 23.8 million l (1.6 to 6.3 million gal) daily requirement, depending on the processing technique, is not an extremely large amount of water compared to other types of industrial plants, but would be significant in areas such as southern California where freshwater supplies are limited. There are various measures which might be utilized to reduce water consumption, e.g., recycling cooling water or the water used in waste slurries. Also to mitigate excess freshwater consumption plants might utilize treated municipal waste water or agricultural run-off. In addition to these mitigation measures, most States with limited freshwater supplies have laws which assure that surface waters are appropriated only for beneficial uses which are not prejudicial to the public interest. Such laws may prevent processing plant siting in areas where water availability could be compromised.

At least part of each nodule processing technique involves dissolving the nodules and putting their minerals into solution and then selectively removing the value metals from the solution. In this "leaching" procedure, potentially hazardous and/or toxic chemicals such as hydrogen sulfide, ammonia, and acids, e.g., sulfuric acid or hydrochloric acid, will be used. Fairly sizeable quantities of these chemicals will be shipped, stored, and used in nodule processing plants.

As is the case with any industry which utilizes chemicals, there is always the possibility that a natural disaster and/or human errors may result in the accidental release of potentially harmful liquids or gases. The chances of such a release are considered to be very small. For example, in their study of the characteristics of manganese nodule processing plants, Dames & Moore and EIC Corp. (1977) estimated that if there were 10 processing plants, there would be on the average only one gaseous release every 10,000 operating years.

The dangers of an accidental release of hazardous and/or toxic substances could be minimized by incorporating relatively simple environmental design safeguards. For example, inclusion of valves limiting contents of storage vessels, inclusion of dikes and sumps in basic plant designs, avoidance of flood zones and active faults, and avoidance of sites with adverse atmospheric dispersion characteristics can reduce risks at essentially negligible costs.

The operation of a nodule processing plant will have important socio-economic impacts on the local community. Once the plant begins three-shift per day operations, it is expected that direct employment will reach a total of 500 to 1,000. Positions are expected to be equal parts managerial and clerical, skilled workers, and unskilled. Depending on the existing industry in the area, a comparable number of secondary and induced jobs could be created. It is possible that economically depressed areas with high levels of unemployment, other things being equal, could be attractive for plant location.

Community infrastructure will also be affected. Sewage, garbage, and trash will be treated by normal municipal operations. Traffic patterns, residential location, commercial opportunities, demand for schools, housing, health care, and other private and public services will be the secondary effects of the plant.

Studies underway at the Massachusetts Institute of Technology and Texas A&M University, have estimated that a processing plant's capital cost would be over $500 million and that a plant's annual payroll would be over $25 million per year. In most areas, economic benefits should substantially offset the demand for services, especially if the local labor market can provide most of the unskilled and some of the skilled workers.

III.A.4 Onshore Disposal of Nodule Processing Waste

Of all the activities associated with the extraction of value metals from manganese nodules, disposal of processing waste will perhaps be of the greatest concern for two reasons: (1) the sheer volume to be disposed; and (2) the unknown chemical and physical nature of the wastes.

Because the value metals comprise only a small percentage of the nodules, each tonne of nodules that is processed for three-metals will result in roughly a tonne of waste materials when combustion ashes and other by-products are considered. Processing may alter nodule constituents into soluble compounds of hazardous or toxic elements, as is presently being assessed by an interagency effort (see Section III.A.3).

Four principal federal environmental laws now regulate mine and mill waste disposal. These are P.L. 95-217, the Clean Water Act; P.L. 93-253, the Safe Drinking Water Act; P.L. 93-319, the Clean Air Act; and, P.L. 94-580, the Resource Conservation and Recovery Act. As provided under the last named, the disposal of water from the processing of nodules is an area of particular concern to EPA. From each of these laws, Federal regulations are developed to define and implement those steps or measures necessary to assure compliance. Each law requires a discharge permit, for which the states may assume responsibility within EPA guidelines.

Researchers working on the age dating of manganese nodules, by means of radioactive-decay determinations, have shown the nodules to be slightly radioactive. For example, Krishnaswami and Cochran (1977), working with nodules from DOMES sites A and C, have detected up to approximately 1000 disintegration products of ^{226}Ra per minute per gram of nodule. Although about 200 times higher than the soil at the University of Georgia (Dr. John Noakes, Center for

Applied Isotope Studies, personal communication), the actual amount of radiation is barely detectable by present instrumentation. Nevertheless, once this natural product has been processed the resultant wastes must be disposed in accordance with standards established under the Resource Conservation and Recovery Act administered by EPA. Since similar low level radiation is a common occurrence, NOAA does not expect this to be of special concern to EPA.

III.A.4.1 Construction

The environmental impacts resulting from the construction of waste processing facilities will not differ significantly from those associated with construction of the other onshore nodule processing facilities. The major problems will be heavy equipment noise, dust, water runoff, and soil erosion resulting from preparation of large tracts of land for the construction of tailings ponds and/or landfills. These impacts however will be mitigated by measures imposed by Federal, State, and local authorities as part of the construction permitting process.

Considerations of concern in siting other onshore facilities are also of concern in siting tailings ponds and landfills. These concerns are accentuated by the potentially hazardous and toxic nature of the process waste materials.

There is little construction associated with ocean disposal techniques, except for a pipeline for returning wastes to the marine terminal or for a pipeline to an ocean outfall.

III.A.4.2 Operations

Two of the major concerns with the disposal of nodule processing waste are the large quantities of waste and their unknown chemical and physical characteristics. The total solid component of a three-metal plant wastes is expected to be around 3 to 4 million MT (3.3 to 4.4 million tons) per year while four-metal plants are expected to produce on the order of 0.5 to 0.75 million MT (0.55 to 0.82 million tons) per year.

Onshore disposal of such large quantities of solid waste material in either landfills or tailings ponds will require relatively large areas of land. The ability to use a landfill depends on the water content of the wastes, which can be decreased if an energy-intensive drying step is included. In general, only slags from a smelting process appear suitable for landfill. For tailings ponds, land reclamation would largely depend on the physical characteristics of the tailings and the degree to which the tailings stabilize as free water evaporates or is removed. Depending on the processing techniques and the net evaporation rate typical of the region in which the disposal facilities are located, it is possible that the tailings could remain unstable for years and, as a further consequence, that the land could remain unsuitable for other uses for an extended period of time.

The contamination of local ground water, surface waters, or aquifers as a result of seepage of liquid wastes from slurry tailings ponds and leachates from landfills may be one of the more significant potential problems associated with the onshore disposal methods. Negative environmental impacts could be mitigated by: (1) locating the disposal facilities in arid or semi-arid regions; (2) locating the facility in an area where the sub-surface geology consists of relatively impermeable soil or rock; or, (3) providing a compacted, relatively impervious base of clay-type soils or a man-made liner for the landfill or tailings pond.

III.B <u>Mitigation Under Existing Laws</u>

In considering the location and operation of future onshore processing facilities, two broad classes of environmental impacts become apparent. The first (Table 19) are those which generally can be avoided by careful planning. These relate primarily to conflicts among natural resource and land uses currently recognized in Federal statute and can be precluded by selecting a site which does not create such conflicts.

The second class (Table 20) contains those environmental impacts which are inherent in the industrial process, but will differ in magnitude as a result of site, design, and operational characteristics. In most cases, existing Federal permits, standards, and regulations ensure that adverse environmental impacts are minimized; in others, e.g., noise, sedimentation, water consumption, impacts are local and properly under the jurisdiction of State and local authorities.

Table 20 includes possible mitigation measures and environmental requirements for various effects. Generally, there are measures to protect almost all impacts; the few areas where Federal authority does not exist are properly covered by State or local authorities. Required permits and consultation with the agencies are included. NOAA concludes that these authorities are sufficient to mitigate any potential adverse impact arising from onshore processing, including the transportation and waste disposal aspects.

III.C <u>Onshore Alternatives, Including Proposed Action</u>

Under existing legislation, NOAA has no authority to approve or disapprove permits for onshore activities. Nevertheless, NOAA is responsible under the Deep Seabed Hard Mineral Resources Act (P.L. 96-283), NEPA, and the CEQ regulations, to prepare an EIS on deep seabed mining, including foreseeable environmental impacts that would result from onshore processing. Further, NOAA permits or licenses for activities affecting the coastal zone must be consistent with the state approved coastal management program.

Also relevant is Executive Order 12114, Environmental Effects Abroad of Major Federal Actions, which requires an environmental review of processing

Table 19. SUMMARY OF ENVIRONMENTAL IMPACTS WHICH CAN BE AVOIDED AND MAJOR RELEVANT FEDERAL LEGISLATION AND PERMITS

POTENTIAL ENVIRONMENTAL IMPACTS	AVOIDANCE/MITIGATION STRATEGIES	RELEVANT FEDERAL LEGISLATION/AUTHORITY			AGENCY
		STATUTE	REGULATIONS	REQUIREMENT	
1. Deposition of dredged or fill material in waters of the United States and contiguous wetlands	Utilize upland disposal areas, contain spoil	Clean Water Act* (33 U.S.C. 1344)	33 C.F.R. 323	Minimize deposition in wetlands and waters	COE/ EPA/ States
2. Interference with federally designated Marine Sanctuaries	Avoid existing or potential Marine Sanctuaries	Marine Protection- Research and Sanctuaries Act of 1972 (16 U.S.C. 1432-1433)	15 C.F.R. 922	Preserve and protect Marine Sanctuaries	DOC
3. Interference with state designated Estuarine Sanctuaries	Avoid existing or potential Estuarine Sanctuaries	Coastal Zone Management Act of 1972 (16 U.S.C. 1461)	15 C.F.R. 921	Preserve and protect Estuarine Sanctuaries	DOC/ States
4. Interference with historical and/or archaeological sites, structures, or objects	Perform adequate historic and archeologic surveys, avoid designated sites and structures	National Historic Preservation Act (16 U.S.C. 470f) Preservation of Historical & Archaeological Data Act (16 U.S.C. 469-469b). Exec. Order No 11593	36 C.F.R. 800 36 C.F.R. 800	Review by state and Federal officials to preserve and protect historic and archaeologic sites	State/ACHP all fed. agencies
5. Jeopardizing existence of endangered or threatened species or adversely modifying their habitats	Perform adequate biological surveys, avoid endangered species habitats	Endangered Species Act (16 U.S.C. 1531-1541)	50 C.F.R. 17 50 C.F.R. 222, 226, 227 50 C.F.R. 402	Review to protect endangered and threatened species	FWS/ NMFS/ States
6. Harassment or "incidental taking" of marine mammals	Perform adequate biological surveys, avoid critical areas	Marine Mammal Protection Act (16 U.S.C. 1361-1382)	50 C.F.R. 18 50 C.F.R. 215-225	Protect marine mammals	FWS/ NMFS/ States?
7. Increased risk of loss from or damage by flooding	Locate structures outside flood hazard areas	Exec. Ord. No 11514 Exec. Ord. No 11988	-- --	No practicable alternative to encroaching on flood plain	all fed. agencies

Table 19 (cont) SUMMARY OF ENVIRONMENTAL IMPACTS WHICH CAN BE AVOIDED AND MAJOR RELEVANT FEDERAL LEGISLATION AND PERMITS

POTENTIAL ENVIRONMENTAL IMPACTS	AVOIDANCE/MITIGATION STRATEGIES	RELEVANT FEDERAL LEGISLATION/AUTHORITY			AGENCY
		STATUTE	REGULATIONS	REQUIREMENT	
8. Destruction or modification of wetlands	Locate all development outside wetlands	Exec. Ord. No. 11990	--	Minimize effect on wetlands	all fed. agencies
9. Conflict with designated Wilderness Areas	Locate away from designated Wilderness Areas	Wilderness Act (16 U.S.C. 1131-1135)	43 C.F.R. 19 36 C.F.R. 293 50 C.F.R. 35	Protect and preserve Wilderness Areas	DOI
10. Conflict with designated Wild or Scenic Rivers	Locate away from designated Wild or Scenic Rivers	Wild and Scenic River Act (16 U.S.C. 1271-1286)		Protect and preserve Wild and Scenic Rivers	DOI
11. Conflict with Prime and Unique Farmland	Avoid areas of designated Prime or Unique Farmland	16 U.S.C. 590 a-f	7 C.F.R. 657	Protect Prime and Unique Farmland	USDA
12. Release of toxic or hazardous materials as a result of flood tsunami, hurricane, or seismic activity	Avoid natural hazard areas	Clean Water Act* 33 U.S.C. 1321 (c)(2)	40 C.F.R. 1510	Oil and hazardous substances spill contingency planning	EPA/CG
		Resource Conservation and Recovery Act (42 U.S.C. 6901)	40 C.F.R. 260-267		

* The reader should note that the following are subject to the EPA consolidated permit program 40 C.F.R. 122-125, 45 F.R. 33287-33558 (May 19, 1980)

- Resource Conservation and Recovery Act (Hazardous Waste Management Program)
- Safe Drinking Water Act (Underground Injection Control Program)
- Clean Water Act (National Pollutant Discharge Elimination System and Dredge and Fill Programs)
- Clean Air Act (Prevention of Significant Deterioration Program)

TABLE 20. SUMMARY OF ENVIRONMENTAL IMPACTS WHICH CANNOT BE AVOIDED AND MAJOR RELEVANT FEDERAL LEGISLATION AND PERMITS

ACTIVITY/ FACILITY	POTENTIAL ENVIRONMENTAL IMPACTS	POSSIBLE MITIGATION STRATEGIES	MAJOR RELEVANT FEDERAL LEGISLATION			AGENCY
			STATUTE	REGULATIONS	REQUIREMENT	
1. Transhipment from port to plant						
1.1 Channel and dockage	Marine traffic congestion, accidents	Improved navigation and traffic control	Ports and Waterways Safety Act (33, U.S.C. 1221-1227)	33 C.F.R. 160-165	Conformance with safety regulations	USCG
	Dredging, bottom disruption	Optimum location and timing	Rivers and Harbors Act of 1899 (33 U.S.C. 403	33 C.F.R 322	Permit	COE
	Modification of waters		Fish and Wildlife Coordination Act (16 U.S.C. 661-665)	50 C.F.R. Part 470 Regulations reproposed 45 F.R. 83412, 12/18/80	Coordination	COE/ FWS/NMFS States
	Land use conflicts	Conformance with local land use plans	Coastal Zone Management Act of 1972 (16 U.S.C. 1456)	15 C.F.R. 930	Consistency with state Program	DOC/ States
1.2 Marine terminal and transportation system	Construction noise	Equipment design and shielding	Noise Control Act (42 U.S.C. 4901-4917)	40 C.F.R. 204 (const. equipment)	Conformance to equipment standards	EPA
	Operating noise	Buffer zones, quiet operations			Local controls	
	Dust	Containment and treatment	Clean Air Act* (42 U.S.C. 7410)	40 C.F.R. 50-81	Conformance to standards, permits, monitoring, modeling.	EPA/ States
	Liquid effluents	Containment and treatment	Clean Water Act* (33 U.S.C. 1311-1321, 1341-1345)	40 C.F.R. 104-142	Conformance to standards, permits	EPA/ States
	Land use conflicts	Conformance with local land use plans and coastal management programs	Coastal Zone Management Act of 1972 (16 U.S.C. 1456)	15 C.F.R. 930	Consistency with state Programs	DOC/ States
2. Nodule Processing						
	Noise	Equipment design and shielding	Noise Control Act (42 U.S.C. 4901-4917)	40 C.F.R.204 (constr. equipment)	Conformance to equipment standards	EPA

TABLE 20 (cont) SUMMARY OF ENVIRONMENTAL IMPACTS WHICH CANNOT BE AVOIDED AND MAJOR RELEVANT FEDERAL LEGISLATION AND PERMITS

ACTIVITY/ FACILITY	POTENTIAL ENVIRONMENTAL IMPACTS	POSSIBLE MITIGATION STRATEGIES	MAJOR RELEVANT FEDERAL LEGISLATION			AGENCY
			STATUTE	REGULATIONS	REQUIREMENT	
	Dust, gaseous emissions	Process design, containment, and treatment; avoidance of "non-attainment" areas and Class I (pristine) areas	Clean Air Act* (42 U.S.C. 7401-7643)	40 C.F.R. 50-81	Conformance to standards, permits, monitoring, modeling	EPA/ States
	Liquid effluents	Process design, containment, and treatment	Clean Water Act* (33, U.S.C. 1311-1321, 1341-1345)	40 C.F.R. 104-142	Conformance to standards, permits	EPA/ States
	Energy consumption	Conservation, use of coal and/or other alternative fuels	Power Plant and Industrial Fuel Use Act of 1978 (92 Stat. 3291-3314)	18 C.F.R. 285	Use of coal and/or other alternative fuels in new large power plants	DOE
	Land use conflicts	Conformance with local land use plans and coastal management program	Coastal Zone Management Act of 1972 (16 U.S.C. 1456)	15 C.F.R. 930	Consistency with state programs	DOC/ States
	Exposure to toxic or hazardous materials	Process design, containment, and treatment	Hazardous Materials Transportation Act (49 U.S.C. 1804-1806) Toxic Substances Control Act of 1976 (15 U.S.C. 2604-2627)	41 C.F.R. 171-179 40 C.F.R. 715 et seq. 40 C.F.R. 125?	Minimize exposure to toxic and hazardous materials	EPA/ DOT
			Resource Conservation and Recovery Act * 42 U.S.C. 6901	40 C.F.R. 260-267		
	Erosion and sedimentation, particularly during construction	Design and construction standards		40 C.F.R. 260-2667	Local controls	EPA
3. Waste Disposal						
3.1 Onshore	Aquifer contamination	Optimum disposal area location, design and operation	Safe Drinking Water Act* (42 U.S.C. 300h-300i)	40 C.F.R. 146	Conformance to standards for underground injections	EPA/States
			Resource Conservation and Recovery Act (42 U.S.C. 6901)	40 C.F.R. 260-267		

TABLE 20 (cont) SUMMARY OF ENVIRONMENTAL IMPACTS WHICH CANNOT BE AVOIDED AND MAJOR RELEVANT FEDERAL LEGISLATION AND PERMITS

ACTIVITY/ FACILITY	POTENTIAL ENVIRONMENTAL IMPACTS	POSSIBLE MITIGATION STRATEGIES	MAJOR RELEVANT FEDERAL LEGISLATION			AGENCY
			STATUTE	REGULATIONS	REQUIREMENT	
	Dust	Surface treatment of landfill, containment and treatment	Clean Air Act* (42 U.S.C. 7410)	40 C.F.R. 50-82	Conformance to standards, permits, monitoring, modelling	EPA/States
	Contamination by toxic solid wastes	Optimum disposal area location, design, and operation	Resource Conservation and Recovery Act* (42 U.S.C. 6901-6979)	40 C.F.R. 260-267 seq. 30 C.F.R. 60?	Conformance to standards, permits	EPA/States
	Liquid effluents	Optimum disposal area location, design and operation; containment and treatment	Clean Water Act* (33 U.S.C. 1311-1321 1341-1345)	40 C.F.R. 104-142	Conformance to standards, permits	EPA/States
			Resource Conservation and Recovery Act (42 U.S.C. 6901)	40 C.F.R. 260-267		
	Fossil Fuel consumption	Energy conservation	Energy Supply and Environmental Coordination Act 15 U.S.C. 792		Regulate the use of oil and gas by power plants and other major fuel burning installations	DOE
	Land use conflicts	Conformance with local land use plans and coastal management prog.	Coastal Zone Management Act of 1972 (16 U.S.C. 1456)	15 C.F.R. 930	Consistency with State programs	DOC/States
3.2 Offshore	Marine traffic congestion, accidents	Improved navigation and traffic control	Ports and Waterways Safety Act (33 U.S.C. 1221-1227)	33 C.F.R. 160-165	Conformance with safety regulations	USCG
	Water pollution, bottom deposition, benthic smothering	Deposit well offshore in deep water, over infertile bottoms	Marine Protection Research & Sanctuaries Act of 1972 (33 U.S.C. 1411-1418)	40 C.F.R. 220-229	Permits	EPA/COE?

* The reader should note that the following are subject to the EPA consolidated permit program 40 C.F.R. 122-125, 45 F.R. 33287-33558 (May 19, 1980)

- Resource Conservation and Recovery Act (Hazardous Waste Management Program)
- Safe Drinking Water Act (Underground Injection Control Program)
- Clean Water Act (National Pollutant Discharge Elimination System and Dredge and Fill Programs)
- Clean Air Act (Prevention of Significant Deterioration Program)

abroad if the processing of the product would be prohibited in the U.S. because toxic effects on the environment create a serious public health risk, or a natural or ecological resource of global importance (designated by the President) is involved. If an applicant requests foreign processing NOAA would have a responsibility to consider impacts in the foreign locations. P.L. 96-283 requires that processing on land of minerals recovered pursuant to a NOAA commercial recovery permit be conducted within the United States unless, among other things, NOAA determines that such processing at a place other than within the U.S. is necessary for the economic viability of the commercial recovery activities of the permittee. This is a significant economic issue which NOAA may be required to address in issuing a commercial recovery permit. Basically, it would involve the comparison of costs and revenues associated with proposed United States and foreign processing sites.

Two statutory purposes govern NOAA involvement in the permitting of onshore activities: (1) to ensure that the environment is adequately protected; and (2) to expedite or facilitate development of the manganese nodule mining industry. Sections III.A and III.B, conclude that further NOAA involvement is not required to ensure adequate protection of the environment; sufficient authority already exists in the authorities of NOAA and other Federal, state, and local agencies to mitigate any adverse environmental impacts. Therefore, NOAA's only reason for involvement in the onshore permitting process would be to facilitate development of the ocean mineral mining industry. This role would further the underlying purpose of P.L. 96-283, to promote the availability of the deep seabed mineral resources for the benefit of the United States and other nations.

Three alternatives for NOAA involvement exist (Table 21) Alternative 1, <u>No Involvement</u>, and the general technology and environmental impact review associated with it represents the least administrative effort that NOAA can under-

Table 21. Alternatives for NOAA involvement in permitting onshore activities.

ALTERNATIVE	IMPACT ON RATE OF DEVELOPMENT	PROVIDES FOR EFFECTIVE PROTECTION OF THE ENVIRONMENT	REQUIRES NEW LEGISLATION	SCOPE OF ADMINISTRATIVE EFFORT	FEASIBILITY	COMMENTS
No involvement (Involvement in at-sea activities only)	None	Yes	No (May violate CEQ regul. on NEPA)	Small	High	(1) NOAA prepares only a general review of onshore processing technology and potential environmental impacts; (2) Rate of development depends on ability of industry to obtain requisite licenses and permits for onshore activities.
Informal involvement in expediting permit approvals	Marginal, but probably helpful	Yes	No	Moderate	Moderate	(1) NOAA prepares comprehensive Environmental Impact Statement for each proposed onshore facility; (2) NOAA serves as the "middle man" expediting preparation and review of requisite applications and their approval by other Federal, State, and local agencies; (3) Involvement would be similar to role of Department of the Interior in OCS Oil and Gas Program.
Formal involvement: "One-Stop" Permitting	Potentially significant	Maybe	Yes	Large	Low	(1) Although this alternative could accelerate development, it might give less rigorous consideration to potential impacts and conflicts; (2) All licensing and permitting authorities would be delegated to NOAA, reducing extent to which other agencies--particularly State and local--could exercise control over development; (3) Involvement would be similar to role of recently rejected energy mobilization board.

take and still comply with P.L. 96-283. This approach may not comply with NEPA requirements, insofar as foreseeable secondary impacts must be assessed in site-specific EIS's.

Alternative 2, Informal Involvement, proposes NOAA as the "lead agency" for facilitating development of the ocean mineral mining industry but falls short of recommending that NOAA be given expanded authority to approve all licenses and permits, i.e., for activities both at-sea and onshore. Under this alternative, NOAA would prepare an environmental impact statement that could serve as NEPA compliance for other agencies' actions such as EPA NPDES permits and Corps of Engineers dredge and fill permits. NOAA would secure the participation of as many Federal and state cooperating agencies as practicable and would provide for public involvement as well. NOAA may also facilitate permits from other agencies to the extent practicable and desirable in a particular application. This degree of involvement is justified under P.L. 96-283.

Alternative 3, One-Stop Permitting, represents the maximum NOAA involvement possible. Under this alternative, each public agency (Federal, State, and local) responsible for permitting the activity would provide the lead agency (NOAA) with a list of requirements which must be met to obtain its approval. If the applicant meets these requirements, NOAA would grant an approval on behalf of all relevant parties which permits all aspects of the project to proceed. NOAA authorizations would preempt those of State and local governments. NOAA could also assume responsibility for other Federal authorizations. An amendment to P.L. 96-283 would be required for NOAA to have this degree of involvement.

Alternative 2 is the preferred course of action for NOAA. It is clear that congressional intent in the Act requires NOAA to take an active role in facilitating development of the manganese nodule mining industry. Also, NOAA must assess foreseeable impacts to comply with NEPA. Alternative 1 would not fulfill these requirements. Under Alternative 3 NOAA would undertake authoritiy currently exercised by other agencies. NOAA does not see the need or desirability of providing this degree of NOAA involvement. Additionally, environmental controls within the expertise of other agencies would be duplicated by NOAA, under this option. We see no advantage of this alternative from an environmental perspective. Finally, it is also unlikely that Congress would amend the Act in the near future to give NOAA the authority necessary for formal one-stop permitting. Alternative 3 is, in NOAA's judgment, not possible at this time. The experience of the Department of Interior (DOI) in implementing its program for outer continental shelf (OCS) oil and gas exploration and development through informal working relationships with the private and public sectors indicates that the preferred alternative, if properly managed, can be effective. Informal NOAA involvement in expediting permit approvals would be roughly analagous to DOI's approach to OCS development. NOAA's role in the Consolidated Application Review for the Ocean Thermal Energy Conversion process may serve as a model for consideration under this alternative. Alternative 2 also maintains the maximum flexibility for modifying the extent of NOAA's involvement in the process of permitting onshore activities as the ocean mineral mining industry develops.

Alternatives 1 and 3 are not environmentally preferable, because of uncertainties in the legal regime. Therefore, Alternative 2 is the environmentally preferred alternative as well as NOAA's preference.

Conclusion

An informal facilitating role for NOAA in the onshore permit process together with its lead agency role for environmental review is preferred environmentally, in terms of sound efficiency as well as intergovernmental policy. The specifics of the role that is desirable would be a matter of discussion between NOAA, the applicant, and other agencies in a particular case.

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William Hedeman (Environmental Protection Agency)
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Raymond Jenkins
Ray Kline (General Services Administration)
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John Morgan (U.S. Bureau of Mines)
Daniel Muller (Nuclear Regulatory Commission)
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Harry Rietman (Department of the Air Force)
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VI. APPENDICES

Appendix 1

References

Ahlstrom, E. H., 1971. Kinds and Abundance of Fish Larvae in the Eastern Tropical Pacific, Based on Collections made on EASTROPAC I. Fish. Bull. Vol. 69: pp. 3-77.

Ahlstrom, E. H., 1972. Kinds and Abundance of Fish Larvae in the Eastern Tropical Pacific on the Second Multivessel EASTROPAC Survey, and Observations on the Annual Cycle of Larval Abundance. Fish. Bull. pp. 1153-1242.

Anderson, J. J., 1978. Deep Ocean Mining and the Ecology of the Tropical North Pacific. Special Report No. 83, Department of Oceanography, University of Washington, Seattle, Washington, 123pp.

Antrim, L., P. L. Spencer, and W. W. Woodhead, 1979. Cobalt, Copper, Nickel, and Manganese: Future Supply and Demand and Implications for Deep Seabed Mining. Office of Ocean, Resource, and Scientific Policy Coordination. Department of Commerce, 60 pp.

Benjamin, M. M., 1981. Trace Metal Exchange Between Ferromanganese Nodules and Artificial Seawater. Chapter in Journal of Marine Mining, in press.

Bischoff, J. L. and D. Z. Piper, 1979. Marine Geology and Oceanography of the Pacific Manganese Nodule Province. Plenum Press, N.Y., N.Y.

Blackburn, M., 1976. Review of Existing Information on Fishes in the Deep Ocean Mining Environmental Study (DOMES) Area of the Tropical Pacific. Final Report, NOAA Contract No. 03-4-022-35125, Institute of Marine Resources, University of California, La Jolla, California, 79 pp.

Bragg, Daniel M., Gulf Coast Manganese Nodule Processing Plant Location Criteria, August 1979. Texas A&M University Sea Grant report prepared for National Oceanic and Atmospheric Administration, Department of Commerce, 160 pp.

Bruland, L. W., 1980. Oceanographic Distributions of Cadmium, Zinc, Nickel and Copper in the North Pacific. Earth and Planetary Science Letters, Vol. 47: 176-198.

Bureau of Land Management, 1981. Draft Supplement to Final Environmental Impact Statement on Proposed Five-Year OCS Oil and Gas Lease Schedule, January 1982 - December 1986. U.S. Department of the Interior, Washington, D.C.

Burns, R. E., B. H. Erickson, J. W. Lavelle, E. Ozturgut, 1980. Observations and Measurements During the Monitoring of Deep Ocean Manganese Nodule Mining Tests in the North Pacific, March - May 1978. NOAA Tech. Memorandum, ERL MESA-47, 63 pp.

Chan, A. T., and G. C. Anderson, 1981. Environmental Investigation of the Effect of Deep-Sea Mining on Marine Phytoplankton and Primary Productivity in the Tropical Eastern North Pacific Ocean. Chapter in Journal of Marine Mining, in press.

Charles River Associates Incorporated, 1980. Draft Final Report - Energy Requirements for Metals Production: Comparison Between Ocean Nodules and Land-Based Resources, in press.

Crutcher, H. L., and R. G. Quayle, 1974. Mariners Worldwide Climatic Guide to Tropical Storms at Sea. Naval Weather Service and NOAA National Climatic Center, Asheville, N.C. NAVAIR 50-1C-61. 114 pp. plus 312 charts.

Dames and Moore, 1980. Draft Final Report - Environmental, Social and Economic Effects of Continued Reliance on Land Mining to Produce Metals Available from Manganese Nodules, in press.

Dames and Moore, E.I.C. Corp., and B. V. Andrews, 1977. Description of Manganese Nodule Processing Activities for Environmental Studies, Volume II, Transportation and Waste Disposal Systems, 108 pp.

Dames and Moore, E.I.C. Corp., 1977. Description of Manganese Nodule Processing Activities for Environmental Studies, Vol. I, Processing Systems Summary, 132 pp.

Defense Mapping Agency Hydrographic Center, (Hydrographic Chart No. 520) Washington, D.C.

Detweiler, T. and G. Zahn, 1980. Decade of the Oceans, in Marine Technology '80 Conference Proceedings Marine Technology Society, October 1980, Washington, D.C.

Documentation Associates, 1977. Deep Ocean Mining Environmental Study (DOMES) Literature Survey. Documentation Associates Information Services Incorporated, Los Angeles, CA, 231 pp.

DOMES Project, Feb. 24, 1976. Summary of minutes of the DOMES mining industry meeting. (National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory, Seattle, Washington), 12 pp. (unpublished manuscript).

Environmental Protection Agency, 1975, Development Document for Interim Final and Proposed Effluent Limitations, Guidelines, and New Source Performance Standards for the Ore Mining and Dressing Industry, Vols. I-II, Point Source Category, U.S. Environmental Protection Agency, Washington, D.C. (EPA 440/1-75/061).

Flipse, John E., The Potential Cost of Deep Ocean Mining Environmental Regulation, July 1980. Texas A&M University Sea Grant report prepared for National Oceanic and Atmospheric Administration, Department of Commerce, 47 pp.

Frazer, J. Z., 1978. Resources in Seafloor Manganese Nodules. Paper presented at seminar on deep-sea mining at Massachusetts Institute of Technology, December 1978.

Gauthier, M. A., and J. H. Marvaldi, 1975. The Two-Ship CLB System for Mining Polymetallic Nodules -- Characteristics and Possiblilities -- Brief Comparison with the Hydraulic Concept. Paper presented at Brighton, England, conference, 12 pp.

Grassle, J. F., 1978. Diversity and Population Dynamics of Benthic Organisms. Oceanus, Vol. 21, No. 1, Winter 1978. Woods Hole Oceanographic Institution.

Hall, A. S., C. R. Houle, F. M. Teeny, and E. J. Ganglitz, Jr., 1977. Trace Metals - DOMES Samples, National Marine Fisheries Service, Seattle, Wash., 154 pp.

Hawaii Department of Planning and Economic Development, March 1980. The Feasibility and Potential Impact of Manganese Nodule Processing in the Puna and Kohala Areas of Hawaii, draft report prepared for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Marine Minerals, Rockville, Md.,

Hecker, B., and A. Z. Paul, 1979. Abyssal Community Structure of the Benthic Infauna of the Eastern Equatorial Pacific: DOMES sites A, B, and C. In: J. L. Bischoff and D. Z. Piper, Eds., Marine Geology and Oceanography of the Pacific Manganese Nodule Province. Plenum Press, N.Y., pp. 287-308.

Hirota, J., 1981. Potential Effects of Deep-Sea Minerals Mining on Macrozooplankton in the North Equatorial Pacific. Chapter in Journal of Marine Mining, in press.

Horn, Horn, and Delach, 1972. Lamont - Doherty IDOE/NSF Technical Report 3.

Hu, V.J.H., 1981. Ingestion of Deepsea Mining Discharge by Five Species of Tropical Copepods. Water, Air, and Soil Pollution 15:433, 440.

Jumars, P. A., 1981. Limits in Predicting and Detecting Benthic Community Response to Manganese Nodule Mining. Chapter in Journal of Marine Mining, in press.

Krishnaswami, S. and J.K. Cochran, 1978. Uranium and Thorium Series Nuclides in Oriented Ferromanganese Nodules: Growth Rates, Turnover Times and Nuclide Behavior. Earth and Planetary Science Letters, 40 (1978) 45-62, Elsevier Scientific Publishing Co., Amsterdam.

Landing, W. M., and K. W. Bruland, 1980. Manganese in the North Pacific. Earth and Planetary Science Letters, 49(1980) 45-56.

Lane, A. L., May 30, 1979. Memo for Record, Regarding Information for House Merchant Marine Fisheries Committee on Manganese Nodule Value Metal Statistics. NOAA, Marine Minerals Division.

Lavelle, J. W., and E. Ozturgut, 1981. Dispersion of Deep-Sea Mining Particulates and Their Effects on Light in Ocean Surface Layers. Chapter in Journal of Marine Mining, in press.

Lavelle, J. W., E. Ozturgut, E. T. Baker, S. A. Swift, 1980. Discharge and Surface Plume Measurements During Manganese Nodule Mining Tests in the North Equatorial Pacific. Contribution No. 447, NOAA/ERL Pacific Marine Environmental Laboratory, Seattle, Wash., 34 pp.

Lavelle, J., E. Ozturgut, S. Swift, and B. Erickson, 1981. Dispersal and Resedimentation of the Benthic Plume From Deep-Sea Mining Operations: A Model with Calibration. Chapter in Journal of Marine Mining, in press.

Legand, M., P. Bourret, P. Fourmanoir, R. Grandperrin, J. A. Gueredrat, A. Michel, P. Rancurel, R. Repelin and C. Roger, 1972. Relations Trophiques et Distributions Verticales en Milieu Pelagiques dans L'Ocean Pacifique Intertropical. (Tropic Relations and Vertical Distribution of Pelagic Organisms in the Intertropical Pacific Ocean.) Cah. O.R.S.T.O.M. Ser. Oceanogr., 10(4): 301-393.

McKelvey, V. E., N. A. Wright, R. W. Rowland, 1979. Manganese Nodule Resources in the Northeastern Equatorial Pacific. Chapter in Marine Geology and Oceanography of the Pacific Manganese Nodule Province, 1979.

Mero, J., C. Masuda, and M. Gauthier, 1974. Industrial Mining of Polymetallic Nodules - Technical Comparison of Both Hydraulic and Two-Ship Continuous Line Bucket System. Paper presented at Bordeaux, France, conference, 20 pp.

National Oceanic and Atmospheric Administration, 1976. Progress Report. Deep Ocean Mining Environmental Study -- Phase I. NOAA Technical Memorandum ERL MESA--15. 178 pp.

National Oceanic and Atmospheric Administration, 1978a. Marine Mammal Protection Act of 1972 Annual Report, April 1, 1977 - March 31, 1978. Annual Report to the Congress from National Marine Fisheries Service, NOAA, 183 pp.

National Oceanic and Atmospheric Administration, 1978b. Final Environmental Impact Statement. Listing and Protecting the Green Sea Turtle "Chelonia mydas," Loggerhead Sea Turtle "Carreta carreta," and Pacific Ridley Sea Turtle "Lepidochelys olivacea" under the Endangered Species Act of 1973. National Marine Fisheries Service, NOAA, Wash., D.C., July 1978, 144 pp.

National Oceanic and Atmospheric Administation, 1980a. Point Reyes - Farallon Islands National Marine Sanctuary Final Environmental Impact Statement. NOAA, Wash., D.C.

National Oceanic and Atmospheric Administration, 1980b. Channel Islands National Marine Sanctuary Final Environmental Impact Statement. NOAA, Wash., D.C.

National Oceanic and Atmospheric Administration, 1981a. Marine Environmental Research Plan (1981-1985). To be submitted to the Congress in 1981.

National Oceanic & Atmospheric Administration, 1981b. Deep Seabed Mining Technical Guidance Document, September 1981.

Nossaman, Krueger, and Marsh, May 29, 1980. An Analysis of Applicable Law Concerning Seabed Mineral Processing in California, Washington, Oregon and Alaska, report prepared for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Marine Minerals Division, Rockville, MD.

Oceanus, vol. 21, No. 1, Winter 1978. Woods Hole Oceanographic Institution, pp. 58-59.

Odum, Eugene P., 1971. Fundamentals of Ecology, 3rd edition. W. B. Saunders Co., Phila., PA.

Ohman, M. D., E. Ozturgut, R. J. Ozretich, 1979. A Seasonal and Spatial Summary of Oceanographic Data From the Northeastern Tropical Pacific (DOMES Region) summer 1975 and Winter 1976. Special Report No. 91, NOAA Contract 03-6-022-35101, Department of Oceanography, University of Washington, Seattle, Washington, 117 pp.

Oregon State University, 1978. Identification of Representative West Coast Areas for Manganese Nodule Processing Activities. Unpublished report to NOAA, by School of Oceanography, Oregon State University. Corvallis, Oregon, 114 pp.

Ozretich, R. J., 1981a. Increased Oxygen Demand and Microbial Biomass. Chapter in Journal of Marine Mining, in press.

Ozretich, R. J., 1981b. Dissolved Components of the Discharge. Chapter in Journal of Marine Mining, in press.

Ozretich, R. J., and R. A. Ozretich, 1978. Bacteria and Sediment Interaction. NOAA Final Report to DOMES Project, 22 pp.

Ozturgut, E., G. C. Anderson, R. E. Burns, J. W. Lavelle, S. A. Swift, 1978. Deep Ocean Mining of Manganese Nodules in the North Pacific: Pre-mining Environmental Conditions and Anticipated Mining Effects. NOAA Tech. Memorandum ERL MESA-33, 133 pp.

Ozturgut, E., J. Lavelle, and R. E. Burns, 1981a. Impacts of Manganese Nodule Mining on the Environment: Results From Pilot-Scale Mining Tests in the North Equatorial Pacific. Chapter 15 in Marine Environmental Pollution, 2. Dumping and Mining by R. A. Geyer (editor), in press.

Ozturgut, E., J. Lavelle, and B. Erickson, 1981b. Estimated Discharge Characteristics of a Commercial Nodule Mining Operation. Chapter in Journal of Marine Mining, in press.

Ozturgut, E., J. W. Lavelle, O. Steffin, S. A. Swift, 1980. Environmental Investigations During Manganese Nodule Mining Tests in the North Equatorial Pacific in November 1978. NOAA Tech. Memorandum ERL MESA - 48, 50 pp.

Richards, F. A., Devol, A. H., Ozretich, R. J., and Anderson, J. J., 1976. Chemical Oceanography of the DOMES. Preliminary report to the DOMES Project, University of Washington, Seattle, Washington, 123 pp. (unpublished manuscript).

Roels, O. A., A. F. Amos, O. R. Anderson, C. Garside, K. C. Haines, T. C. Malone, A. Z. Paul, and G. E. Rice, 1973. The Environmental Impact of Deep-Sea Mining, Progress Report. NOAA Tech. Report ERL 290-OD 11, available from National Technical Information Service, (COM7450489/5), Springfield, Virginia, 185 pp.

Ryan, W. B. T., and B. C. Heezen, 1976. Smothering of Deep-Sea Benthic Communities from Natural Disasters. Final Report, NOAA contract No. 03-6-022-35120, Lamont - Doherty Geological observatory of Columbia University, Palisades, N.Y., 132 pp.

Shomura, R. S., 1980. National Marine Fisheries Service, Southwest Fisheries Center, Honolulu, Hawaii. Personal Communication, October 24, 1980.

Smith, K. L. Jr., et al., 1979. Free Vehicle Capture of Abyssopelagic Animals. Deep-Sea Research Vol. 26A: pp. 57-64.

Thiel, Hi., and R. R. Hessler, 1974. Ferngesteuertes Unter Wasserfahrzeug Erforscht Tjefseeboden. UMSCHAU 14:451-453.

U.S. Department of Commerce, Maritime Administration, 1979. United States Oceanborne Foreign Trade Routes, Wash., D.C.

Western Miner, December 1974. Island Copper Mine - Tailings Disposal and the Environment, pp. 23-24.

Appendix 2. Acronyms, abbreviations, and glossary

Acronyms

EA - Environmental Assessment
EAR - Environmental Assessment Report
EIS - Environmental Impact Statement
PEIS - Programmatic Environmental Impact Statement
DOMES - Deep Ocean Mining Environmental Study
NEPA - National Environmental Policy Act
LOS - Law of the Sea
BLM - Bureau of Land Management
NOAA - National Oceanic and Atmospheric Administration
EPA - U.S. Environmental Protection Agency
USCG - U.S. Coast Guard
USGS - U.S. Geological Survey
CLB - continuous line bucket
PDP - program development plan
SPM - suspended particulate matter
OMA - Ocean Mining Associates
OMI - Ocean Management Inc.
OMCO - Ocean Minerals Company
AFERNOD - Association Francaise pour L'Etude et la Recherche des Nodules
DWT - dead weight tons
TCR - terms, conditions, and restrictions
pH - a measure of acidity/alkalinity
TPD - tons per day
TPY - tons per year
NPDES - National Pollutant Discharge Elimination System
IMCO - Intergovernmental Maritime Consultative Organization
RS - Reciprocating States
RSA - Reciprocating States Arrangement

Chemicals and Trace Metals

Ag - silver
Al - aluminum
Cd - cadmium
Co - cobalt
Cr - chromium
Cu - copper
Fe - iron
Mn - manganese
NH_4 - ammonium
Ni - nickel
Si - silicon
Zn - zinc

Measurements

- distance

u - microns
mm - millimeters
cm - centimeters
m - meters
km - kilometers
in - inches
ft - feet
yd - yard
smi - statute mile
nmi - nautical mile

- ratios

nmol/kg - nanomole per kilogram
°C/m - degrees centigrade per meter
ug-at/l - microgram atoms per liter
kg C/d - kilograms of carbon per day
cm/s - centimeters per second
in/s - inches per second
g/l - grams per liter or ppM
mg/l - milligrams per liter or ppm
ug/l - micrograms per liter or ppb
°/°° - parts per thousand
ppm - parts per million
ppb - parts per billion
mg/m^3 - milligrams per cubic meter
g/m^2 - grams per square meter
oz/ft^2 - ounces per square foot

- weight

ug - micrograms
mg - milligrams
g - grams
kg - kilograms
MT - metric ton or tonne
oz - ounce
lb - pound

- others

°F - degrees fahrenheit
°C - degrees centigrade or celsius
m^2 - square meters
m^3 - cubic meters
yd^2 - square yards
yd^3 - cubic yards
ft^2 - square feet
ft^3 - cubic feet
ml - milliliter
l - liter
gal - gallon
a - acres
ha - hectares
d - day

Glossary

Abyssal--Depths greater than 4,000 m (13,200 ft).

Abyssal hills--Elongate, sediment covered features of the seafloor with a relief of 50 to 300 m (165 to 900 ft) and a 2° to 3° slope.

Adsorption--The adhesion of a thin film of liquid or gas to a solid substance.

Advection--The horizontal or vertical flow of sea water as a current.

Aeration--Changing in treating with air.

Air Stripping--Treatment of pregnant solution with air in order to remove dissolved values.

Ambient--The environment surrounding a body but undisturbed or unaffected by it.

Amphipods--An order of elongate, usually laterally compressed, mostly benthic crustaceans.

Anaerobic--Conditions in which air is excluded from the environment.

Beneficiate--To upgrade the richness of an ore by the mechanical separation of minerals; usually followed by another method to extract the metals.

Benthic--Pertaining to seafloor.

Benthic plume--A stream of water containing suspended particles of seafloor sediment, abraded manganese nodules, and macerated benthic biota that emanates from the mining collector as a result of collector disturbance of the seafloor and subsequent rejection of seafloor sediment from the mining system. The far-field component of the benthic plume is termed the "rain of fines".

Benthopelagic--Pertaining to seafloor of deeper portions of open ocean.

Benthos--Organisms living on or in the seafloor.

Bioaccumulation--The accumulation of a substance, usually considered a pollutant, in the tissues of an organism above ambient levels. This can occur through ingestion of food or absorption from the water.

Biochemical oxygen demand--A measure of the quantity of oxygen used in the biochemical oxidation (decay, degradation, etc.) of organic matter.

Biomagnified--Increased concentrations in predator compared to its prey.

Biomass--The amount of living matter per unit of water surface or volume expressed in weight units.

Bivalves--One class of molluscs, generally attached to hard substrata or burrowing into soft sediment, that possess a hinged shell and a hatchet-shaped foot. Includes clams, oysters, and mussels.

Brachiopods--A phylum of attached, marine, mollusk-like animals in which the body is enclosed in a calcareous bivalve shell.

Brittle Star--A class of phylum Echinodermata of spiny-skinned, starfish-like, bottom-dwelling, mobile organisms with five or more elongated, brittle arms.

Bryozoans--A phylum of minute, colonial, aquatic animals with body walls often hardened by calcium carbonate that usually grow attached to plants, rocks, or other firm surfaces.

Calcareous--Consisting of or containing calcium or calcium carbonate.

Cathode specification--Refers to the purity of the metal during the refining process.

Centrifugation--The process of using a rotating device to produce centrifugal force to separate liquids of different densities or to separate suspended particles in an aqueous suspension.

Chlorophyll a--One of a group of green pigments, identified as chlorophyll a, b, and c, occurring in plants that are active in the process of photosynthesis. The concentration of these pigments is used as an index of the standing crop of phytoplankton.

<u>Clay</u>--As a size term, refers to sediment particles ranging in size from 0.0039 to 0.00024 mm. Mineralogically, clay is a hydrous aluminum silicate material with plastic properties and a crystal structure.

<u>Clarifier</u>--A centrifuge, settling tank, or other device for separating suspended solid matter from a liquid to produce an essentially solid-free liquid stream and a more concentrated solids stream.

<u>Coelenterates</u>--A phylum of mostly colonial marine animals that exist in both a free-swimming and an attached stage. Includes corals, sea anemones, and jellyfish.

<u>Copepods</u>--Minute shrimplike crustaceans that often occur in large concentrations ("insects of the sea") in the surface waters and are an important link in many marine food chains.

<u>Coprecipitation</u>--Separation of two or more metals during the same metallurgical step.

<u>Coprophagy</u>--Eating, by detritivores, of fecal pellets after pellets have been enriched by microbial activity in the environment.

<u>Crustaceans</u>--A class of animals with a segmented external skeleton and jointed appendages. Includes barnacles, crabs, shrimp, lobster, copepods, and amphipods.

<u>Ctenophore</u>--Spherical, pear-shaped, or cylindrical animals of jellylike consistency, ranging from several centimeters to about one meter in length. Also called "comb-jellies" because the outer surface of the body bears eight rows of comblike structures.

<u>Dead weight tonnage</u>--The difference between the loaded and light displacement tonnage of a ship.

<u>Decapods</u>--An order of crustaceans which includes shrimps, lobsters, and crabs.

Deposit feeder--An animal inhabiting bottom sediments feeding on organic detritus by digesting or otherwise separating it from inorganic particles.

Detritivore--Detritus consumers; includes worms, crabs, snails, shrimp, and amphipods.

Diagenesis--The chemical and physical changes that sediments undergo after their deposition, compaction, cementation, and recrystallization which result in the formation of rocks.

Diatoms--One of a class of microscopic phytoplankton organisms, possessing a wall of overlapping halves impregnated with silica. Diatoms are one of the most abundant groups of organisms in the sea and the most important primary food source of marine animals.

Diffusion--The spreading or scattering of matter under the influence of a concentration gradient with movement from the stronger to the weaker solutions.

Distillation--The evaporation and subsequent condensation of a liquid.

Divergence zone--Zone of horizontal flow of water, from a common center, associated with upwelling of water from the lower water column. In the DOMES area, such a zone separates the North Equatorial Current from the North Equatorial Counter-Current.

Epibenthic--Organisms living on the surface of the seafloor.

Epipelagic--That portion of the oceanic province extending from the surface to a depth of about 200 meters (660 ft).

Euphotic zone--Depth zone with sufficient light for photosynthesis to occur.

Ex-vessel value--The value of the catch as it is sold by the fisherman at the dock.

Fecal pellet--Excrement of marine animals, frequently found in sediments.

Filter feeding or suspension feeding zooplankton--Animals that feed by filtering plankton or detritus from the water by means of cilia, bristles, hairs, and/or tentacles.

Filtration--To remove suspended particulate matter from a liquid by passing it through a very fine sieve.

First generation mining--Hydraulic mining of deep seabed manganese nodules in the DOMES area by four or five international consortia, coming into production between 1988 and 1995 at a rate determined by the world demand for nickel.

Flocculant--An agent that induces or promotes flocculation, or produces floccules or other aggregate formation.

Flocculate--To aggregate into lumps, as when fine or colloidal clay particles in suspension clump together and settle out of suspension.

Foraminifera--An order of protozoa, that are often microscopic, single-celled (or acellular) animals possessing a shell of calcium carbonate, silica, or chitin. Some species form an important part of marine sediments.

Fracture zone--An extensive linear zone of irregular topography of the seafloor, characterized by seamounts, steep-sided ridges, and escarpments.

Gastropods--A large class of mostly bottom-dwelling molluscs. Most forms have a spiral shell; includes all snails and slugs.

Guild--A group of species which utilize the same resource in similar ways.

Haul outs--Shoreline, or ice, where marine mammals such as seals, walruses, and sea lions come ashore to establish territory, mate, and bear young.

High temperature sulfuric acid leaching--Nodule processing method that utilizes high temperature and pressure cooking of the nodules in an aqueous sulfuric acid solution.

Hydras--Small (few mm to 1 cm in length), carnivorous freshwater animals that are related to corals, jellyfish, and anemones.

Infauna--Animals living in soft bottom sediments.

Intertropical convergence zone--Zone just north of the equator where the northeast tradewinds meet the southeast tradewinds. The mean position of the zone oscillates north and south depending on the strength of the tradewinds.

Interstitial water--Water contained in the pore spaces between the grains in rock and sediments.

Isopods--An order of crustaceans with generally flattened bodies. Most are deposit feeders.

Lime boil--A chemical reaction between lime and ammonium sulfate where steam is introduced to the reacting slurry. Ammonia is released and gypsum is formed.

Lime precipitation--To separate a solid form from a solution by adding lime.

Live-bait fisheries--A method of fishing that catches fish on hooks at the surface after exciting them by throwing live bait.

Longline fisheries--A method of fishing that employs lines up to about 93 km (50 nmi) long with up to 2,000 baited hooks (dead baited) per line.

Macrofauna--Marine animals retained on a sieve of 0.3 to 1.0 mm (0.02 to 0.04 in) meshes.

Macrozooplankton--Zooplankton ranging in size from about 1 mm to 1 cm in length.

Meiofauna--Usually refers to animals that will pass through a 0.3, 0.5 or 1.0 mm mesh sieve and be retained on a 0.05 mm mesh sieve.

Mesopelagic--That portion of the oceanic province extending from about 200 m (660 ft) down to a depth of about 1,000 m (3,300 ft).

Micronekton--Early planktonic stages of fish and other actively swimming organisms, such as squids.

Microzooplankton--Zooplankton ranging in size from 60 u to 1 mm.

Mine site--Area selected by applicant for exploration under terms of a NOAA license or recovery under terms of a NOAA permit.

Mixed layer depth--Depth of bottom of the mixed layer.

Mollusc--A phylum of soft, unsegmented animals, most of which are protected by a calcareous shell. Includes snails, clams, oysters, squids, and octopi.

Mysid--One of an order of shrimp-like, elongate, crustaceans which often are transparent and benthic.

Nannofossils--The skeletal remains of pelagic plants and animals that range in size from 5 to 60 u.

Near-field--1 to 100 km (0.5 to 55 nmi) from ship.

Nepheloid layer--Suspension of fine sediment and organic matter found near the ocean floor.

Nephelometer--An instrument for measuring the concentration or particle size of suspensions by means of transmitted or reflected light.

Neuston--Surface dwelling organisms.

Neuston layer--The water surface film.

Neutralization--To change the pH of a solution to 7.

Non-Ferrous--Not containing iron.

Ooze--A fine-grained pelagic sediment containing undissolved sand or silt-sized, calcareous or siliceous skeletal remains of small marine organisms in proportion of 30% or more, the remainder being amorphous clay-sized material or dead organisms, including fecal material.

Organic detritus--Consists of decomposition or disintegration products or dead organisms, including fecal material.

Ostracods--A subclass of crustaceans with the body enclosed in a bivalve shell. Often called mussel or seed shrimps.

Oxidation--Combination with oxygen; increase in oxygen content of a compound.

Oxygen minimum zone--A subsurface water layer in which the dissolved oxygen is very low.

Pelagic--Relating to or living in the open sea.

Pelagic clays--Fine grained pelagic sediments, rich in silica, that are found predominately in the deepest portions of the ocean.

Phytoplankton--Plant forms of plankton.

Plankton--Passively drifting or weakly swimming organisms. May consist of plants, animals, and eggs or larval stages of fish.

Polychaete worms--An order of the phylum Annelida; marine worms with segmented bodies; includes fan worms and clam worms.

Potential temperature--The temperature that a water sample would attain if raised adiabatically to the sea surface.

Predator--An organism that captures and feeds on other organisms.

Pregnant liquor--A value-bearing solution in a hydro-metallurgical operation.

Primary productivity--The amount of organic matter synthesized by organisms from inorganic substances in unit time in a unit volume of water.

Purse-seine fishing--A method of fishing that surrounds the fish with nets that hang down from the sea surface.

Pycnocline--Zone where density increases rapidly with depth. It separates the well-mixed surface waters from the dense waters of the deep ocean.

Radiolarian--One of an order of single-celled planktonic protozoa possessing a silica shell.

Rain of fines--Far-field component of the "benthic plume" that consists mainly of fine sedimentary particles which drift with the bottom current and slowly settle to the seafloor generally outside of the mining "subareas."

Raffinate--The solvent-lean, residual feed solution with one or more constituents having been removed by extraction or ion exchange.

Reductant--A reducing agent, one which readily parts with valence electrons and by becoming oxidized reduces the acceptor of these electrons. Carbon and hydrogen are important chemical reductants.

Reduction--A chemical reaction in which electrons are added to the constitutents of the reactant. A reaction which takes place at the cathode in electrolysis.

Reduction/ammoniacal leaching--Process for removing Mn, Ni, Cu, and Co from the nodules by the reduction of manganese dioxide to manganese carbonate with carbon monoxide and the removal of the metals from the nodules by leaching with aqueous ammonia.

Reduction/hydrochloric acid leaching--Nodule processing method that involves the reduction of the manganese with hydrogen chloride gas and the removal of the Mn, Ni, Cu, and Co from the nodules by leaching with hydrochloric acid.

Refractory--Difficult to oxidize; the organic matter in the sediment is composed of high molecular weight organic molecules that tend to be resistant to bacterial attack.

Salinity--A measure of the quantity of dissolved salts in sea water.

Saprotrophs--Microscopic organisms (bacteria, fungi, protozoa) which break down organic matter and release inorganic nutrients back into the environment.

Scavenger--An organism that feeds on dead organic matter.

Sea anemone--Sedentary marine animal of the phylum Coelenterata, having a columnar body and one or more circles of tentacles surrounding the mouth.

Sea cucumbers--A class of the phylum Echinodermata; elongate, tube-like, bottom-dwelling organisms that feed by ingesting sediment or suspension feeding.

Seamount--A submarine mountain, volcanic in origin, generally rising 1,000 m (3,300 ft) or more from the seafloor.

Sea star--A class of the phylum Echinodermata; true starfish with a flat, usually five-armed, body.

Sea urchins--Bottom-dwelling marine animals with a skeleton composed of immovable hard plates; many species possess long sharp spines.

Selective mining--Mining the richest zones of a mineral deposit first.

Serpulids--Tubeworms (polychaetes) that build calcareous tubes on submerged surfaces.

Settling pond--Earth embankment behind which processing plant wastes are deposited in slurry form.

Short-term--Hours to days in duration.

Sigma T--A conveniently abbreviated value for the density of sea water.

Siliceous ooze--A fine-grained pelagic sediment containing more than 30% siliceous skeletal remains of pelagic plants and animals.

Slurry--Pulp not thick enough to consolidate as a sludge but sufficiently dewatered to flow viscously; a mixture of nodules and water.

Smelt--To melt or fuse an ore to separate the metal.

Spore--A walled, single-to many-celled reproductive body of an organism, capable of giving rise to a new individual either directly or indirectly.

Sub-area--The area(s) to be mined by one consortia in one year; part of the mine site.

Sulfide precipitation--To separate the metal sulfides from solution.

Suspended particulate matter--Concentrations of organic and inorganic particles found suspended in the water column.

Standing stock--The biomass or abundance of living material per unit volume or area of water or sediments.

Surface mixed layer--Layer of surface waters that overlay the thermocline. It is characterized by fairly uniform temperature, salinity, and density values. The waters are well-mixed through wind and wave action and are high in oxygen content. Nutrient content is low because of uptake by phytoplankton.

Tailings Pond--A waste-disposal pond within a sealed earth embankment where tailings are allowed to settle out of the liquid. The liquid is allowed to evaporate or is decanted off.

<u>Tanaids</u>--An order of very small crustaceans that live burrowed in the mud or in self-constructed tubes. Superficially, they resemble tiny (1 mm) lobsters.

<u>Temperature inversion</u>--In oceanography, a water layer in which temperature increases with depth.

<u>Test site</u>--Area(s) selected by licensee, within his mine site, for tests of a mining system(s) under terms of a NOAA license.

<u>Thermal ridge</u>--An east-west oriented feature of the water column in the DOMES area that is characterized by an upward bulge of the 25°C isotherm toward the water surface. This causes the mixed layer and thermocline to be shallower than normal.

<u>Thermocline</u>--Layer of water, at the base of the surface mixed-layer, in which there is a sharp decrease in temperature with depth.

<u>Trophic level</u>--A successive stage of nourishment as represented by links of the food chain. In a representative food chain, phytoplankton constitute the first trophic level, herbivores the second and the carnivores the third level. In some ecosystems (e.g. detritus-based ones) exact trophic levels are very difficult to assign.

<u>Year class strength</u>--Relative term used to describe the number of fish surviving to a certain age from a single spawn.

<u>Zooplankton</u>--Animal forms of plankton.

Appendix 3. Projected deep seabed mining systems and processes for first generation development authorized under a license/permit from NOAA.

Appendix 3. PROJECTED DEEP SEABED MINING SYSTEMS AND PROCESSES FOR FIRST GENERATION DEVELOPMENT

3.0 INTRODUCTION

Four international mining consortia involving United States' corporations were formed in the 1970s to share the cost of exploration and development of first generation mining and processing systems (see Table 2). A fifth consortium, Association Francaise pour L'Etude et la Recherche des Nodules (AFERNOD), consisting solely of French organizations, has been engaged in similar activities since 1971. These consortia have completed initial research in one specific area of the eastern Pacific Ocean where manganese nodule density and composition appear to be sufficiently high for commercial mining. The at-sea portion of the following scenario is based on that area, called the "DOMES" (Deep Ocean Mining Environmental Study) area, and on the mining technologies investigated as of late 1979.

Several alternative courses of development exist for the collection, transportation, and processing of nodules and disposal of wastes. Table 22 presents and briefly describes some requirements of each alternative. Discussions below address each alternative in Table 22.

3.1 Marine Activities

3.1.1 Mining Systems and Operations

Industry has been developing two main types of mining systems: hydraulic and continuous line bucket (CLB). Hydraulic systems are favored by most of the consortia; all three demonstration scale tests monitored by DOMES in 1978-79 used hydraulic systems. A CLB system is under consideration by Japanese and French companies but is only briefly discussed in this document. Table 23 describes some general characteristics of each mining system.

Several operational aspects of nodule mining apply to both hydraulic and CLB systems. For example, industry estimates that vessels will mine 24 hours per day for an average of 300 days per year. The remainder of the year will be devoted to mechanical overhaul (about 30 days) and to transit and downtime for weather (about 35 days). Secondly, each mine site will be serviced by one or more ships designed to recover a total of 3,000 to 10,000 metric tons or MT (3,300 to 11,000 tons) of nodules (dry weight) daily. The larger tonnage operations will probably require at least two ships to operate efficiently. Within a given mine site, mining will probably take place in one sub-area at a time. For example, one year of mining with one vessel might take place in a 900 km^2 (262 nmi^2) sub-area (Ozturgut et al. 1981), approximately 25% of which could be unmineable due to topographic constraints on the collector apparatus. A 3 x 10^6 MT/y (3.3 x 10^6 tons/y) operation could involve twice this area, or 1,800 km^2 (524 nmi^2). The collector will travel along depth contour lines covering about 100 km (54 nmi) daily, in such a manner as to sweep the bottom in nearly abutting swaths much as a farmer plows a field. Based on developing collector technology, each swath could be up to perhaps 15 m to 20 m or 50 to 65 ft. wide for hydraulic systems, much wider for CLB.

Table 22. Schematic overview of first generation mining operations. Where listed, numbers in parentheses denote amount of vessels involved per mining operation.

AT SEA

Continuous Line Bucket (CLB) → Support Activities ← Hydraulic Pump System (towed or self-propelled)

Support Activities

1. Nodule transport vessels (2 to 8)
2. Supply vessels (1)
3. Exploration/mapping vessel (1)
4. Operate about 300 days per year

↓

ON SHORE

↓

Port Facilities
(including 12 m. or 40 ft. minimum mooring site)

1. Slurry terminal
   a. 180 to 270 m. (600 to 900 ft.) waterfront
   b. 4 to 10 ha. (10 to 25 a.) land
   c. Total of about 10 to 50 ha. (25 to 125 a.)
   d. Storage
2. Dry nodule terminal
   a. 4 ha. (10 a.) minimum land
   b. transport system for nodule handling

↓

Port-to-Plant Transportation

1. Slurry pipeline
   a. 1.5 ha. (3.8 a.) of land per 1 km (0.6 smi) traversed
   b. pumping station at port
2. Conveyer
   a. land needs similar to slurry pipeline
   b. feasible up to about 32 km (20.5 mi.)
3. Railroad
   a. use existing lines
4. Trucks

↓

Nodule Processing Plants and Operations

1. Operate 24 hrs. a day year round
2. Two types of plants
   a. Three-metal
      (1) Copper-nickel-cobalt
      (2) Process 2.3 to 3.6 million tonnes (2.5 to 4.0 million tons) dry weight per year.
   b. Four-metal
      (1) Copper-nickel-cobalt-manganese
      (2) Process 0.6 to 1.4 million tonnes (0.7 to 1.5 million tons) dry weight per year.

↓

Waste Disposal Facilities

1. Containment structures (tailings ponds)
   a. Three-metal plant -- 40 ha. (100 a.) at 13 m. (40 ft. depth per year
   b. Four-metal plant -- 8 ha. (20 a.) at same depth per year
2. Landfill
   a. Three-metal plant -- half of tailing pond size and depth each year
   b. Four-metal plnat -- half of tailing pond size and depth each year
3. Ocean dumping
   a. two barges of solid wastes per week or use outbound nodule transport ships
   b. waste slurry to port for holding, could require at least an additional 4 to 6 ha. (10 to 15 a.) of holding ponds.

Table 23. Ranges and mean values of mining systems (National Oceanic and Atmospheric Administration, 1976).

A - Hydraulic Systems

Parameter	Range	Mean Value
Seafloor nodule coverage	10 kg/m^2	10 kg/m^2
Nodule moisture, by weight	30%	30%
Collector efficiency (nodules collected/total nodules encountered)	50 to 85%	67.5%
Sweep efficiency (mineable area swept/ total mineable area)	40 to 75%	57.5%
Track width	10 to 25% of collector width	17.5%
Depth of cut into seafloor	3 to 10 cm	6.5 cm
Sediment rejection efficiency of collector (sed. rejected/total sed. intake)	90 to 99%	97.5%
Benthic discharge nodule loss, % of daily production	1 to 5%	3%
Surface discharge nodule loss % of daily production	1%	1%
Benthic discharge, % solids by volume	5 to 30%	17.5%
Lift system solids content, % solids by volume	10 to 30%	20%

B - Continuous Line Bucket System

Parameter	Range	Likely Value
Bucket collection efficiency (nodules collected ÷ nodules encountered)	?	80%
Intra swath efficiency (area contacted by buckets ÷ area of swath)	?	90%
Inter swath efficiency (area of all swaths ÷ mineable area)	?	80%
Depth of cut into seafloor	2 cm	2 cm
Sediment rejection efficiency of buckets (sediment rejected ÷ total sediment excavated)	80 to 90%	85%
Bucket ascent velocity	$<$ 7.4 km/hr	3.7 km/hr
Midwater sediment loss, % of load at start of bucket ascent	?	90%
Surface sediment loss, % of load at start of bucket ascent	?	10%
Nodule losses after collection	Nil	Nil

Hydraulic mining systems (Figure 24) are designed to recover nodules in a slurry of seawater pumped either by conventional slurry pumps or by airlift systems through a pipeline from a seafloor collector to a surface mining ship. During nodule collection, bottom sediments also will be hydraulically drawn into the collector. As much of this sediment as possible will be rejected at or just above the seafloor before being drawn into the pipeline. However, some sediments will travel the entire pipeline and be discharged at the water surface. To improve the efficiency of this lift system, nodules may be crushed at the lower end of the pipeline. Conversely, nodules may not be crushed until recovered aboard the vessel, brought to port, or brought to the process plant. Hence, this report refers generically to nodules, be they crushed or whole.

Results from past research provide a glimpse of an average (based on Table 23-A) hydraulic mining operation. Assuming a production of 5000 MT (5500 tons) of dry nodules per day, the collector will contact 1.1 km^2 (0.4 nmi^2) each day. An additional 0.8 km^2 (0.3 nmi^2) will remain unmined owing to the inability of the system to sweep the seafloor in perfectly abutting swaths. The total area traversed daily will be 1.9 km^2 (0.7 nmi^2). On an annual basis that area may be inflated up to 25% due to topographic limitations or low nodule concentration. The daily throughput in the system is shown in Table 24.

The hydraulic collector will be either towed or self-propelled; industry is testing both designs. Towed collectors will rest on the seafloor and be pulled by the surface mining vessel. The mining pattern of such a collector will depend on the course plotted by the surface vessel. To increase mining efficiency, the collector may be pulled along a depth contour. Self-propelled systems, thus far represented only by the Archimedes screw design of the Ocean Minerals Company consortium, will differ principally in two ways: the degree of control over the collector's ability to follow a pre-determined path; and, the collector (U.S. Patent no. 4,232,903; Nov. 11, 1980) will operate within a generally kidney-shaped area beneath the mining ship. Each such area would presumably be swept clean before moving to an adjacent area.

The two-vessel CLB system (Figure 24-B) involves a series of 1 m (3.3 ft) buckets attached to a continuous line that travels from the mining ship to the seafloor, along the bottom, up to the second mining ship, over to the first ship and back down again. The original method, utilizing a single ship, is still under development; the two-ship system has received more industrial attention in recent years. Whereas the hydraulic system discharges sediments only at the seafloor or water surface, sediments scooped up by the CLB system would wash out during retrieval of the buckets (Table 23-B). The rate of wash out and the amount of sediments contributed to the water column depend largely on sediment type, bucket size, and retrieval rate. Because of current industry interest and development in hydraulic mining, the CLB system, as a viable recovery system, is not discussed further in this appendix. Further information on this system may be found in Mero et al. (1974), Gauthier and Marvaldi (1975), Shaw (Personal Communication, 1976), and Mero (Personal Communication, 1977).

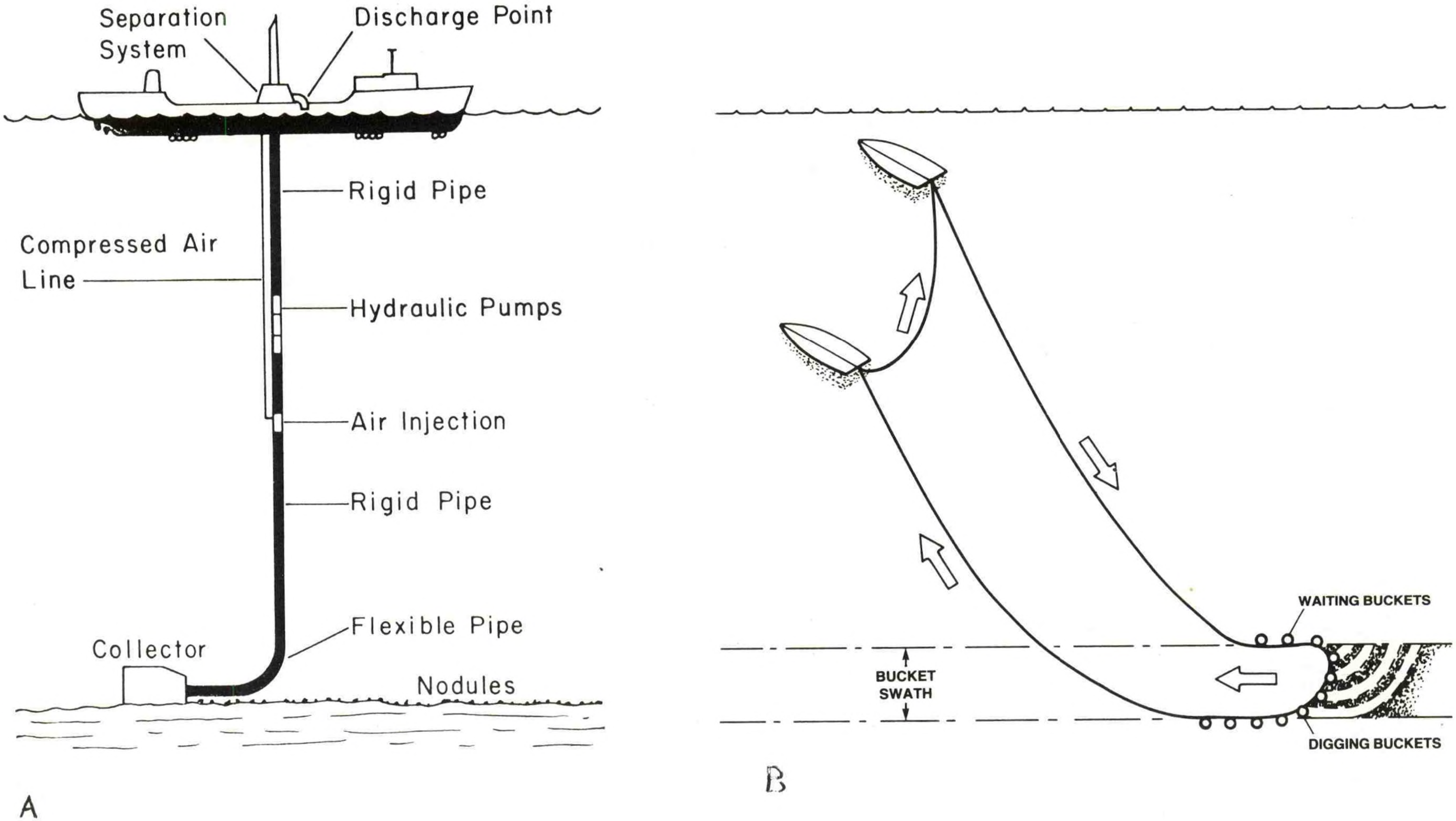


Figure 24.--Diagrams of two major mining systems. (A) Hydraulic pumping and compressed air lifting (both have been used) (Burns, et al. 1980); (B) continuous line bucket (conceptualized by NOAA).

Table 24. Daily mining system throughput for a 5000 MT (dry wt.) hydraulic production unit (National Oceanic and Atmospheric Administration, 1976, and Ozturgut _et al_. 1981b)

Components	Input	Losses: Benthic Discharge	Losses: Surface Discharge
Nodule, MT (dry wt.)	5,500	250	250
m^3	4,000	180	180
Sediment, MT (dry wt.)	54,000	52,000	1,600
m^3	20,000	19,000	600
Biota, kg	783	760	23
Bottom water, m^3	58,000	----	----
Interstitial water, m^3	42,000	----	----
Total water, m^3	105,000	80,000	25,000

Note: Components entering the collector at seafloor. Although both bottom water and interstitial water are inputs to the collector, they are combined as "total water" in the discharges. Components discharge within 20 m of seafloor.

3.1.2 Processing At Sea

Broadly three classes of treatment schemes might be attempted for pre-processing or processing nodules at sea. They are:

1. A minimum treatment to upgrade nodules by physical means (beneficiation).
2. Partial treatment of nodules by chemical and physical means to produce an intermediate product whose volume is less than that of raw nodules.
3. Complete at-sea treatment to produce finished metal products.

Alternatives for onshore processing are discussed in Section 3.3.3 of this Appendix.

If nodule mineralogy permitted carrying out a physical beneficiation operation at sea, it would probably be economically attractive. Low-grade tailings would be rejected at sea as waste and the product would be an upgraded nodule material which would be shipped to land-based plants for further processing. It has been repeatedly demonstrated that the nodules are not amenable to such physical beneficiation, and at least some chemical processing would be required to liberate the valuable metals from the nodule's matrix.

The installation of a processing plant or any element of that plant in a sea-going vessel will subject the equipment to some motion. This is the principal difference from a land-based plant. Operations or equipment which would be most affected by vessel motions are smelting, electrowinning, decanting, rake classification, leach thickeners, stripping and scrubbing tanks, furnaces and converters, extraction tanks and possibly fluidized bed reactors.

In the land-based process routes, all value metals are dissolved in the pregnant liquor from leaching operations and must be selectively removed (separated) to permit the direct production of marketable metals. These operations are normally carried out in conventional mixer-settler units. Since these units depend on gravity, the operation would be adversely affected by fluid motions induced by the pitching and rolling of the processing vessel, even if the degree of motion were quite small.

Even if adequate ion exchange separation technology could be developed, problems would still occur in the metal reduction step. The operation of a conventional electrowinning tank house on seagoing vessels would be difficult because of the problems associated with vessel motion. A modification of the conventional cell design can be envisioned to permit anodes and cathodes to be stabilized against the ship's motion. However, this would require the development of new technology.

An at-sea smelting route offers a potentially significant advantage in both transportation and waste disposal costs in that the metallic phase produced in the first smelting step is very highly concentrated in copper, nickel, and cobalt, amounting to less than 3 percent of the original nodules weight. However, severe technological problems with motion exist in attempting to carry out smelting operations at sea.

In summary, complete at-sea processing of nodules would require the development of new technology in the areas of metal separation and reduction which are not likely to be implemented in first generation process plants.

As an alternative to complete treatment to produce metals of cathode specification, the pregnant liquors might be treated to reduce selectively or totally the primary metals with the production of materials which would require further refining on land. Such an approach, however, would involve the transport of a large amount of reductant from land to the processing facility. Thus, transportation cost savings which would result from shipping highly concentrated, impure metal precipitates would be partially offset by the costs of transporting reductants.

An alternative to reduction at sea is to transport the pregnant liquors produced at sea to land-based plants for metal separation and reduction (Section 3.3.3.2 below). However, with the exception of the reduction/hydrochloric acid leach and smelting processes, the pregnant liquors produced in the hydrometallurgical portions of the processes are very diluted. Thus, except for the fact that the shipment of clear solutions would be somewhat easier than the shipment of nodules slurries, savings would be unlikely in transportation costs for this approach.

If partial processing of nodules at sea were to be adopted, a significant number of activities would remain to be carried out on land. The configurations of land based plants for pregnant liquor processing would be identical to those for full processing except that front end activities such as nodules receiving, ore preparation and drying, reduction, leaching, washing, and reductant gas generation would be eliminated. If concentrated, impure metal precipitates were produced at sea, a metals dissolution step would have to be incorporated in the land-based plant. In this case, the amount of waste produced in the land plant would be quite small, consisting mainly of precipitates such as lime boil solids arising from solution purification steps. If pregnant liquors were processed in land plants, similar amounts of solid wastes would be produced along with large amounts of metal-free raffinate solutions which would be recycled to the sea based plant or impounded for treatment and disposal.

The wastes produced in the at-sea plants would be disposed of at sea after suitable treatment. They would be very similar in amount and chemical and physical properties to the tailings fraction of the wastes produced in fully integrated land-based plants since the processing technology used to develop them would be fundamentally the same. It is to be expected that minor differences could occur because the wastes would be discharged directly and not be aged in the way that land-based materials would even prior to at-sea disposal. Aging could affect the propensity of certain types of wastes to flocculate naturally and thereby modify their settling characteristics. In addition, wastes directly discharged would be significantly warmer than those produced in land-based plants, perhaps by as much as 50°C.

3.1.3 Support Operations

During commercial recovery one exploration vessel will be used to continue to delineate important characteristics of the site, such as nodule density, mineral grade, and seafloor topography. In addition, a small, fast ship will be required to provide personnel transportation to and from the logistics base ashore and to bring mail, spare parts, food, and other supplies. A mine site fleet could include one or two mining ships, one exploration/mapping vessel, one fast service vessel, and at least two bulk ore carriers to transport the nodules, probably in slurry form, to shore for metallurgical processing.

Fresh water for boiler water makeup and human consumption would probably be distilled in seawater evaporators aboard the mining ship, rather than carried out from shore. However, water transport is possible in large volume on all ship types, and would be readily pumpable to the mining ship.

Sea water would probably be used mostly for cleaning of the ship's holds, followed by a fresh water rinse. Ballast tanks would probably remain clean for all vessels, because the high density of the nodules permits a generous volume of tanks for segregated fuel, ballast, fresh water, and cargoes.

Sewage treatment and holding devices are common on all new ships, and would be expected on the transport ships. Garbage and trash incinerators are also common.

A principal feature of the transportation operation which will require innovative engineering will be the transfer of nodules from the mining ship to the ore carrier. This will most likely involve a slurry pumping system with flexible hose. The ore carriers could carry personnel, fuel, and supplies to the mining ship on return trips. To avoid characterization as tanker(s), the ore carriers would each haul less than 2,000 tons of fuel, in holds separate from their own fuel. Oil spills from non-tanker ships are not significant because cargo oil holds are less vulnerable than tanker hulls, and, small volumes of oil are involved (Ben Andrews, personal communication). If ocean dumping of processing wastes is the selected disposal technique (see Section 3.3.4.3.3 below), ore carriers could transport wastes from shore to the disposal site.

3.2 Transportation to Shore

This section is based upon a contract study (Dames & Moore *et. al.* 1977) that investigated transportation and waste disposal systems.

3.2.1 Shipping routes

For comparison purposes, two locations within the DOMES area were selected as mining sites and three U.S. coastal areas for discharging of nodules. This relationship is shown in Table 25:

Table 25

Port to mining site distances

	Distance to Site B Kilometers	(nautical miles)	Distance to Western Boundary Kilometers	(nautical miles)
Pacific Northwest	4,220	2,270	6,950	3,750
Southern California	3,240	1,750	6,180	3,850
Texas via Panama Canal	9,140	4,930	12,880	6,950

3.2.2 Vessels

Because of the high density of manganese nodules, an ore-carrying type ship with reduced hold width and higher hold center of gravity will be required --for stability. Allowing 12.2 meters (40 feet) as a realistic maximum draft, the maximum size vessel is likely to be about 65,000 DWT (dead weight tonnage; the difference, in long tons, between the loaded and light displacement of the vessel). A vessel transiting the Panama Canal would be smaller--55,000 DWT. In either case, the vessel would travel at about 28 to 30 kilometers/hour (15 to 16 knots) when laden.

3.2.3 Loading

If the nodules are fragmented into small pieces as a result of their half-hour journey up the mine ship riser pipe, they can be transferred to the ore carrier through a slurry hose (Figure 25). If they are not badly broken they may be too large and heavy for slurry pumping and may have to transfer via conveyor. If the nodules are crushed and ground in the mine ship they can transfer via slurry hose. There is a chance they may be crushed, ground, and dried. In that case, pneumatic conveying could be used. These options are shown in Figure 26.

3.2.4 Fleet

The number of vessels serving each mine site will depend upon the rate of production, the distance to port, the form in which the nodules are transported, and whether or not the Panama Canal is to be utilized. Thus, there are numerous combinations explained in detail in the reference noted at the outset. For illustrative purposes, the fleet requirements to haul nodules in a slurry are shown in Table 26.

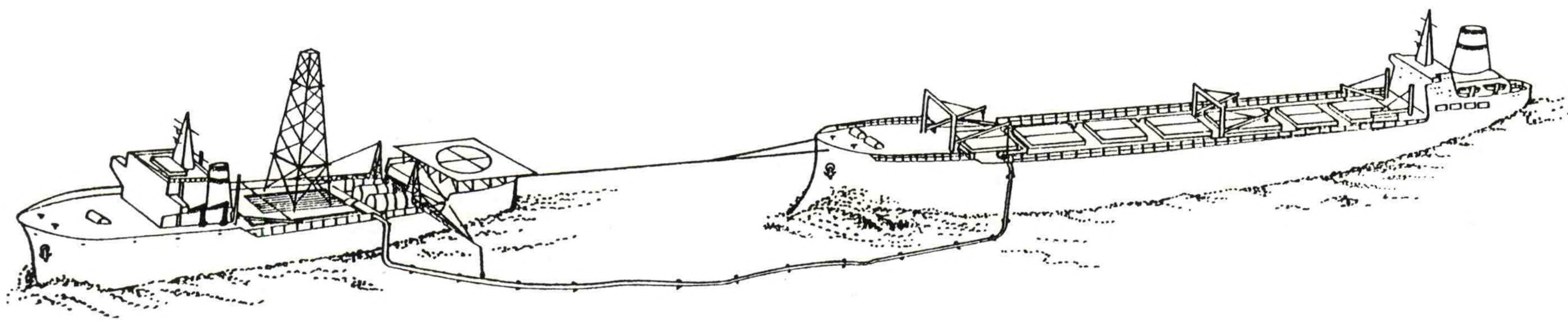


Figure 25.--Transfer-at-sea of slurry from mining ship to transport ship (Dames, Moore, _et al._ 1977).

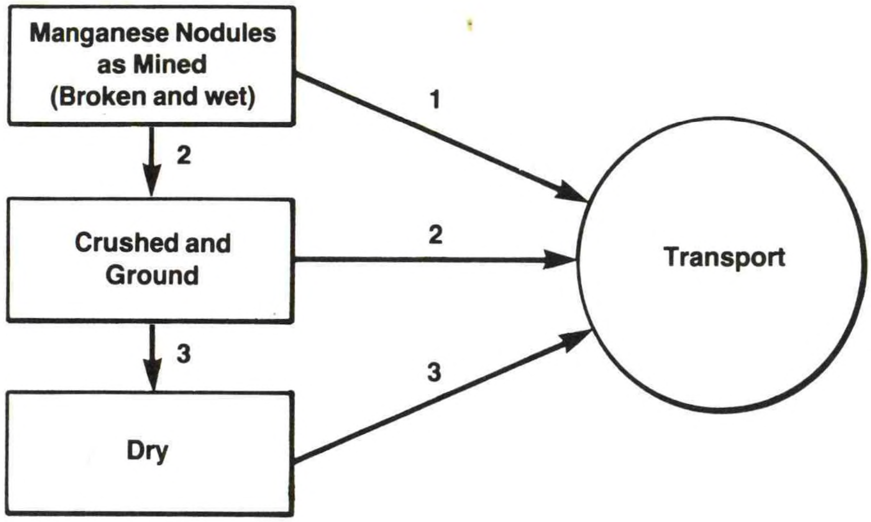


Figure 26.--Three forms in which manganese nodule material may leave the mining ship.

Table 26

Likely Fleet-Nodules Slurry
(3-Metal Plant; 3.7×10^6 MT per year)

	Southern California		Pacific Northwest		Central Texas
Site B to:					
Number of Ships	2	3	2	3	8
DWT each	63,000	44,000	87,000	58,500	55,000
Arrival Interval, (Days)	5.4	3.8	7.2	4.0	4.0

(4-Metal Plant; 1×10^6 MT per year)

	Southern California		Pacific Northwest		Central Texas
Site B to:					
Number of Ships	1	2	1	2	2
DWT each	43,000	22,000	56,000	30,000	55,000
Arrival Interval, (Days)	11.2	5.3	14.5	6.0	16

Clearly the 925 kilometers (500 nautical miles) added voyage length to the Pacific Northwest adds substantial cost to the transport system. Vessels with capacity about one-third larger are required, and the extra size of the largest ship would be too large for the harbors. Therefore, three vessels are required rather than two for southern California, which increases transportation costs approximately 35 percent.

For the Texas site, eight of the largest ships able to transit the Panama Canal would be required for a three-metal plant. The investment cost in the larger number of small ships is about three times the average investment in ships for service in the Pacific Ocean only.

3.2.5 Fuel

The pollution of the seas by petroleum and its products is of major concern, and applies to the nodule mining and transportation ships because these ships both carry and burn fuel oil, and receive fuel aboard in a bunkering operation. The foreign ship for this service will probably be diesel powered for maximum fuel economy and construction cost savings. American ships have been primarily steam boiler and turbine powered, and burned heavy Bunker C or residual fuel oil. Any new mining and transport ships constructed will most probably be diesel powered.

3.2.6 Shipyards

The construction of two to eight new mining and transport ships in the mid to late 1980's is within the existing capabilities of many American shipbuilding yards. Few if any additional resources would be required at the construction yards; however, several thousand man-years of labor would be expended to manufacture the ship and its components. Steel, the largest item required for each ship, is an insignificant portion of existing U.S. steel plant capacity, which is not now being fully utilized.

The principal requirements for vessel maintenance are the same as for existing tankers and bulk ships of similar size and power. Hull preservation would be a continuous operation for spot surface repairs in the American port. Engine room repairs and maintenance would also be undertaken at the marine terminal. The major demand would be for drydocking, and several Pacific and Gulf of Mexico coastal shipyards have adequate facilities that are at present under-utilized. Each year during the short down period of the mining ship, the transport vessels would normally spend a few days at a drydock.

The mono-mooring buoy (Section 3.3.1.1), if used, probably would be dry-docked every several years. The small craft fleet associated with the mono-buoy operations would probably be maintained in existing nearby boat yards. The incremental docking traffic from any one mining program would be an almost imperceptible increase in business, and not generate any need for new repair or docking facilities. Existing facilities are also available and adequate for equipment manufacture and testing of new equipment and procedures related to shipping.

3.2.7 Labor

The shipboard crew would range between 26 and about 40 for each vessel, depending upon the propulsion plant and type of cargo handling on board, if any. Ship size would have little effect on crew size.

Because of the short voyage and frequent calls in the U.S., at least 1-1/2 men would be employed for each berth. For a three-ship fleet of large slurry vessels, a crew pool of 160 men would be needed, plus about 30 engineers, maintenance and management staff ashore.

3.2.8 Navigation Resource Requirement

Navigation resources include channels, aids, and controls. Examples of U.S. ports on the Pacific and Gulf of Mexico were described earlier. Each port has a unique set of physical characteristics which assist or limit ship transportation in the channels. These include other vessel traffic; river flow and tidal rise and fall and their currents; fog, rain, snow, and river curvature affecting visibility; aids to navigation and radar-assisted shore traffic direction; tug assistance and similar activities. The depth and width of navigation channels set upper limits on the draft of transiting vessels, and thus directly limit the size, capacity, and efficiency of the ships.

Increasingly, large size ships are directly and adversely affected by all of these factors. Larger ships are less maneuverable, slower in stopping, and occupy more of a restricted channel than smaller vessels. Large ships in tidal or flowing currents are strongly pushed and not well able to control their heading or position in confined quarters. Reduced visibility hinders navigators in meeting obligations to keep clear, and prompt action is essential to avoid collisions or groundings. Channel markers are not always on station, and rapid shoaling near channel limits cannot be detected early enough on most ship depth sounders. Radar-assistance to navigators from Coast Guard shore stations is advisory and only available to large ships and not the small boat traffic. Tugs are sometimes inadequate for the tasks of keeping large ships in position and channel, or from bumping into bridges, docks, shoals, and other vessels.

Although each of these resources can be identified for a particular area, to quantify the benefit from their presence in any particular degree is most difficult. Adequate data is probably not available to estimate the likelihood of grounding with or without tugboats in any specific channel, for example. If data were available, analysis would probably conclude that operating managements have, through experience, learned to make judgments that are close to optimum. These include when to use tugs, when to enter a channel, where and how to berth, when to back down and change rudder position, and like decisions.

All of the navigation channels considered here have been used many times by very large ships, over 100,000 DWT, on suitable occasions. Even 70,000 DWT ships, with about 55,000 long tons of cargo, have transited the Panama Canal regularly. These ships have not had the advantage of regular calling and special port facilities, and yet accidents rarely happen. Given the infrequency of channel use by these large ore carriers, little traffic increase can be measured which would raise the exposure and probability of collision. From past experience, the expected incidence of accidents would probably be longer than the project life.

Additional information on this subject is provided in Dames & Moore et al. 1977.

3.3 Onshore Activities

Land based activities associated with deep seabed mining can be considered most conveniently by grouping them into four categories of facilities, which may or may not be located adjacent to each other: 1) a marine terminal for unloading the nodules from transport ships and temporarily storing them onshore; 2) transportation facilities for (a) moving the nodules from the marine terminal to the processing plant and possibly (b) transporting process tailings, or waste products, from the processing plant to a land-disposal site or, if at-sea disposal is selected, back to the transport ships; 3) the processing plant where the ore metals will be extracted from the nodules; and 4) the waste disposal facilities where the processing wastes will be treated, if necessary, to remove any potentially toxic or hazardous substances and/or be permanently stored. The remainder of this Appendix briefly describes these four aspects of the industry and possible design options. Resource requirements for the latter three aspects are summarized in Table 27 (this table appeared in Section III as Table 16).

3.3.1 Port Facilities

3.3.1.1 Slurry Terminal

Based on economics, it seems most logical to handle the nodules in slurry form for transportation purposes.

The primary features of a slurry terminal (Figure 27) are a pier for tying up the nodule (crushed or whole) transport ships, one or more traveling cranes on the pier for swinging portable pumps onto each transport ship,

TABLE 27. Preliminary Identification of Resource Requirements for Major Activity Alternatives for Onshore Marine Nodule Processing[a].

MAJOR ACTIVITIES	RESOURCE REQUIREMENTS															
	THREE-METAL PROCESSING								FOUR-METAL PROCESSING							
					ENERGY								ENERGY			
						FUELS								FUELS		
	Nodule Input (10^6 t/yr)	Land (Hectares)	Labor (Persons)	Water (10^6 m^3/yr)	Electrical (10^3 kw)	Coal (10^3 t/d)	Gasoline (10^4 l /yr)	Diesel (10^4 l /yr)	Nodule Input (10^6 t/yr)	Land (Hectares)	Labor (Persons)	Water (10^6 m^3/yr)	Electrical (10^3 kw)	Coal (10^3 t/d)	Gasoline (10^4 l /yr)	Diesel (10^4 l /yr)
1. Transshipment From Port to Processing Plant																
•Marine Terminal																
Whole Nodules	-	8.0	58	-[b]	N/A	-	-	-	-	4.8	49	-	N/A	-	-	-
Slurry	-	5.2	33	N/A	N/A	-	-	-	-	2.4	28	N/A	N/A	-	-	-
Dried/Ground	-	4.4	47	-	N/A	-	-	-	-	3.2	39	-	N/A	-	-	-
•Transportation System																
Rail[c]	-	N/A	15	-	N/A	-	-	56.0	-	N/A	12	-	N/A	-	-	19.0
Truck	-	N/A	N/A	-	-	-	N/A	N/A	-	N/A	N/A	-	-	-	N/A	N/A
Slurry[d]	-	4.8 + 3.8/km	6-12	2.70	1.2	-	N/A	N/A	-	2.4 + 3.8/km	6-12	0.81	0.4	-	N/A	N/A
Conveyor[e]	-	4.8 + 3.2/km	N/A	-	0.5	-	N/A	N/A	-	1.6 + 3.2/km	6	-	0.5	-	N/A	N/A
2. Nodule Processing at Onshore Plant																
•Reduction/Ammonia Leaching Plant	3.7	80.0	500	6.00	23.5	2.1	-	-	-	-	-	-	-	-	-	-
•Cuprion/Ammonia Leaching Plant	3.7	80.0	500	7.90	0.0	1.9	-	-	-	-	-	-	-	-	-	-
•High Temperature Sulfuric Acid Plant	3.7	73.0	500	5.40	28.8	1.0	-	-	-	-	-	-	-	-	-	-
•Reduction/HCl Leaching Plant	-	-	-	-	-	-	-	-	1.4	40.0	300	1.40	94.5	1.2	-	-
•Smelting Plant	-	-	-	-	-	-	-	-	1.4	50.0	300	1.40	70.3	0.8	-	-
3. Waste Disposal																
•On-site and/or Off-site Disposal																
Landfill	-	20.0/yr	20	0.09	0.23	1.5	8.7	160.0	-	4.0/yr	5	0.02	0.12	N/A	2.7	27.0
Tailings Pond	-	40.0/yr	4	Neg.	0.66	-	N/A	N/A	-	7.2/yr	3	Neg.	0.06	-	N/A	N/A
Manganese Storage	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
•Off-site Disposal																
Ocean Dumping	-	-	N/A	-	N/A	-	-	N/A	-	-	N/A	-	N/A	-	N/A	N/A

Abbreviations: m^3/yr, cubic meters per year; t/d, tons per day; KW, Kilowatt; N/A, data not available; l/yr, liters per year; km, kilometer; Neg., negligible.

a. All values are rounded; all units are metric.
b. - indicates none.
c. Assumes: 8 km of rail.
d. Assumes: 32 km pipeline.
e. Assumes: 3050 meter length, 24 hour continuous operation.

Source: Computation based on material in Dames & Moore (1977).

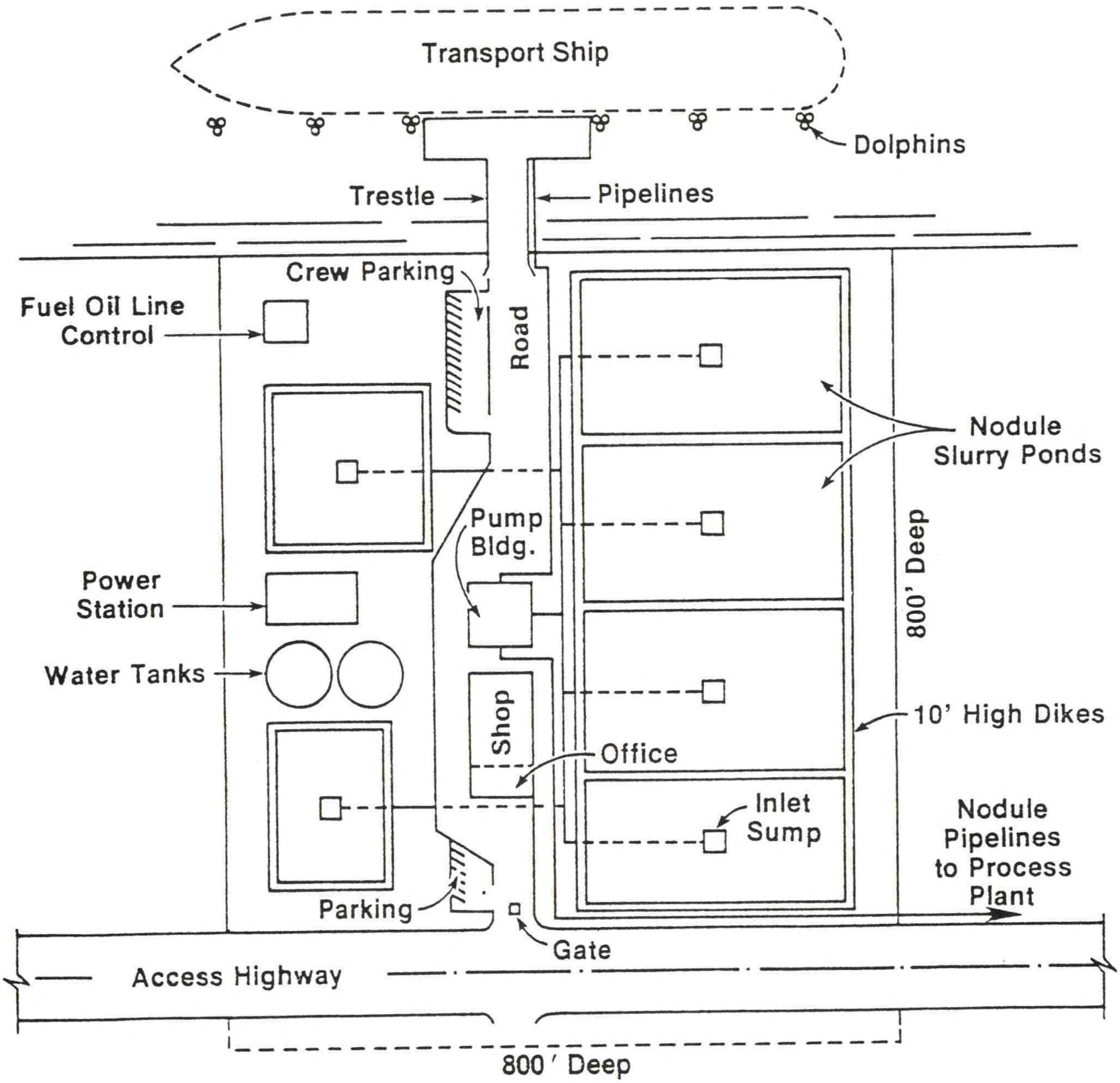


Figure 27.--Illustrative slurry terminal (Dames and Moore, et al. 1977).

containment areas to hold nodules awaiting onshore transportation to the processing plant, tailings holding facilities (only if ocean disposal is used), and a facility for loading fuel destined for the mineship by way of returning transports. The terminal might be a dedicated facility at which one 50,000 to 70,000 dead weight tons ship could call every four to 10 days.

Land requirements for the terminal would be similar to those for any comparable commercial port facility. Between about 180 and 270 m (600 and 900 ft) of waterfront and 2.4 to 10 hectares, ha. (10 to 25 acres, a.) of adjacent level land would be required for dockage and land facilities. Water depth (draft) in the dock approach and mooring site would have to be at least 12 m (40 ft). Salt water used for slurrying the nodules would probably be recycled; the processing plant would de-water the slurry and return the salt water to the terminal for holding and reuse. Additional salt water would be drawn from the harbor to replace that small amount of water not recovered during dewatering or lost to evaporation. The total volume of salt water required by slurrying would vary depending on the quantity of nodules, whether the nodules are whole or fragmented, the distance of transportation, slurry velocity, and other factors.

Terminals would also load fuel onto the nodules vessels for transport to and supply for mining vessels. The amount of oil transported would be well below the volume for the transport to be considered a tanker ship. Fuel oil storage onshore is assumed to be located off-site; a pipeline station would probably be the only on-site requirement. Fuel oil may be piped directly to the ship's side for bunkering while the cargo is being discharged or it could be delivered by barge to the offshore side of the moored ship.

If an ocean waste disposal system is utilized, process tailings may be held at the marine terminal for shipment out to sea. These tailings could be delivered to the terminal in a slurry with large quantities of salt water and could be stored in separate containment ponds. To load or unload tailings, a substantial pumping system would have to be installed which would probably require several thousand kilowatts of electricity during the period of pumping. This electrical power could come from on-site diesel engines or gas turbines or could be purchased from electrical utility companies.

The total land area required for waste handling facilities for a first generation operation could require at least 4 ha. (10 acres), and up to several times that for large volumes of tailings storage. Therefore, the marine terminal for slurry nodules and slurry waste, including tailings waste ponds, transport water storage, and ship loading pumps may occupy from 6.4 ha. (16 a.) to as much as 20 ha. (50 a.) for large volume tailings storage.

Where onshore space is limited, an offshore terminal may be an option. Moorings can be located in deep water where adequate space is available for a slurry ship to moor safely and transfer cargo. Modern mono-moorings permit the ship to swing freely about the center of the mooring area, where a surface buoy provides securing lines (or chains) to the ship. For a 70,000 DWT ship, an area about 610 meters (2,000 feet) in diameter is the minimum required in deep water, plus deep water fairway access channels.

Offshore mono-moorings in deep water are feasible with slurry systems and larger vessels in southern California and Texas waters. The rough ocean waters of northern California and the Pacific Northwest probably would not be practical locations for offshore mono-mooring buoys. However, buoys and slurry pipelines could be put inside harbor entrances in deep water if space is available.

The slurry, recycle water and fuel lines, and possibly tailings waste slurry line, would all be underwater pipelines from a shore terminal to underneath the buoy, where flexible hoses rise to the buoy and float on the surface to the ship side. There the lines can be lifted aboard for connection to appropriate outlets. Mooring lines would be connected to the buoy and the ship and would be handled by a small boat upon arrival of the ship. The ship alone could drop the 30-to 45-centimeter (12-to 18-inch) hose and mooring lines quickly in an emergency. Pumping clear salt water would, within a few minutes, empty the pipe and hose of slurry down to the sea floor.

The buoy would be moored with multiple spread anchors, chains, and clump weights of adequate design for the transport vessel.

The same buoy system could be used to load waste tailing products aboard the ship for disposal at sea, with a return line of the closed loop system to recycle water for slurrying tailings. Finally, fuel oil and other bulk liquids could be handled in a separate hose and pipeline simultaneously with nodule or tailings pumping.

The water front dock, ship mooring dolphins and pipeline connections would be omitted, being replaced by the mooring. Depending upon the elevation and distance from the mooring, an auxiliary pumping station may be needed to speed off-loading of the slurry transport ship.

Support facilities are required at the waterfront for buoy mooring systems. Small craft for line handling, a work barge with derrick for anchor handling, and maintenance boats are usually specially provided for the mooring. These boats require shallow water berths and maintenance. The total installation of a mono-mooring system, including its support boats and facilities, would cost about as much as a conventional slurry berth.

3.3.1.2 Dry Nodule Terminal

Nodules could be shipped to shore in either a dry whole bulk form or in a dried and ground form. In either case, the terminal facilities would be slightly different than described above for a slurry system.

A marine terminal for dried and ground nodules would probably resemble a terminal designed to handle dry bulk chemicals, fertilizers, or cement. Enclosed handling and storage equipment would be required for dust control and to reduce loss of material. Because of the 30 to 40 percent loss of water weight during shipboard nodule drying, either lower cargo tonnages could be handled or fewer vessels would be needed and terminal arrivals would be less frequent. The essential elements of a dried and ground nodule terminal are the ship dock, the pier or wharf, shore side or shipboard centrifugal suction cargo unloaders, or clamshell or bucket unloaders, and an enclosed conveying system to a stockpile building. From the stockpile building, another enclosed conveyor would lead directly to the processing plant or to closed rail car loading equipment. With the most compact terminal arrangement, at least 4 ha. (10 a.) of land plus waterfront would be required for a first generation terminal handling about 0.6 million to 1.4 million MT (0.7 to 1.5 million tons) per year for a four-metal plant (see Section 3.3.3.1 of this Appendix) or about three times that volume for a three-metal plant (also, Section 3.3.3.1).

The dry nodule facilities would not handle slurried processing waste for at-sea disposal. A separate terminal and tug-barge system would be needed because the transport ships servicing these terminals would lack the required material handling capabilities to transport and dispose of slurried waste at sea.

3.3.2 Port-to-Plant Transportation

Land transportation of nodules from port terminals to processing plants and the transport of waste to disposal areas would depend, to a large extent, on the physical form of the nodule material. If the material is brought to port wet, either as broken nodules or crushed and ground, it could be transported to the processing plant in a slurry pipeline. If the nodules are ground and dried, either conveyor or rail transportation appears most likely, depending on the onshore transportation distance. Unless a requirement is imposed to dry waste before disposal, the transportation of waste from the plant to the disposal site would probably be by slurry pipeline.

3.3.2.1 Slurry Pipeline

A slurry pipeline system might consist of a slurry pumping station adjacent to the terminal storage ponds, a buried steel pipeline, and storage ponds at the processing plant. For distances less than about 13 km (8/smi), a bank of pumps could be used; greater distances would probably require booster pumping stations, unless positive displacement pumps are used. The latter could transport slurry about 56 to 64 km (35 to 40 smi) without intermediate booster stations. A second pipeline could be installed to return transport salt water to the terminal for reuse or to return plant waste to the port for disposal at sea.

A pond could be required at the plant site to provide for nodule storage in case of a plant shut down and could also provide a surge pile of nodules in case of a pipeline shut down. It is estimated that a slurry pipeline would require approximately 1.5 ha. (3.8 a.) of land per 1 km (0.6 smi) of pipeline and would utilize between about 1 million to 3 million m^3 (1.2 million to 3.6 million yd^3) of recycled water per year to move the nodules. This water would most likely be sea water but may be fresh water.

3.3.2.2 Conveyor

Long distance, high capacity conveyor systems have been in use in the mining, construction, and bulk handling industries for many years and could be used for transporting bulk nodules to plant sites up to about 32 km (20 smi) from the port. Such a conveyor system would be enclosed for dust control purposes. Land requirements would be approximately the same as for a slurry pipeline.

3.3.2.3 Railroad

A nodule processing plant could be located to use existing rail lines with no new track construction except for sidings and/or new spur lines at both the port and the plant. It is assumed that the freight cars would be hauled by diesel electric locomotives. The nodules could be loaded into the freight cars at the port terminal by means of an overtrack hopper and could be unloaded at the plant by means of bottom dumping. Transfer from the dumping area to the plant storage areas could be by conveyor, truck, or slurry.

3.3.2.4 Trucks

The use of trucks to haul nodules from the terminal to the processing plant is possible. Truck size will be limited by highway load limit regulations to about 18 MT (20 tons) capacity. The units would be covered to prevent loss of fines through wind erosion. The size of the operation and the haul distance are major factors in determining the number of trucks. For example, 66 trucks would be required to service a 3-metal plant located 80 kilometers (50 miles) from port.

3.3.3 Nodule Processing Plants

3.3.3.1 Types of Processing Plants

A key element in determining the structure of a nodules processing plant is the decision as to whether or not to recover manganese in addition to nickel, copper, and cobalt. If recovery of only the latter three value metals is desired (three-metal plant), the reduction of manganese must be carefully controlled. Not only is chemical reduction an energy intensive and expensive step, but it would be highly desirable not to further complicate the required nickel/copper/cobalt separation steps (see section 3.3.3.2) with the presence of dissolved manganese if it could be maintained as the relatively inert, benign oxide.

If, on the other hand, manganese recovery is desired (four-metal plant), the required selectivity of the reduction step(s) is dictated primarily by the economic constraints involved in producing metals of the required purity. The manganese may be recovered as an integral operation of the sequence of reduction and purification steps in a process plant designed to produce all four metals, or may be recovered from the partially processed nodule residues from which nickel, copper, and cobalt have already been extracted. In either case, the amount of wastes produced from a four-metal plant will be less than those from a three-metal plant per unit of nodule treated since the major constituent (manganese) will have been recovered for sale, not rejected.

Since the first nodule processing plant has yet to be built and the location has not been selected, the estimates of requirements of processing facilities are based in part on assumptions and judgments. However, this information should be indicative of typical requirements of a nodule processing plant and should be adequate to serve as a base for a general assessment of the environmental impacts.

A major factor in determining whether or not to produce manganese in a "four-metal" plant will be the near-term market for this metal. Because of the high percentage of manganese (25.2% average) in the nodules, a single nodule processing vessel recovering 0.9 million MT (1 million tons) of nodules per year could be expected to supply about one third of the manganese consumed annually in the United States at 1979 rates. Thus, a company interested in processing manganese nodules must balance the scale of operations needed to make the endeavor economically attractive against the potential ability to penetrate the near-term manganese market, considering future changes in that market. It is currently estimated that a first generation four-metal plant could be designed to process about 1 million MT (1.1 million tons) of nodules per year, dry weight. Total production of manganese would be 200,000 to 250,000 MT (220,000 to 275,000 tons) per year.

The alternative to a four-metal plant is one designed to produce copper, nickel, and cobalt only, with the option of producing manganese as a secondary product. The minimum production level needed to make a three-metal plant economically attractive is based largely on nickel production since that metal is the most important to the economics of nodule mining. It is currently estimated that the smallest sized initial three-metal plant would be designed to process about 3.0 million MT (3.3 million tons) of nodules per year (dry weight). Production from such a plant would be about 50,000 to 75,000 MT (55,000 to 82,500 tons) of total product each year.

The following types of processes have been identified as the most likely three-metal processes for first-generation plants: 1) cuprion reduction ammoniacal leach; 2) ammoniacal leach; and 3) high temperature sulfuric acid leach. One of two additional steps is likely in first-generation four-metal plants: 1) hydrochloric acid wash and 2) smelting and leach.

3.3.3.2 Description of Processes

There are several options for nodule processing depending on whether a three-metal or four-metal plant is used. Table 28 briefly presents the chemical processes required to recover each of the four primary metals.

3.3.3.3 Processing Plant Operations

A processing plant can be viewed conceptually as a "black box" into which flow nodules, energy, reagents, water, and labor and out of which flow products, solid and liquid wastes, airborne emissions, and noise. Also flowing out will be the pay of the work force, payments to local businesses for supplies and services, and tax dollars. The plant can be expected to operate three shifts per day about 330 days per year. There would be about 300 to 500 employees at the plant site itself, divided among the three shifts, depending on plant volume and processing techniques employed.

Energy is a major input and will consist of a combination of hydrocarbon fuel and purchased electrical power. Based on the current uncertainties regarding oil supplies and prices, it is generally expected that coal will be the hydrocarbon fuel chosen. However, oil or natural gas could be substituted under special circumstances. Depending on the process, coal usage could range from 900 to 2,140 MT (1,000 to 2,350 tons) per day. It is expected that plants will take advantage of heat produced in processing to generate some of

Table 28. Possible processing systems for three-metal and four-metal plants.

Three-metal plant

Grind nodules → Cuprion reduction ammoniacal leach →
- liquid phase → Leach copper and nickel by electrowinning → Contact remaining liquid with hydrogen sulfide → Precipitate cobalt → Dispose of remaining liquid (or use in four-metal plant process)
- solid phase → Dispose

Four-metal plant

Option 1:

Liquid waste after cobalt recovery → Hydrochloric acid leach → Evaporate, heat, and electrolysis → Produce molten manganese

Option 2:

Grind nodules → Smelt and leach →
- Manganese and iron slag → Recover manganese
- Copper, nickel, and cobalt slag → Grind and submit to three-metal plant process
- Slag of unwanted constituents → Dispose

the electric power required during processing. Full onsite generation is possible, but would be a last resort since it would be an inefficient use of the capital of the operator. Quantities sought from outside would range from about 25 megawatts per year for a first generation three-metal plant to nearly 100 megawatts for a first generation four-metal plant.

Although the types and quantities of reagents will probably vary from process to process, the combination of the major materials used directly in nodule processing is summarized in Table 29. It is anticipated that most reagents will be shipped to the plant in commercial concentrations by bulk transportation methods. The exceptions would be those reagents which are particularly hazardous or which could be easily generated onsite, e.g., hydrogen sulfide.

The large quantities of hydrocarbon fuels, reagents, and products will require access to an economical bulk transportation system. Trucks may be economical over short distances and railroads or barges over long distances.

Fresh water will be used for the generation of steam, cooling, process steps, and perhaps the slurrying of wastes. For steam generation and cooling, there are limits on water hardness and suspended solids in order to avoid process system fouling. This water would have to be fresh water, but would not need to meet drinking water standards. The quantities of water required range from 6 million to 24 million liters (1.6 million gal. to 6.3 million gal.), per day depending on three- or four-metal plant designs. Cooling water is expected to be recycled. Some process waters will be lost as waste.

Airborne emissions, such as combustion products from the burning of hydrocarbon fuel, are significant potential pollutants. These emissions should be limited by the Clean Air Act, which requires that the best available control technology will be used. Control technology should be sufficient to adequately limit dust from grinding and flume reagents.

Since copper, nickel, and cobalt are about 3% of the nodules by dry weight, solid waste in a three-metal plant will amount to approximately 97% of the nodules weight. For a four-metal plant, the recovered metals account for about 30% and solid waste 70% of the dry weight. Thus, whether three or four metals are recovered, a sizeable percentage of the nodules will be unused. This is comparable to or even less wasteful than, land-based mining; many domestic ores, such as copper, contain less than 1% of the primary metal.

Table 29

Composition of process materials and supplies (Dames & Moore and EIC Corp., 1977)

Gases:

Ammonia - Commercial Anhydrous
Hydrogen - Commercial 99% Minimum
Hydrogen Sulfide - (Liquid) Commercial 97.5%
Chlorine - (Liquid) Commercial 99.5%
Nitrogen - Commercial

Liquids:

Organic - Liquid ion exchange/chelating agent dissolved in dilutent at concentration appropriate to each process

Sulfuric Acid - Commercial 93%
Nitric Acid - Commercial 60%
Sodium Hydroxide - Commercial 50%
Fuel - Vehicular and combustion fuel as required
Oxygen - Commercial
Water - Salt & Fresh

Solids:

	Limestone	Lime
% Calcium	80 (Calcium Carbonate)	79 (Calcium Oxide)
% Magnesium	15 (Magnesium Carbonate)	12 (Magnesium Oxide)
% Inerts	5	9

Flocculants - Commercial Polyelectrolytes
Additives - Commercial Electrowinning Additives
Sodium Sulfate - Anhydrous, Photo Grade
Boric Acid - Commercial Granular, 99.9%
Carbon - Commercial Activated C
Borax - Technical, Anhydrous, 99%
Electrode Paste
Salt - Commercial Rock Salt

Energy needs:

Coal-generated electricity

3.3.4 Waste Disposal Facilities

3.3.4.1 Types and Quantities of Nodule Processing Waste

It has been pointed out that the amount of waste produced varies greatly from process to process, particularly between three- and four-metal processes. The chemical and physical properties of the wastes also vary, since their nature is determined by the sequence of treatment steps to which they have been subjected.

The design and operation of a nodules processing plant will be carried out in such a way to insure compliance with applicable regulations covering the discharge of solid, liquid, and gaseous effluents. In particular, this will require that the following design features or variations thereof be adopted:

1. All combustion gases will be scrubbed with limestone slurry for sulfur removal and the combustion processes will be controlled so as to permit compliance with nitrogen oxide and sulfur oxide emission regulations. Alternate scrubbing techniques are, of course, possible.

2. Process wastes which are combustible will be burned onsite.

3. Adequate measures will be taken for dust control at appropriate places within the process, with effluents discharged after further treatment, as required.

4. Gaseous emission control in high temperature operations will be achieved by the use of hooding and high volume ventilation, with the fugitive gases being scrubbed prior to release to the atmosphere, as required.

5. All vents on process tankage will be manifolded to scrubbers or protected with conservative units.

6. Process solid and liquid waste, including plant run-off, will be combined with leached tailings or granulated slags, neutralized if required, and disposed of in a suitable manner.

The majority of the solid wastes from the three-metal processes consists of finely divided "tailings," residues of the nodule which have been chemically and physically altered and from which the desired metals have been extracted. This material will exit the process plant in slurry form, being accompanied by an approximately equal amount of water which contains small amounts of dissolved materials including sea salts and trace elements. In addition, lesser but significant amounts of solid residues, in slurry form, may accompany the tailings.

The physical form of the tailings from all three-metal process plants would be similar and closely related to wastes currently produced in processing nickeliferous laterites at Nicaro and Moa Bay, Cuba. The bulk chemical composition would be different, however, consisting mainly of manganese oxides and carbonates. These materials are dense and will settle and may compact on long standing in waste containment areas to forms which can be stabilized to prevent dispersion. It is to be expected, however, that new or revised techniques will have to be developed to handle this material.

The bulk of the residues from a three- or four-metal smelting process will be quite different, however, consisting of granular slags. Similar materials are produced in large volume in the production of nickel and copper from terrestrial ores and are known to be inert and stable over long periods. This material is also essentially free draining, and need not be accompanied by equal amounts of liquid wastes if the latter can be disposed of by alternate techniques such as impounding and evaporation.

The wastes from the reduction/hydrochloric acid leach process are more difficult to characterize, since there is no directly analogous terrestrial process on which to base analogies. The wastes consist of roughly equal amounts of leached tailings accompanied by other process wastes and fused salts. The former would have properties which would be analogous to those from three-metal plants but the latter would consist of dry, bulk material. However, since it would be subject to dissolution on standing by contact with water, it will have to be contained to prevent its migration.

Nodules contain many components which appear on lists of hazardous or toxic substances in either their elemental form or in certain compounds. These total less than 0.5% of the nodules by dry weight. Table 30 identifies and groups the elements found in the nodules and shows the percentage by weight for each group. As the nodules occur in nature, these constituents are chemically bound in the complex matrix of the nodules and do not appear to be accessible to the environment from actions of natural systems. While harmless in their natural state, it is not currently known to what extent or in what manner these constituents might be transformed during processing operations. This large data gap is currently being addressed through several channels. In concert with NOAA, the Bureau of Mines (U.S. Department of the Interior) is characterizing process wastes. Industry tests may also contribute data on constituents. Perhaps most significantly, the five-year research plan generated in response to the Act also addresses processing wastes and their characterization. These efforts should provide data on the stability of waste components, possible toxicity, relative concentrations, and more.

As noted in the preceding section, both three- and four-metal processing plants will generate considerable solid waste. Depending on the processing techniques used, the rate of processing, and the form of waste disposal, waste from each nodule processing plant may accumulate at a rate of from 4 to 40 ha. (10 to 100 a.) per year at a depth of about 13 m (40 ft.).

Table 30

Major categories of elements in manganese nodules.
(Dames & Moore and EIC Corp. 1977)

Type	Element	Percentage by Dry Weight of Group in Nodules
Major and Value Metals	Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Molybdenum	29% total
Innocuous Non-Minor Elements	Sodium, Potassium, Magnesium, Calcium, Aluminum, Titanium, Silicon, Phosphorus, Sulfur, Chlorine	14% total
Known Toxic Elements, Chemically Bound	Barium, Lanthanum, Vanadium, Chromium, Silver, Cadmium, Thallium, Lead, Arsenic, Antimony	0.5% total
Innocuous Minor Elements	Boron, Carbon, Scandium, Strontium, Yttrium, Zirconium, Niobium, Gallium, Tin, Bismuth	0.3% total
		44% total
Oxygen as Oxides and Pore Water		56% total
		100% total

3.3.4.2 Usual Practice for Disposing of Mineral Processing Wastes

The most common method used by the mineral processing industry to dispose of tailings and other processed wastes is in a slurry form behind an earth embankment. The reservoir behind the embankment is lined or otherwise sealed to eliminate contamination of the environment and the slurry liquids are either allowed to evaporate or are decanted and recycled, or both. Alternative process waste disposal methods are dependent on the character of the wastes. Whereas a tailings slurry must be placed in a reservoir because of its fluid character, dry solid wastes may be disposed in a landfill (which may have to be lined if the wastes are not innocuous) or sold for recycling. For instance, granulated slag can make suitable fill or ballast, and gypsum and lime waste are sometimes used as soil additives. Dry solids with potential pollution problems would be disposed in a safe manner, if not recycled.

3.3.4.3 Nodules Processing Waste Disposal Methods

A variety of options are available for treating process wastes which range from relatively simple chemical steps such as treatment with lime to much more complex operations such as washing, drying, or chemical fixations. Treatment of wastes with lime serves to stabilize them by adjusting the pH and precipitating potentially toxic materials. The more complex alternatives are all much more costly, and are not practiced in the extractive metallurgy of terrestrial ores. The advantages of adopting such techniques would require a demonstration that they mitigate a problem encountered by the more conventional disposal techniques. Such a demonstration would require production of a significant amount of "real" nodules wastes so that their properties can be determined experimentally, rather than by analogy.

The deep seabed mining industry is expected initially to follow typical mining disposal practices. Thus, it is expected that the first generation processing wastes will be disposed on land by means of containment structures ("tailings ponds") or landfills. The legal feasibility of ocean dumping is uncertain at this time, because of possible limitations placed on sea disposal of wastes by the Ocean Dumping Act (Marine Protection, Research and Sanctuaries Act) and the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Materials (the London Convention), though it has obvious economic advantages to industry. The seriousness of its potential environmental consequences and lack of data on the nature of the wastes, necessitates consideration of ocean disposal in this PEIS.

3.3.4.3.1 Containment Structures (Tailings Ponds)

In this method, the mixed and neutralized slurry waste would be pumped through a pipeline from the plant to the disposal area. At the disposal area, the slurry would be directed into ponds which would depend largely on natural evaporation to dry and stabilize the wastes (Figure 28) Several ponds would be in use at the same time; one pond would be in active use while others would be in various stages of drying. To facilitate drying, clear or nearly clear surface water could be drawn off and either returned to the plant for reuse, placed in a broad shallow pond for more rapid evaporation, or, if clean enough to meet water quality standards, be discharged into a nearby waterway.

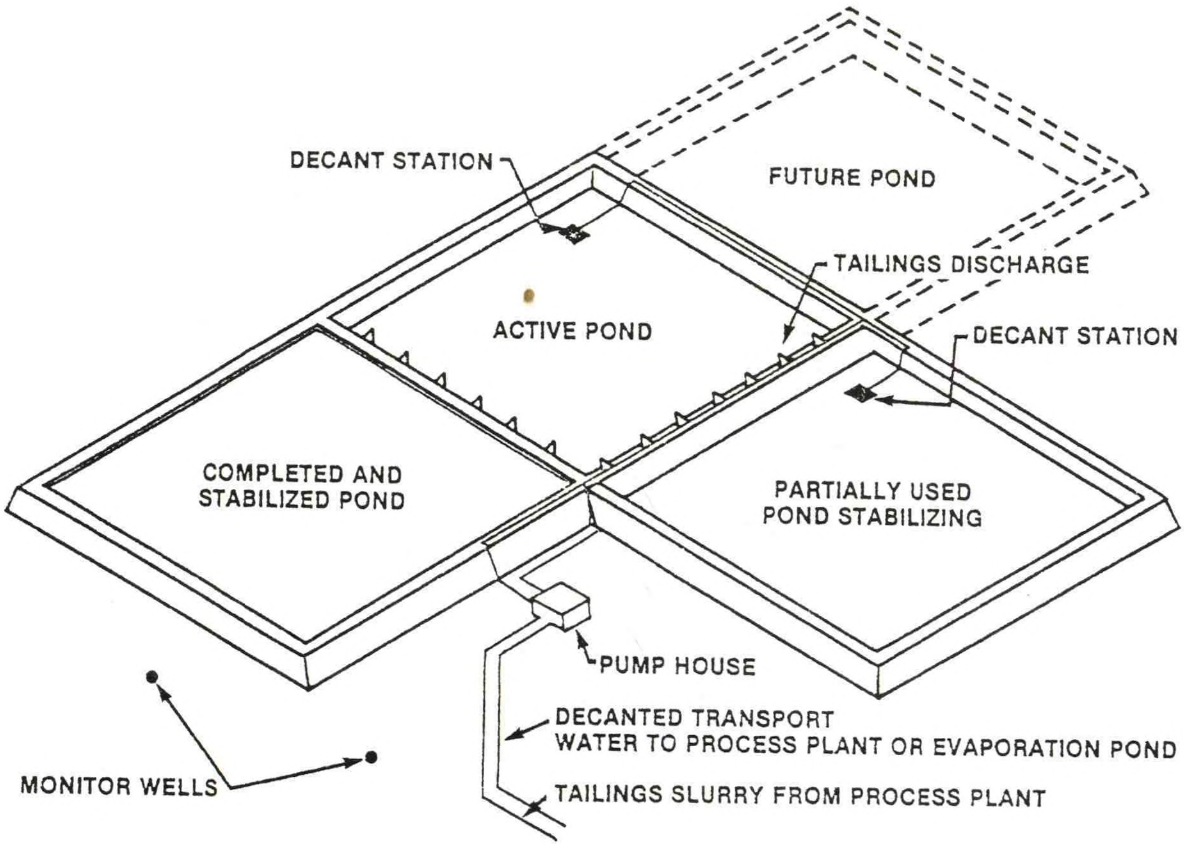


Figure 28.--Illustrative tailings ponds (Dames and Moore, et al. 1977).

A relatively large and flat land area will be required for the tailings ponds. A three-metal processing plant and a four-metal plant would require about 40 ha. (100 a.) per year and 8 ha. (20 a.) per year, respectively to a 13 m (40 ft.) depth for tailings disposal over the 20-year (or more) operating period of a processing plant. After a tailings pond area has been completely filled, it would be covered and revegetated. The physical and chemical characteristics of the material, coupled with the climatic conditions of the region, will determine the extent to which the tailings will stabilize, what vegetation will grow on the material, and therefore what uses may be made of the area after the disposal operations are completed. If the tailings never completely dry (a sediment condition referred to as a hydrous slime) or if covering fill chemistry is greatly changed, vegetation growth or use of the area could be restricted indefinitely. NOAA's five-year research plan on mining mandated by the Act will investigate this possibility.

3.3.4.3.2 Landfill

This disposal method consists of placing dry or nearly dry process wastes in a landfill with alternating layers of cover materials consisting of natural, on-site soils. The method is similar to the practice of land reclamation which is common in the strip mining industry. After construction of a given section of the landfill, the entire section will be covered with top-soil and revegetated. To protect the disposal area from flooding and to prevent surface runoff from escaping the disposal area, a containment and flood control dike would probably be constructed around the disposal facility. Conventional construction equipment consisting of scrapers, trucks, bulldozers, and graders would be utilized to smooth and distribute the waste dumped on the fill.

Assuming equal process volumes, the land requirements for this disposal method would be roughly half that required for the tailings pond method, i.e., approximately 20 ha. (50 a.) per year for the four-metal plant, both about 6 m (20 ft.) deep.

3.3.4.3.3 Ocean Dumping

This method would consist of transporting the nodule process wastes from the plant to a port facility and into the hold of dumping barges or outbound nodule transport vessels. It is assumed that the wastes are suitable for obtaining a dumping permit and have been suitably treated.

Conventional dumping barges are simply loaded through the weather deck hatches and dewatered to the sea by overflowing. At the disposal site, barges open a hatch in the bottom and the wastes slide out -- a simple and inexpensive procedure. Because of the large volumes to be handled, even under the smallest load, about two (6,000 to 8,000 MT or 6600 to 8800 tons) barge loads per week of solids would be dumped. This would be about a single 6000 DWT barge towed not far beyond the 370 km (200 nmi) limit, weather permitting. Alternatively, a pair of 8000 DWT barges and tugs could dump over 920 km (500 nmi) at sea, at a much higher cost. These barges and their tugboats are substantial vessels and investments, but they are proven and economical equipment.

The principal disadvantage of dump barges is that the surface disposal of the tailings may leave a near-surface plume of sediment, which would spread as it falls through the ocean to the bottom. Also with the barging system, little other use of the dump barges is possible and when the slurry is loaded into the dump barge, overflow of slurry liquids may occur.

Another feasible mode of waste tailings disposal would be to pump the slurry aboard ship, dewater, transport to the deep sea, and pump the slurry overboard using the shipboard equipment. This dumping method is more expensive than bottom dropping because of the pumping requirements. One advantage of the slurry ship is the possibility to dump the waste through a pipe suspended from the ship to a deeper water level well below the surface. This would place the plume below the surface water and sunlight penetration zone, at a depth at which some potential harmful effects may be mitigated. Since a separate fleet of dumping barges would not be required if the transport vessels were also used to dispose of the tailings, the transport vessels would most likely be used to dump the tailings at sea if ocean disposal were selected.

The ocean disposal of waste tailings would also require facilities at the marine loading terminal, new or larger ships or barges, and some small labor, fuel, and maintenance inputs. The marine terminal for the ship would have to be large enough to store at least one week's volume of waste, and would probably include transport water tanks, slurry ponds, pump station, pipeline access to and from the process plant, electrical power in moderate amounts, and road access. Installation of waste slurry ponds at the port terminal could require 4 to 6 ha. (10 to 15 a.) of adjacent land depending on processing volume and plant type.

3.3.4.3.4 Near Shore Ocean Disposal

The near shore disposal of process wastes would be through an ocean outfall pipe that extends from a shore facility to a certain depth of water offshore. The technology for outfalls is available and is presently being used for the ocean disposal of effluents from municipal sewage treatment facilities on all U.S. coasts and for sewage sludge disposal off southern California. An ocean outfall is also being used by the Utah International Island Copper Project on Vancouver Island, Canada for the underwater disposal of copper processing tailings into Rupert Inlet at a depth of 46 m (Western Miner, 1974).

An outfall should be located at the greatest practicable distance from shore and should be designed to provide the maximum dispersal of effluent. The location and physical configuration of the outfall should be determined by the depth, distance from shore, circulation and mixing characteristics of the particular ocean location, and factors influencing interactions of wastes with the environment. The advantage of this method of ocean disposal is lower costs entailed when compared to the continuous transportation of wastes to sea for dumping. A potential disadvantage is the present uncertainty over the exact chemical makeup of processing wastes and the possible harm to the environment if toxic metals are present in the effluent.

3.3.4.4 Waste Transportation

If all wastes are combined into a single slurried waste stream, the most likely means of waste transport would be by slurry pipeline. The physical characteristics of the pipeline would be very similar to the pipeline used to move slurried nodules from the port terminal to the processing plant (see Section 3.3.2.1 of this Appendix). Further, from a technical viewpoint, use of the pipeline would permit the waste disposal area to be located a considerable distance (100 km or 60 smi or more, for example) from the plant.

As noted previously, it is not necessary to combine all wastes into a slurry form for disposal. In two of the processing techniques, a large part of the rejects are expected to exit in a dry form (fused salt from the hydrochloric acid process and granulated slag from the smelting process). Based on site-specific factors such as land availability and net evaporation, part of the waste could be disposed of as a slurry and part as a dry material. The slurried portion would probably use a slurry pipeline while dry-bulk transportation methods such as conveyors, rail cars, or trucks would be used for the dry material. Conveyors or trucks are probably the most likely means by which solid waste would be transported to a near-plant site. Distant dry-bulk disposal areas, including at-sea, could utilize other methods.

3.4 Development of Technology During Licensing

3.4.1 Exploration and Testing

The multidisciplinary nature of deep seabed mining activities has resulted in some confusion with regard to terminology and it would be useful here to clarify the meanings of various significant terms as they have been traditionally used in the minerals industry.

The sequence of activities* in bringing a mine to production is:

1. Prospecting (searching, locating, surveying, random sampling, reconnaissance, exploring.)

2. Exploration (sampling, location, delineation, characterization, evaluation.)
3. Development (evaluation, blocking out, mining, and processing systems testing, pilot testing.)

Under the law prospecting is excluded from regulation (section 101(a)(2)) but exploration, which by definition includes development (section 4(5)), is prohibited except under license (section 101(a)). The Act defines exploration to mean:

*The terms in parentheses are sometimes used to describe these activities though they may not always be synonymous.

"(A) any at-sea observation and evaluation activity which has, as its objective, the establishment and documentation of

(i) the nature, shape, concentration, location, and tenor of a hard mineral resource; and

(ii) the environmental, technical, and other appropriate factors which must be taken into account to achieve commercial recovery; and

(B) the taking from the deep seabed of such quantities of any hard mineral resources as are necessary for the design, fabrication, and testing of equipment which is intended to be used in the commercial recovery and processing of such resource;"

In carrying out these activities, four major types of operations are of concern: namely, navigation and positioning of the surface vessel (or platform); measurement in place of the environment, including the deposit, by remote sensing; physical sampling of natural materials for measurement and testing; and, testing of equipment for mining and processing. These activities may be further elaborated:

Surface Vessel Navigation and Positioning.

Navigation and positioning of the surface vessel does not normally require contact with the seabed. Where high accuracy of positioning is required for detailed survey work or for equipment test and evaluation, electronic transducers may be placed on the bottom as reference points (Figure 29). These instruments are about the size of a 5-gallon drum and are buoyed above the seabed attached to a block anchor of concrete or other inert substance which may weigh about a hundred pounds. The transponders are recoverable but the anchors are not. They may require to be placed about 10 km apart, a density of approximately 1,000 per exploration site of 100,000 km^2.

Remote Sensing Tools and Techniques.

Remote sensing of the deep seabed and its environs includes measurement techniques utilizing reflected sound pulses, visual observations, and induced radiation. In most cases the measuring instruments are towed quite close to the bottom and the imagery transferred by cable to the surface, or stored on tape or film in the towed vehicle for recovery later.

Sound pulses for acoustic imagery, which is somewhat like radar imagery, are generally of low energy and generated by electro-mechanical means at the surface ship or on the towed vehicle. Explosives are not used in this type of work as deep penetration of the bottom is not required. Total darkness prevails at ocean depths below a few hundred feet and all visual observation whether by television camera, photographic camera, or manned deep submersibles

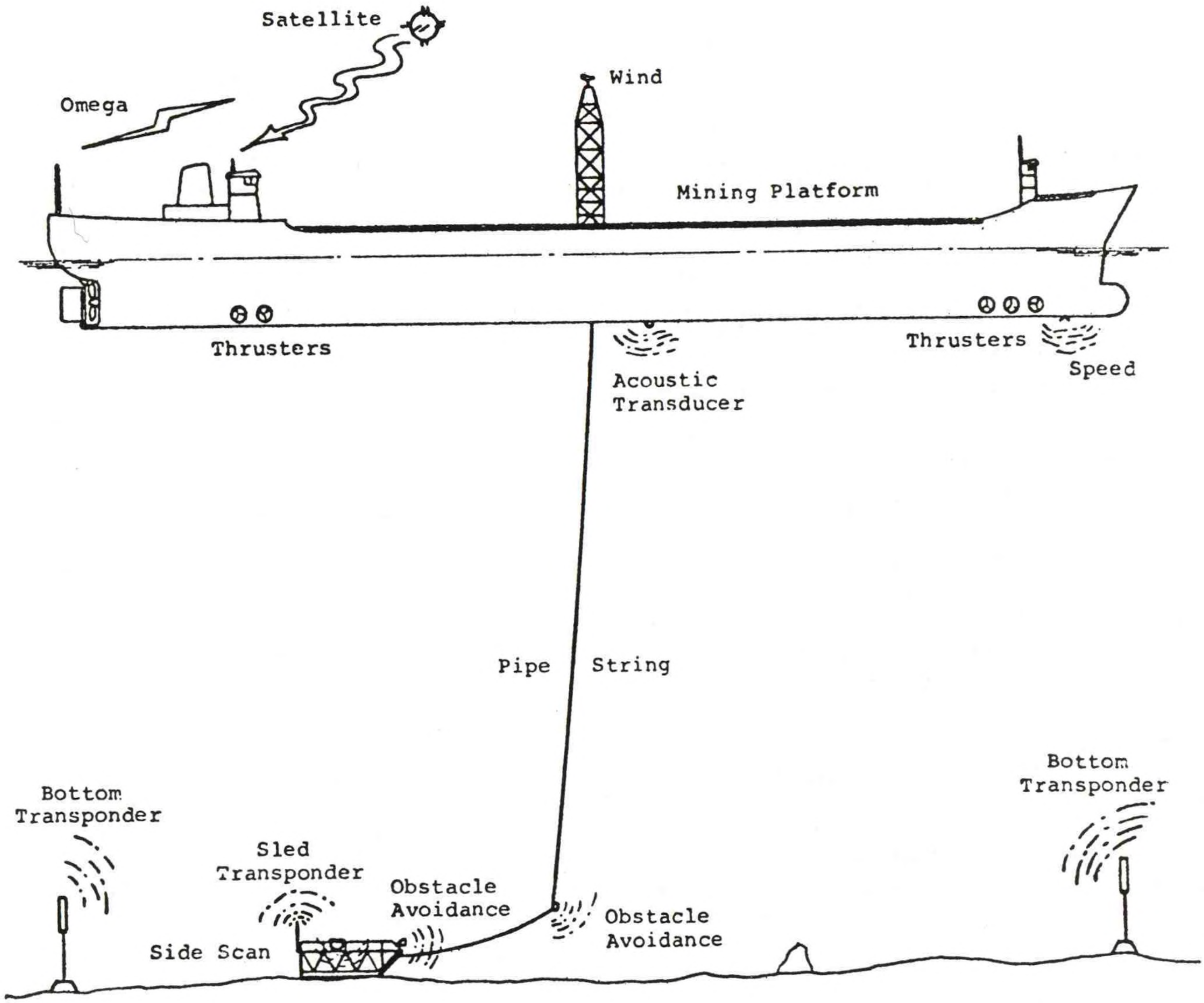


Figure 29.--Some aids for navigation and positioning used in deep seabed exploration and systems development (Detweiler and Zahn, 1980).

must be carried out by artificial light. This generally requires several kilowatts of electrical illumination which must be maintained during the periods of observation. Measurements taken by induced radiation are not common mainly because the technology has not been perfected for sustained use and the equipment must remain stationary during the measurement, which may take from several minutes to several hours. The general principle is that a natural material, if subjected to natural or artificial radiation under controlled conditions, will respond by emitting a characteristic radiation of its own by which it can be identified. On removal of the instrument the induced radiation is extinguished and the material reverts to its original state. By this means deep seabed materials such as nodules can be chemically analyzed in place.

Techniques used in the measurement of the physical properties of seabed soils involve placing instrumented packages or towing instrumented vehicles or sleds on the bottom. The measured data are generally stored on tape and recovered with the package, but continuous measurements may be sent to the surface ship for the preparation of maps as the survey continues.

Sampling Tools and Techniques.

Sampling of the deep seabed may take place while the ship is stationary or under way. Sampling on station is the traditional method where hydrographic casts or bottom corers are winched over the side and retrieved on completion of the task. A round trip may take 3 to 4 hours. Dredge samples are taken with the ship moving slowly with the sample bucket on the bottom over a distance of a kilometer or so. In nodules sampling, however, the trend is toward the use of unattached boomerang samplers which may be dropped in clusters of 5 or 10 and which automatically return to surface after contact with the bottom. The exploration vessel may utilize the 3 to 4 hours between dropping and retrieval, in placing further clusters at designated spots within steaming range. In this way idle ship time is reduced. The samplers may be equipped with core barrels, grabs, box corers, cameras, or any other instruments required. An expendable weight, generally concrete, is released on the bottom, to make the sampler positively buoyant for the trip to surface. Initially, samples may be placed tens or even hundreds of kilometers apart, but for evaluation of deposits the spacing will eventually be reduced to one kilometer or less.

Testing of Equipment for Mining and Processing.

The testing of systems for commercial recovery which may take place under the terms of a license may involve any activity up to and including full scale testing of prototype commercial operations. The difference between the activities under the license and under the permit is that in the development and testing phase operations would not be sustained for long periods. They would probably be more varied in that several systems might be developed and evaluated at the same time or sequentially, and they would generally involve more intensive scrutiny and instrumentation.

3.4.2 Processing

In order to characterize the resource requirements and operating considerations which will arise during the course of industry development before January 1, 1988, i.e., operations with a license prior to commercial recovery with a permit, it will be necessary to assume a scenario for these activities. While many sequences of development are possible, depending upon management risk-taking attitudes, time and funding constraints, etc., a reasonable assumption is that the development effort would be divided into three major phases:

- o Bench scale research and development (R&D)
- o Pilot plant testing
- o Demonstration plant testing.

It is likely that bench scale R&D will proceed through several phases from purely exploratory work to a point at which the objective of the work would be to provide design data for a pilot plant. The people involved in the research effort would support the operation of the pilot plant. An independent process evaluation would be carried out and presented to management in order to obtain approval to construct the pilot plant, since to this point no new facilities would have been required and all process and business options would have been open.

Some of this may well have been carried out before the licensing process is initiated. This work should require less than 1 MT (1.1 tons) of nodules and could be carried out in a relatively small, conventional laboratory. Since an inconsequential amount of wastes would be generated, treatment and disposal should be typical of land mining operations.

The construction and operation of a pilot plant would probably require significant additions of facilities and personnel. Key operational objectives of the pilot plant would include: a demonstration of the process concept in an integrated plant, i.e., with recycle, until steady state is achieved -- normally at least two months of operation would be required; acquisition of preliminary design data for key operations in the process; confirmation of projected materials consumption, product yields, and product purities; and process revisions and optimization studies as required.

The pilot plant would be designed to validate all key steps by testing the smallest size equipment from which valid scale-up data could be obtained. This would require a plant with a processing capacity of the order of 1 MT (1.1 tons) per day and an inventory of as much as 100 MT (110 tons) of nodules. Not all processing steps would be carried out continuously nor would all commercial operating procedures be verified. For example, reduction gases (if required) would be obtained in purified form from commercial sources and not generated onsite. The operation of the electrowinning facilities would not require that all the systems work needed in a commercial tank house, but would be more carefully set up. An entire run's worth of nodules might be ground and dried (if required) prior to initiating operations rather than continuously throughout the test. This equipment and associated test facilities could probably be located in a 3,670 m^3 (4,400 yd^3) multi-stage, heavy duty building.

Any gaseous emissions from a pilot plant of this scale could be coped with in small, conventional equipment, and liquid wastes could probably be discharged to local systems after conventional treatment at the pilot plant. However, up to 100 MT (110 tons) of solid wastes could be generated, and its treatment and disposal could require careful attention. This quantity might be processed during one year of test work. The required inventory of materials, supplies, and nodules would be significant. All environmental control measures deemed necessary in a commercial plant would be incorporated in the design of the demonstration plant. If possible, the demonstration plant would be located adjacent or close to the site selected for the commercial plant so that common services could be shared at a later date.

Operation of the plant would require support from the community; in addition to power from local grids, water from local sources, roads and perhaps rail for transportation of materials and supplies, an operating staff of at least 100 persons would be needed. In the course of one year test operations, the plant could generate as much as 100,000 MT (110,000 tons) of waste which would be representative of those expected from commercial operations. This quantity would be available up to five years prior to those from a commercial plant and should be ample to permit representative testing of the anticipated disposal method. Plant operations will be monitored to insure compliance with air and water quality standards routinely throughout the course of testing.

The demonstration plant would probably have a prolonged start-up schedule, and might never meet target production rates. A favorable commercialization decision could still be made if design data showed that design or technology flaws could be eliminated at a reasonable cost, but a decision to proceed with detailed engineering on a commercial plant would probably not be made until the demonstration plant had been in operation for six months to a year. After that, the demonstration plant would be run to obtain data for process improvement and optimization.

Appendix 4.

Public Involvement 1975 to Present

1. DOMES Technical Workshop
   Washington, D.C.
   April 29-30, 1975

   Purpose: Technical review of DOMES I Work Plans.

   Comments: Attended by Federal Government, industry, academia, environmental groups

2. DOMES Advisory Panel Meeting
   Seattle, Washington
   December 16, 1975

   Purpose: To review DOMES activities and to provide advice to DOC in order to assure the relevancy of DOMES activities. Included presentations by principal investigators and discussions on how the research parts would ultimately fit together. Recommended funding for DOMES II.

   Comments: Announced in Federal Register and was open to public. Attended by Federal Government, industry, academia, environmental groups

3. DOMES Advisory Panel Meeting
   Washington, D.C.
   February 12-13, 1976

   Purpose: Presentations and panel discussions were directed to the DOMES I research projects and the proposed DOMES II Technical Development Plan. Additional research tasks to be accomplished by DOMES II were identified.

   Comments: Announced in Federal Register and open to public. Attended by Federal Government, industry, academia, environmental groups

4. DOMES Advisory Subpanel Meeting
   Seattle, Washington
   February 24, 1976

   Purpose: Industry representatives presented a definition of the mining system parameters of importance to an environmental monitoring study of deep sea mining. Subpanel discussed DOMES II Technical Development Plan and made revisions to DOMES I TDP.

   Comments: Attended by Federal Government, industry and public.

5. Marine Minerals Workshop
Silver Spring, MD
March 23-25, 1976

Purpose: To provide an information base of past and present marine mineral-related activities sponsored by NOAA; encourage better communications amongst investigators; develop information to further develop marine mineral resources in an environmentally safe manner.

Comments: Attended by Federal Government, industry, academia, environmental groups

6. DOMES Advisory Panel Meeting
Seattle, Washington
June 2-3, 1976

Purpose: To identify the present status of DOMES I project and schedule for publishing DOMES Preliminary Report. Members agreed to expand studies on distribution, abundance and heavy metal content of pelagic fish in DOMES area. Panel discussions dealt with mining system parameters, budget, and DOMES program plan options, such as using satellite imagery to analyze plume trajectories.

Comments: Attended by Federal Government, industry, academia, environmental groups and the public

7. Briefings on Manganese Nodule
Processing Study
Washington, D.C.
September 15-16, 1976

Purpose: Contractor briefing on nodule processing techniques that will be used for subsequent environmental and socio-economic impact studies using representative processing plant sites.

Comments: Attended by Government, industry and public

8. DOMES II Workshop
Washington, D.C.
November 17-18, 1976

Purpose: To review the DOMES I Progress Report. Presentations were made on the executive summary of DOMES Progress Report and critiques received on the report. Workshop sessions recommended follow-on research for DOMES II.

Comments: Attended by Federal Government, industry, academia, environmental groups

9. Briefing and Progress Report on Nodule Processing Study
Washington, D.C.
February 1, 1977

Purpose: To present contractor's preliminary findings on manganese nodule processing plant parameters of importance for subsequent environmental and socio-economic impact studies.

Comments: Attended by Federal Government, industry, environmental groups

10. Final Briefing on Manganese Nodule Processing Impact Study
Washington, D.C.
April 5, 1977

Purpose: To present contractors' briefing on second phase of contract dealing with at-sea processing, transportation, and waste disposal.

Comments: Attended by State and Federal Government, Industry, academia, environmental and public groups

11. DOMES II Scientific Workshop
Seattle, Washington
April 25-27, 1977

Purpose: To discuss, criticize and evaluate draft of DOMES II Project Development Plan.

Comments: Attended by scientists from NOAA, industry and universities

12. West Coast Manganese Nodule Processing Workshop
Corvallis, Oregon
June 15-16, 1977

Purpose: Oregon State University presentation on final draft of its report on identifying representative West Coast areas for nodule processing.

Comments: Attended by Federal and State Government and industry

13. DOMES II Workshop
Washington, D.C.
January 10-11, 1978

Purpose: To discuss the DOMES II Technical Development Plan that deals with the environmental monitoring of prototype or pilot-scale mining systems tests, and discuss the proposed Preliminary Environmental Guidelines.

Comments: Attended by Federal Government, industry, academia, environmental groups

14. Manganese Nodule Processing Plant Location Criteria (Gulf Coast)
Houston, TX
January 25-26, 1978

Purpose: To validate physical and regulatory criteria for locating manganese nodule processing plant on Gulf Coast; develop a list of geographical areas for further evaluation, apprise state and environmental interests of key requirements of a processing plant.

Comments: Attended by Federal and State Government, industry, academia, environmental groups

15. Technical Review Meeting on Transportation & Manganese Nodule Processing Alternatives in Hawaii
Honolulu, Hawaii
April 6-7, 1976

Purpose: To discuss the potential environmental, social and economic effects of processing in Hawaii.

Comments: Attended by NOAA, Hawaii State Government, industry and environmental groups

16. DOMES WORKSHOP
Silver Spring, MD
April 25-26, 1979

Purpose: To identify the concerns about deep seabed mining which can be laid to rest based on DOMES research; identify the remaining environmental concerns resulting from DOMES project that will require subsequent research to resolve; broadly describe the required subsequent research and its importance.

Comments: Attended by Federal Government, academia, environmental groups, industry

17. Manganese Nodule Processing Workshop
Hilo, Hawaii
August 1-2, 1979

Purpose: To discuss the results of preliminary assessment of environmental and socio-economic effects of locating processing plant in Puna or Kohala Districts of Hawaii island.

Comments: Attended by Federal and State Government, academia, environmental and public groups, industry

18. Planning Conference for Research on Manganese Nodule Processing Waste Management
Bethesda, MD
September 11-12, 1979

Purpose: To identify major environmental concerns associated with the disposal of processing wastes from future deep-sea mining operations; assess the need for a Federal research program to address these concerns; and critique a draft preliminary research program plan developed for the conference.

Comments: Attended by Federal and State Government, academia, environmental and public interest groups, industry

19. Briefing on Land Mining Aspect of NOAA's Environmental Assessment of Deep Seabed Mining
Washington, D.C.
February 8, 1980

Purpose: Contractor's presentation and discussion on the environmental and socio-economic implications of a long delay in initiation of deep seabed mining.

Comments: Attended by Federal Government, industry, academia, environmental groups

20. Briefing on the energy implications of deep seabed mining
Washington, D.C.
February 12, 1980

Purpose: Contractor's presentation on a comparison of the energy requirements and costs needed to produce equivalent amounts of metals from land vs deep seabed manganese nodules.

Comments: Attended by Federal Government, industry, academia, environmental groups

21. Briefing on applicable law concerning seabed mineral processing in California, Washington, Oregon, and Alaska
Silver Spring, MD.
March 6, 1980

Purpose: To present contractor's findings and to solicit comments to be used in the preparation of the final report.

Comments: Attended by Federal and State Government, industry, academia, environmental groups and public

22. Final briefing on land mining aspect of NOAA's environmental assessment of deep seabed mining
Washington, D.C.
July 30, 1980

Purpose: Contractor's final briefing on the environmental, social, and economic implications of a long delay in initiation of deep seabed mining.

Comments: Attended by Federal Government, industry, academia, environmental groups, and public

23. Final briefing on the energy implications of deep seabed mining
Washington, D.C.
August 27, 1980

Purpose: Contractor's final briefing on a comparison of the energy requirements and costs needed to produce equivalent amounts of metals from land vs deep seabed manganese nodules.

Comments: Attended by Federal Government, industry, academia, environmental and public groups.

24. Public Scoping Meeting
Washington, D.C.
September 4, 1980

Purpose: To determine the scope of the environmental and regulatory issues to be addressed and to identify the significant issues related to deep seabed mining.

Comments: Attended by Federal Government, industry, academia, environmental and public groups.

25. Marine Minerals Workshop on Five-Year Research Plan
Bethesda, Md.
September 16-17, 1980

Purpose: To identify research needed to be conducted in the next five years to be able to assess and predict the environmental effects from deep seabed mining and at-sea disposal of processing wastes.

Comments: Attended by Federal and State Government, industry, academia, and environmental and public interest groups.

26. Public Hearing on Interim Regulations for Pre-Enactment Explorers
Washington, D.C.
December 17, 1980

Purpose: To solicit public comments on the interim regulations dealing with the registration of pre-enactment explorers and with the issuance by NOAA of emergency orders needed to prevent a significant adverse effect on the environment.

Comments: Attended by Federal Government, industry, environmental groups.

27. Public Meeting on Regulations Discussion Paper
Washington, D.C.
December 17, 1980

Purpose: To solicit public comments on major deep seabed regulatory issues in order to be able to develop better proposed rules for promulgation in March 1981.

Comments: Attended by Federal Government, industry, and environmental groups.

28. Briefing for Environmental and Oceanic Organizations
Washington, D.C.
February 17, 1981

Purpose: To brief environmental and oceanic organizations on NOAA's Office of Ocean Minerals and Energy and its role in administering the Deep Seabed Hard Mineral Resources Act and the Ocean Thermal Energy Act. To invite these organizations to be active participants in NOAA's program.

Comments: Attended by Federal Government, environmental, and oceanic representatives.

29. Public Hearing on Draft PEIS and Proposed Regulations
Honolulu, Hawaii
April 24, 1981

Purpose: To solicit comments on draft PEIS and Proposed Regulations.

Comments: Attended by Federal and State Government, industry, academia, and environmental groups.

30. Public Hearing on Draft PEIS and Proposed Regulations
San Francisco, California
April 28, 1981

Purpose: To solicit comments on draft PEIS and Proposed Regulations.

Comments: Attended by Federal and State Government, industry, environmental groups, and private individuals.

31. Public Hearing on Draft PEIS and Proposed Regulations
Washington, D.C.
May 8, 1981

Purpose: To solicit comments on draft PEIS and Proposed Regulations.

Comments: Attended by Federal Government, industry, and environmental groups.

32. Workshop on Draft Technical Guidance Document
Washington, D.C.
June 17, 1981

Purpose: To solicit comments on the draft Technical Guidance Document and on the information to be submitted by industry with applications for an exploration license.

Comments: Attended by Federal Government, industry, and environmental groups.

Appendix 5.

Effects of Prohibition or Long Delay in Initiation of Deep Seabed Mining

A NOAA-sponsored study by Dames and Moore (1980) has assessed the potential environmental and socio-economic effects of continued reliance on land mining to produce metals available from manganese nodules if seabed mining does not commence until the year 2010. The main reason for the study was to provide data on the environmental effects of land mining with which the effects of deep seabed mining can be compared. A secondary reason was to help elucidate a possible justification for deep seabed mining beyond its strictly economic advantages.

Demand for the four major nodule metals was forecast based on recycling and substitution trends. Dames and Moore then assessed onshore sources, recognizing the variety of factors that result in long lead times involved in mine development. The types of ore bodies to be mined were then categorized and likely methods of mining predicted. Mining forecasts were projected (Tables 31-34 and Figures 30-33). Finally, the probable environmental and socio-economic effects of mining through the year 2010 were quantified (Tables 35 and 36; Figure 34).

In this time frame, manganese availability could become a problem, particularly for the U.S. There are relatively few producers in the world and there have been no major discoveries in the past 20 years. The U.S. has no known deposits that can be mined, even at substantially higher prices. World demand is forecast to increase at an annual rate of 2.93 per cent. In order to meet this demand and avoid shortages in the late 1980's and beyond, South Africa and other producers must keep expanding their mines or new sources like the seabed must be developed.

There is no shortage of nickel in the world; worldwide reserves should be adequate to meet a forecast annual increase in demand of 2.78 percent.

There is no shortage in sight for copper either; world reserves can easily meet the forecast increase in annual demand of 3.76 percent.

Most cobalt production is related to nickel and copper since the minerals frequently occur together. Nevertheless, in order to meet the 3.38 percent increase in annual world cobalt demand that is forecast, substantial planning and capital investment are required to avoid problems. It is a distinct possibility that cobalt could be in short supply due to capacity limitations by the year 2010. The U.S. may be able to develop some domestic production, but will continue to rely on foreign mines through at least 2010. As with manganese, the continued flow of imports will depend on the maintenance of a reliable supply from South Africa.

A portion of the aggregated impacts would occur if deep seabed mining did not take place prior to 2010. Several assumptions must be made, some of which are discussed in Section I.C:

(1) the supply of metals produced from manganese nodules would reduce the production of these metals from land mining operations by the same tonnage;

TABLE 31

SUMMARY OF PROJECTED WORLDWIDE SUPPLY OF NICKEL BY
BY MAJOR DEPOSIT TYPE, 1980-2010
(1000 Short Tons)

Year	Copper-Nickel Sulfide UDG	Nickel-Cobalt Laterite S
1980	268	402
1985	269	499
1990	264	616
1995	293	717
2000	324	834
2005	365	963
2010	412	1113
Cumulative	9281	22,075
Percent of Total Demand	30	70

S = surface mine. UDG = underground mine.

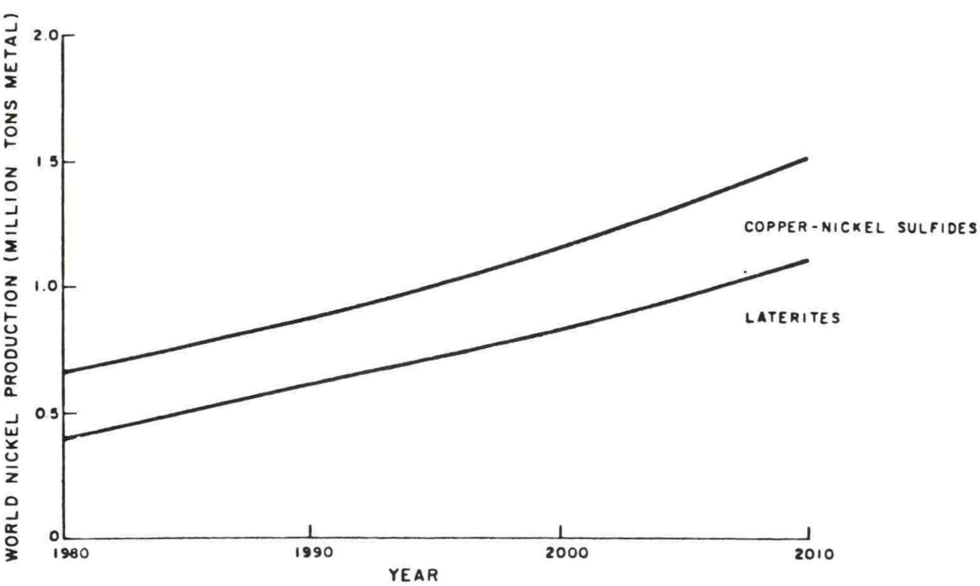


Figure 30.--Projected annual nickel production from land resources, 1980 - 2010.

TABLE 32

SUMMARY OF PROJECTED WORLDWIDE SUPPLY OF MANGANESE, 1980-2010
(1000 Short Tons)

	Manganese	
Year	S	UDG
1980	4805	7207
1985	5551	8327
1990	6414	9620
1995	7410	11,114
2000	8560	12,840
2005	9890	14,836
2010	11,427	17,140
Cumulative	237,819	356,728
Percent of Total Demand	40	60

S = surface mining. UDG = underground mining.

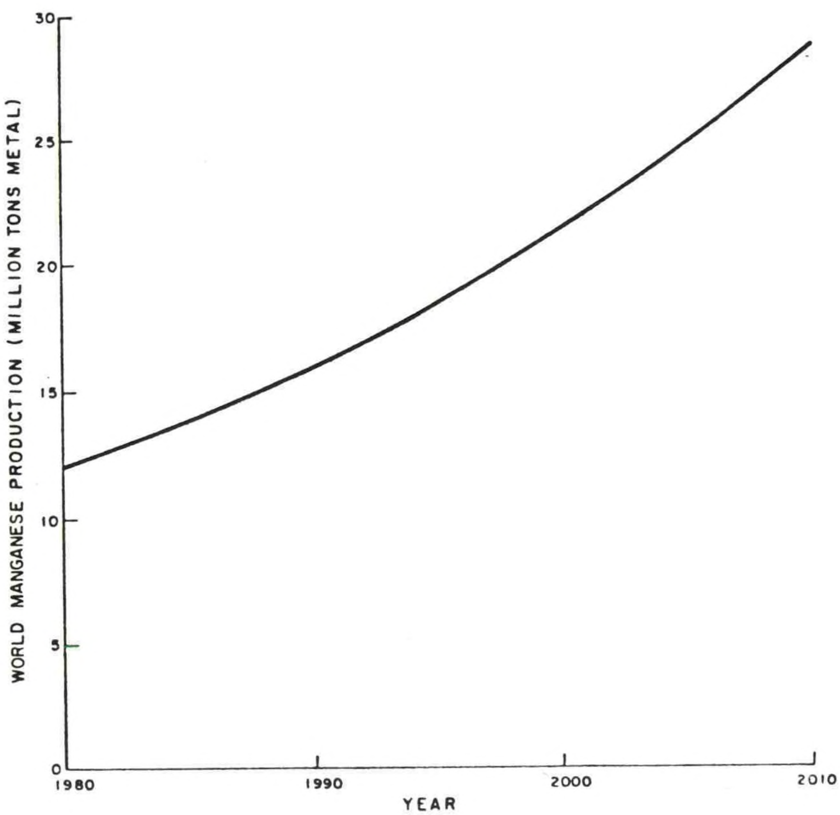


Figure 31.--Projected annual manganese production from land sources, 1980 - 2010.

TABLE 33

SUMMARY OF PROJECTED WORLDWIDE SUPPLY OF COPPER
BY MAJOR DEPOSIT TYPE, 1980-2010
(1000 Short Tons)

Year	Porphyry		Copper-Cobalt Stratabound		Copper-Nickel Sulfide	Massive Sulfide
	S	UDG	S	UDG	UDG	UDG
1980	3653	913	1623	800	932	1398
1985	4330	1443	1857	915	1043	1619
1990	5420	1806	2139	1054	1178	1885
1995	5832	3140	2478	1221	1339	2205
2000	7197	3875	2886	1421	1533	2589
2005	7479	6120	3375	1663	1766	3052
2010	9150	7487	3965	1953	2047	3608
Cumulative	185,017	110,902	80,269	39,536	43,115	71,603
By Deposit Type	295,919		119,805		43,115	71,603
Percent of Total Demand	55.8		22.6		8.1	13.5

S = surface mine. UDG = underground mine.

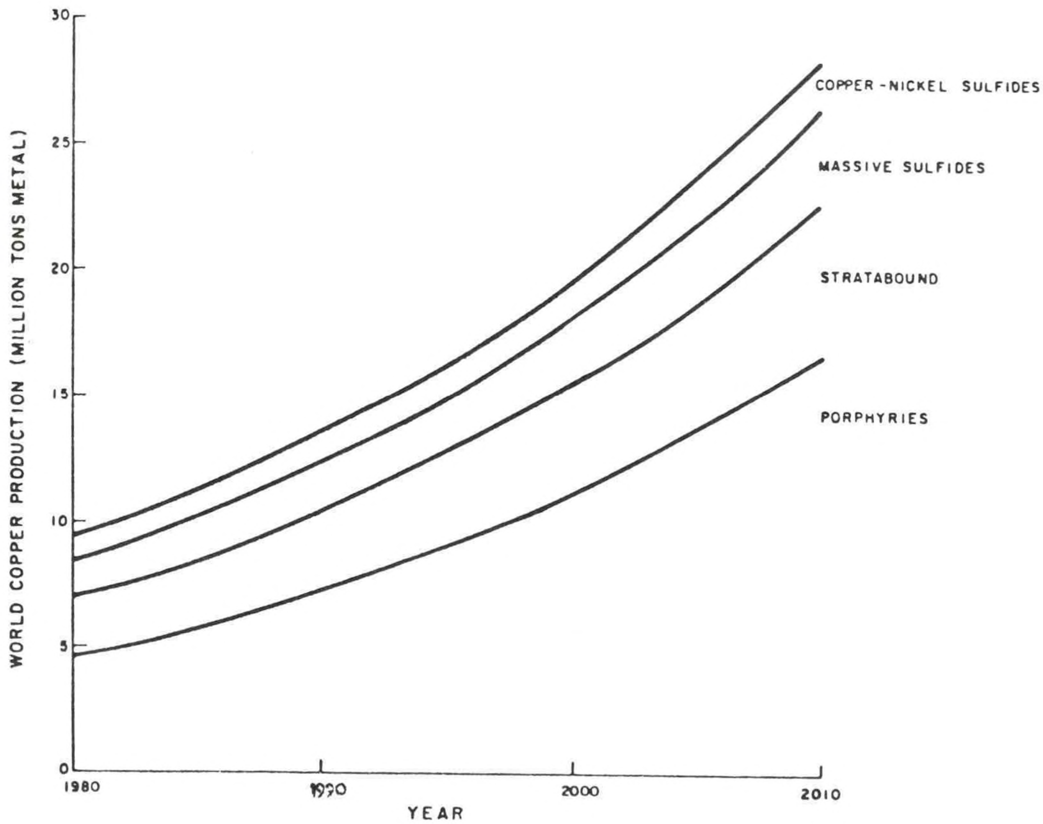


Figure 32.--Projected annual copper production from land resources, 1980 - 2010.

TABLE 34

SUMMARY OF PROJECTED WORLDWIDE SUPPLY OF COBALT
BY MAJOR DEPOSIT TYPE, 1980-2010
(1000 Short Tons)

	Copper-Cobalt Stratabound		Copper-Nickel Sulfide	Nickel-Cobalt Laterite
Year	S	UDG	UDG	S
1980	10.2	5.0	6.9	5.5
1985	12.0	6.0	8.2	6.5
1990	14.2	7.1	9.6	7.7
1995	16.8	8.4	11.4	9.1
2000	19.8	9.8	13.5	10.8
2005	23.4	11.5	15.9	12.7
2010	27.7	13.6	18.8	15.0
Cumulative	533.6	262.8	362	289.6
By Deposit Type	796.4		362	289.6
Percent of Total Demand	55		25	20

S = surface mine. UDG = underground mine.

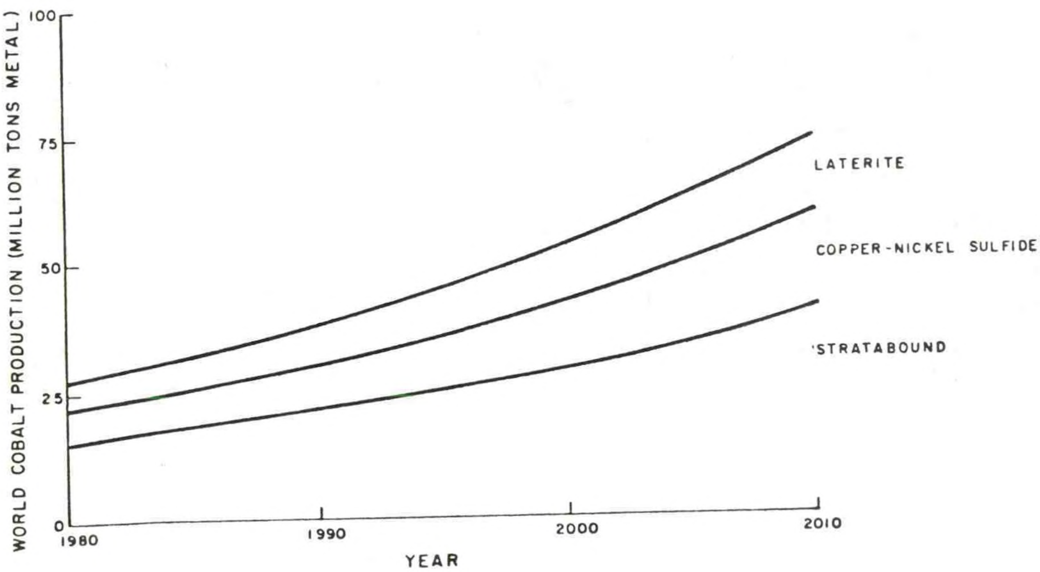


Figure 33.--Projected annual cobalt production from land resources, 1980 - 2010.

TABLE 35

SUMMARY OF UNIT IMPACT PARAMETERS USED IN AGGREGATE ANALYSIS OF WORLDWIDE MINING AND PROCESSING

	Resource Use Per 1000 Short Tons Metal									
	Mining Activities			Processing Activities						
	Land for Mine Site (Acres)	Land for Waste Dumps (Acres)	Energy (10^{10} BTU)	Land for Process Plants (Acres)	Land for Tailings Ponds (Acres)	Energy (10^{10} BTU)	Water Use (10^7 Gal)	Potential SO_2 Emissions (Tons)	Total Employment (Man years)	Typical Mine Size (Short Tons Metal Per Year)
Copper										
Porphyries - S	0.27	1.0	1.45	0.23	1.0	8.37	5.0	2000	20	125,000
- UDG	0.23	0.26	1.82	0.23	1.0	8.37	5.0	2000	35	125,000
Stratabound - S	0.75	0.95	0.42	0.59	0.15	1.70	0.78	1000	8	40,000
- UDG	0.40	0.40	0.40	0.59	0.15	1.70	0.78	1000	12	40,000
Cu-Ni Sulfides - UDG	a	a	a	0.08	a	4.80	a	2000	83	13,500
Massive Sulfides - UDG	0.4		1.4	0.50	0.27	5.70	1.3	2000	44	8,400
Nickel										
Cu-Ni Sulfides - UDG	0.34		4.12	0.26	0.51	12.3	2.36	3200	83	15,600
Ni-Co Laterites - S	1.62	0	2.05	0.75	0	61.7	1.69	0	67	30,000
Cobalt										
Cu-Ni Sulfides - UDG	a	a	a	0.03	a	10.6	a	1000	83	90
Stratabound - S	b	b	b	2.5	b	1.9	b	2000	8	500
- UDG	b	b	b	2.5	b	1.9	b	2000	12	500
Ni-Co Laterites - S	a	a	a	0.01	a	18.0	a	0	67	600
Manganese[c]										
- S	0.039	0	0.019	0.007		0.007	0.058	0	1.7	400,000
- UDG	0	0	0.034	0.007		0.007	0.058	0	1.7	400,000

[a]Included with impact parameter for nickel.
[b]Included with impact parameter for copper.
[c]The analysis includes only physical processing of manganese ores; specifically, smelting to high-carbon ferromanganese is excluded.
S = surface mines; UDG = underground mines

TABLE 36

SUMMARY OF IMPACTS ASSOCIATED WITH CONTINUED RELIANCE ON LAND MINING DURING THE PERIOD 1980-2010

	Land (Acres)	Energy (10^{15} Btu)	Water (10^{12} Gals.)	Potential SO_2 Emissions (1000 tons)	Employment (10^6 Man years)	Disabling Injuries (10^3)
World Demand						
Copper Supply	995,988	39.2	16.6	941,079	15.4	1,178
Nickel Supply	62,619	15.6	1.7	29,699	2.3	111
Cobalt Supply	2,005	0.11	0	1,955	0.06	3.8
Manganese Supply	13,435	0.21	0.4	0	1.01	68.6
Total World	1.074,047	55.1	18.7	972,733	18.8	1,361
U.S. Demand						
Copper	178,855	7.0	3.0	168,995	2.8	212
Nickel Supply	21,721	5.4	0.58	10,253	0.78	39
Cobalt Supply	794	0.04	0	774	0.02	1.5
Manganese Supply	1,356	0.02	0.04	0	0.10	6.9
Total U.S.	202,726	12.5	3.6	180,022	3.7	259

Figure 34a.--Open pit mine (courtesy U.S. Bureau of Mines).

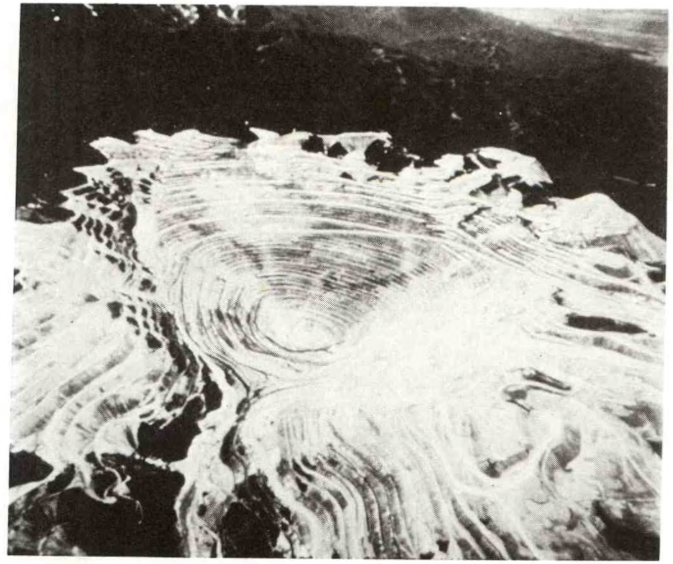


Figure 34b.--Open pit mine showing waste dumps (courtesy John Padan).

Figure 34c.--Land mining processing plant (courtesy Dames and Moore).

Figure 34d.--Land mining waste disposal tailings pond (courtesy U.S. Bureau of Mines).

(2) five operations will come on-stream during the period 1988-1995, three of which will be "three-metal" 3 million MT (3.3 million tons) per year mines and two of which will be "four-metal" 1 million MT (1.1 million tons) per year mines (Table 37)

(3) between 1995 and 2010 the growth rate of "second generation" seabed mining will be a fairly unrestrained 15 percent annually, as mining in the DOMES area approaches maturity (Table 37); and,

(4) the second generation operations will be four-metal (Table 37).

The resultant production of nodules and metals (Table 38) can now be compared to total world demand for the four metals (Tables 31-34). If first generation technology is profitable enough to result in the 15 percent second generation growth rate assumed in this discussion, then deep seabed mining could supply a substantial portion of world needs by 2010 (Table 38).

On this basis, impacts due to land mining would be substantially reduced (Table 39). It should be noted, however, that the net reduction in impacts would require the same generic consideration of those impacts due to the mining and processing of the manganese nodules. This comparison is presented in Appendix 6.

Table 37. Potential rate of development of deep seabed mining 1988-2010

Year	Comment	10^6 tons Nodules	10^3 tons recovered metal Nickel	Copper	Cobalt	Manganese[c]
1988	One 4-metal start[a]	0.5	8	6	1	139
1989	Two 3-metal starts[b]	3.7	55	46	7	734
1990	One 4-metal and One 3-metal start	6.8	102	84	13	1,350
1991	Continued phase-in	8.7	130	109	17	1,730
1992	Continued phase-in	10.3	153	128	19	2,030
1993	Continued phase-in	11	164	137	21	2,170
1994	Full production, first generation	11	164	137	21	2,170
1995		12.6	189	158	24	2,500
1996		14.5	217	181	28	2,900
1997		16.7	249	208	32	3,300
1998		19	287	240	37	3,800
1999		22	330	276	42	4,400
2000	15% growth scale (all 4-metal)	25	379	317	49	5,000
2001		29	436	364	56	5,800
2002		34	502	419	64	6,600
2003		39	577	482	74	7,600
2004		44	663	554	85	8,800
2005		51	763	637	98	10,100
2006		59	877	733	112	11,600
2007		68	1,010	843	129	13,400
2008		78	1,160	969	149	15,400
2009		89	1,330	1,110	171	17,700
2010		100	1,530	1,300	197	20,300
Cumulative Production		760	11,300	9,400	1,400	150,000

a - 4-metal operations phase in over three years, @ 0.5, 0.7, 0.8, 1 (x10^6 TPY)
b - 3-metal operations phase in over three years, @ 1.5, 2.0, 2.5, 3 (x10^6 TPY)
c - Manganese content in ferro and silico manganese

Table 38. Cumulative world demand for nodule metals and the deep seabed contribution

Metal	Total World Demand to 2010 AD ($x10^3$ short-tons)	Deep Seabed Mining Cumulative Production to 2010 AD ($x10^3$ short-tons)	Deep Seabed Production as a Percent of Total World Demand
Nickel	31,000	11,300	36
Copper	530,000	9,400	1.8
Cobalt	1,400	1,400	100
Manganese	600,000	150,000	25

Table 39. Impacts Associated with a delay until 2010 AD in the initiation of deep seabed mining

Impact	Nickel	Copper	Cobalt	Manganese	Total
Land (acres)	22,543	17,928	2,005	3,359	45,835
Energy (10^{15} Btu)	5.6	0.7	0.11	0.05	6.46
Water (10^{12} Gals)	0.6	0.3	0	0.1	1
Potential SO_2 Emissions (10^3 tons)	10,692	16,939	1,955	0	29,586
Employment (10^6 man years)	0.8	0.3	0.06	0.25	1.41
Disabling Injuries (10^3)	40	21.2	3.8	17.1	82.1

Appendix 6.

Comparison of Impacts of First Generation Deep Seabed Mining and Impacts from the Equivalent Amount of Land Mining

This appendix quantifies those impact parameters that lend themselves to comparison between deep seabed mining and land mining, i.e., impacts associated with the amount of mining needed to satisfy the production expected from 20 years of mining on the part of the first generation miners (see Table 37, Appendix 5). The tonnage of metal is shown below:

Nickel	$2,900 \times 10^3$
Copper	$2,400 \times 10^3$
Cobalt	370×10^3
Manganese	$39,000 \times 10^3$

Most of the onshore impacts for equivalent land production are derived from Table 35, Appendix 5. Ore body types used for comparison are:

Nickel	laterite
Copper	porphyry
Cobalt	laterite
Manganese	N/A

For simplification only surface mining was considered in these comparisons. Other assumptions were:

Slurry terminal

50 km transport to plant

Cuprion process for three-metal plant

HCl process for four-metal plant

Tailings ponds for waste disposal

50 people per mine ship

20 people per mapping ship

10 people per fast service vessel

60 people per ore carrier

Table 40 compares the impacts for those parameters that lend themselves to comparison. In fairness it must be pointed out that these data reflect an over-simplistic view of the future in that the assumption is that land production declines in equal proportion to increases in deep seabed production. In fact, this is not likely to be the case because land production will not be greatly curtailed until deep seabed mining has proven itself to be a reliable source of metals of interest. The implication is that for at least the first few years environmental impacts will be a little greater than those calculated here.

Table 40. Comparison of impacts of first generation deep seabed mining and from the equivalent amount of land mining.

	Deep Seabed Mining			
Impact	Offshore	Onshore	Total	Onshore Mining
Land Use (km^2)	N/A	40	40	60
Water Use ($10^6 m^3$)	Nil	700	700	700
Energy Consumption[1] (10^{12} BTU)	60	2,500	2,600	2,600
Potential SO_2 Emissions (10^6 tons)	Nil	Nil[2]	Nil	4.8[2]
Labor (Man years)	1,400	2,300	4,000	16,000
Disabling Injuries (est.)	300	500	800	3,000

1 Charles River Associates (1980)

2 Exact amount will depend on process (as well as source of energy); however, deep seabed manganese nodules contain only 0.08 percent sulfur (Dames & Moore and EIC, 1977) and therefore have a relatively small potential for SO_2 production.

Appendix 7.

Energy Implications of Deep Seabed Mining

A NOAA-funded study by Charles River Associates (1980) compared the energy requirements of producing economically important metals from manganese nodules with energy requirements to produce equivalent quantities of these metals from land sources. Energy requirements were analyzed for three different approaches to processing: 1) ammonia leach (cuprion ammoniacal leach -- both three- and four-metal); 2) acid leach (reduction/hydrochloric acid leach -- four-metal and high temperature sulfuric acid leach -- three-metal); and, 3) pyrometallurgical (electric furnace smelting -- three- and four-metal).

Mining systems were examined from mining through transportation, processing, waste treatment and disposal, and transportation of primary products to markets. Most of the energy used in producing metals from nodules occurs in the metallurgical processing steps, where 62 to 91 percent of the total energy is consumed. Up to 24 to 89 percent of this energy could be supplied by coal, depending upon the process and the plant location.

The energy comparisons of manganese nodule processing with respect to land production were based upon both a present and a future scenario. The present scenario compares nickel from nodules with nickel from sulfide and laterite ores in proportion to their present mix of imports into the U.S. The future scenario presupposes that by the time deep seabed mining becomes commercial all new sources of nickel will be from laterite ore bodies. That is the ore body type most logically used for comparison purposes.

Nodule processes were found to be comparable to land processes for the future ore scenario except for the pyrometallurgical approach which is energy intensive. Therefore, when nodules begin to enter the market place (1988 at the earliest), the transition will not cause the world to expend more energy. The reason that energy will not be saved by turning to the sea is because of the complex nature of the nodules.

Manganese nodules are either a three- or four-metal ore. Most land ores used in these comparisons are one-metal ores, such a porphyry copper. From the perspective of energy alone, nodules represent good nickel and cobalt ores but are a poor source of copper (because the nodules don't lend themselves to concentration by froth flotation). However, the copper revenue will make copper recovery worthwhile. The nodules are a low grade source of manganese which is not presently in short supply, but the U.S. may need that metal in the years ahead.

While world energy consumption will not change, U.S. consumption will if processing is done domestically. The U.S. will consume more energy in exchange for reduced imports of metal processed abroad. The energy source can be mainly coal. Thus, the U.S. will utilize more coal, in exchange for a measure of security with respect to availability of metals nearly non-existent domestically.

Appendix 8. Summary of Federal endangered and threatened marine mammals and turtles that could inhabit the DOMES area or transportation corridors leading to possible process plant locations. (National Oceanic and Atmospheric Administration, 1978a and b; Federal Register 45: (33768) May 20, 1980

Geographical Area	Species	Status	Ecological Characteristics
DOMES Area (5 to 20°N, 100 to 180°W)	Humpback whale (*Megaptera novaeangliac*)	Endangered	Eastern North Pacific stock migrates from its summer range of Chukchi Sea to southern California to its winter range of southern California to Jalisco, Mexico and points west, including Hawaii. This Pacific stock is severely depleted to about 850 individuals, 500 of whom winter in Hawaii. Some individuals could migrate through the DOMES area.
	Blue whale (*Balaenoptera musculus*)	Endangered	Circumglobal distribution. Migrates seasonally between higher latitudes in summer and near 80°N in winter. Distinct North Pacific stock. Could migrate through DOMES area.
	Sperm whale (*Physeter catadon*)	Endangered	Nearly worldwide distribution except in pack ice. Females and immature males generally found between 40°S and 50°N. Migrate north during the northern summer and south during northern winter. Males found as far north as Bering and Okhotsk Seas. Could migrate through DOMES area.
	Sei whale (*Balaenoptera borealis*)	Endangered	See below under "Alaska."
	Fin whale (*Balaenoptera physalus*)	Endangered	Circumglobal. Eastern Pacific individuals summer from California to the Chukchi Sea and migrate south in the winter, perhaps passing through DOMES area.
	Right whale (*Eubalaena spp.*)	Endangered	Oceanic in temperate waters.
	Green sea turtle (*Chelonia mydas*)	Endangered/ Threatened	Circumglobal from 35°N to 35°S in Pacific, Atlantic, and Gulf of Mexico. Nesting areas in southeast Florida, French Frigate Shoals in the Hawaiian Leewards, and west coast of Mexico. Threatened everywhere except breeding colonies in Florida and west coast of Mexico.
	Hawksbill sea turtle (*Eretmochelys imbricata*)	Endangered	Found in tropical seas.

Appendix 8 (continued)

Geographical Area	Species	Status	Ecological Characteristics
	Loggerhead sea turtle (Caretta caretta)	Threatened	See below under "West Coast of U.S. and Central America."
	Leatherback sea turtle (Dermochelys coriacea)	Endangered	Could possibly range into Eastern DOMES area from Central American coastal nesting areas.
Hawaiian Islands	Humpback whale	Endangered	See above under "DOMES Area."
	Blue whale	Endangered	See above under "DOMES Area."
	Sperm whale	Endangered	See above under "DOMES Area."
	Fin whale	Endangered	See above under "DOMES Area."
	Sei whale	Endangered	See below under "Alaska."
	Right whale	Endangered	See above under "DOMES Area."
	Leatherback sea turtle	Endangered	See above under "DOMES Area."
	Green sea turtle	Endangered/ Threatened	See above under "DOMES Area."
	Hawksbill sea turtle	Endangered	Nesting areas on island of Hawaii, in western Gulf of Mexico and on both sides of Florida peninsula.
	Hawaiian monk seal (Monachus schauinslandi)	Endangered	Only breeding site is in Leeward Islands in the Hawaiian Islands National Wildlife Refuge. Seals rarely range southeastward along Hawaiian archipelago. Probably would not be affected by process plant activities in larger islands.
West coast of United States and Central America	Gray whale	Endangered	See below under "Alaska."
	Humpback whale	Endangered	See above under "DOMES Area."
	Fin whale	Endangered	See above under "DOMES Area."

Appendix 8 (continued)

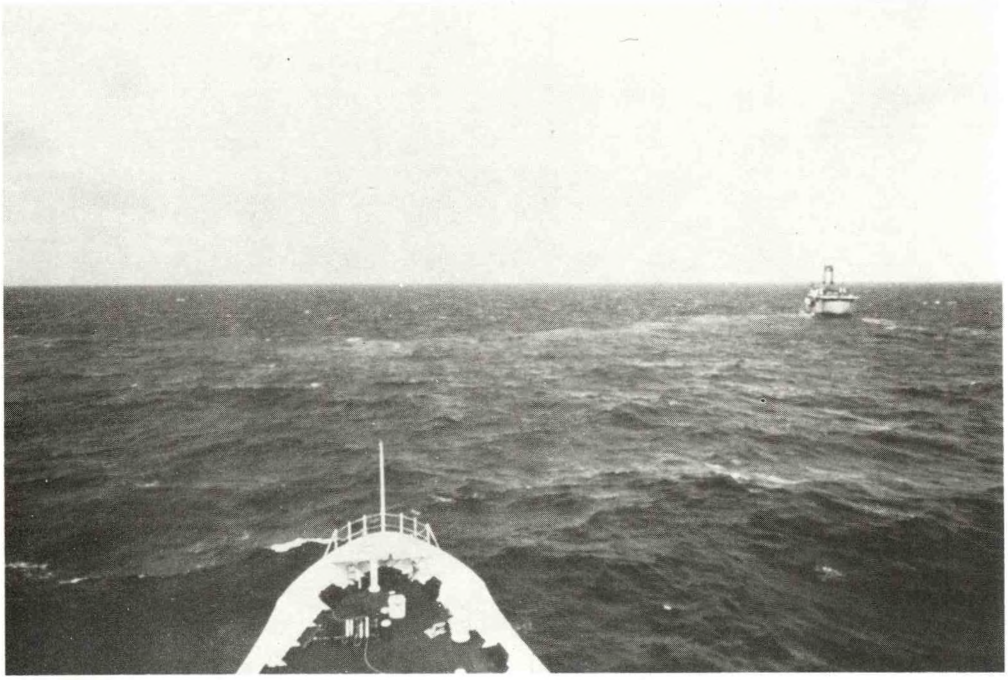
Geographical Area	Species	Status	Ecological Characteristics
	Blue whale	Endangered	See above under "DOMES Area."
	Sperm whale	Endangered	See above under "DOMES Area."
	Sei whale	Endangered	See below under "Alaska."
	Right whale	Endangered	See above under "DOMES Area."
	Leatherback sea turtle	Endangered	Nesting areas along West Coast of Central America
	Green sea turtle	Endangered/ Threatened	See above under "DOMES Area."
	Loggerhead sea turtle (*Caretta caretta*)	Threatened	Circumglobal in tropical and temperate waters. Found from California south to Chile in the Pacific Ocean and in the Atlantic near Florida where it nests.
	Hawksbill sea turtle	Endangered	See above under "Hawaiian Islands."
	Pacific ridley or olive ridley (*Lepidochelys olivacea*)	Endangered/ Threatened	Endangered stocks found along west coast of Mexico and in the Gulf of California south to Costa Rica. Breeding colonies along Mexican coast.
	Sea otter (*Enhydra lutris*)	Threatened	Inhabits kelp beds and coastal waters along California coast, occasionally further north.
Alaska	Gray whale (*Eschrichtius robustus*)	Endangered	Isolated population in eastern Pacific (California stock) which summers in the Chukchi, western Beaufort, and northern Bering Seas and migrates to the west coast of Baja, California and southern Gulf of California for the winter.
	Sei whale (*Balaenoptera borealis*)	Endangered	In eastern North Pacific; summers from California to the Gulf of Alaska and Aleutian Islands, winters in lower latitudes.

Appendix 8 (continued)

Geographical Area	Species	Status	Ecological Characteristics
	Bowhead whale (Balaena mysticetus)	Endangered	Inhabits arctic and subarctic waters in the Bering, Chukchi, Beaufort, and East Siberian Seas plus elsewhere around the world. Travel singly, in pairs, or threes during the spring; in autumn they scatter but may occur in groups of up to 50. Migrate in association with pack ice.
	Right whale	Endangered	See above under "DOMES Area."
	Humpback whale	Endangered	See under "DOMES Area."
	Blue whale	Endangered	See under "DOMES Area."
	Sperm whale	Endangered	See under "DOMES Area."
	Fin whale	Endangered	See under "DOMES Area."
	Leatherback sea turtle	Endangered	Observed very rarely in Alaskan waters.
Gulf of Mexico	West Indian or Florida manatee (Trichechus manatus)	Endangered	Found in coastal waters of Florida and the Caribbean, often in lagoons.
	Loggerhead turtle	Threatened	See above under "West Coast of U.S. and Central America."
	Green sea turtle	Endangered in state waters of Florida, Threatened elsewhere	See above under "DOMES Area."
	Kemp's, Flatback, or Atlantic Ridley sea turtle (Lepidochelys kempii)	Endangered	Major nesting site in Western Gulf of Mexico
	Hawksbill sea turtle	Endangered	Minor nesting sites in southwestern Gulf of Mexico

Appendix 8 (continued)

Geographical Area	Species	Status	Ecological Characteristics
	Leatherback sea turtle	Endangered	Minor nesting sites in southwestern Gulf of Mexico
	Humpback whale	Endangered	See above under "DOMES Area."
	Fin whale	Endangered	See above under "DOMES Area."
	Blue whale	Endangered	See above under "DOMES Area."
	Sperm whale	Endangered	See above under "DOMES Area."
	Right whale	Endangered	See above under "DOMES Area."



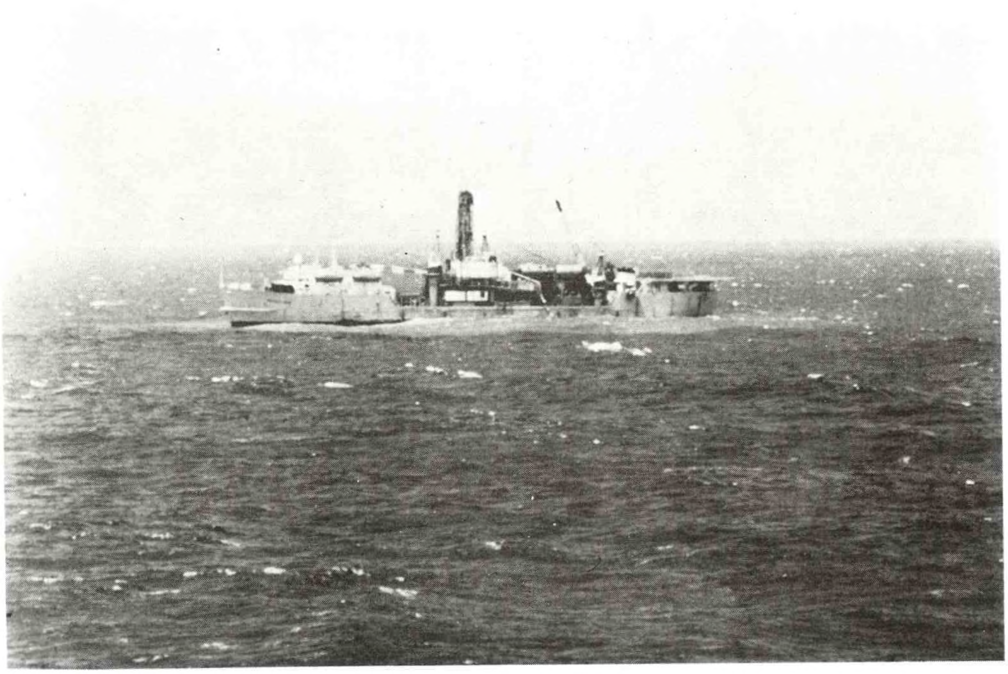


Figure 35.--Photos of Surface Plume During Test Mining

VII. Index of Major Subjects not Identified in Detailed Tables of Contents that Precede Each Section (Pages 1, 13, 149, 199, 221)

*U S GOVERNMENT PRINTING OFFICE: 1981 352-741/9017

CONVERSION FACTORS

English to Metric	Metric to English
- Rate	
1 nmi/hr = 1 knot = 1.852 km/hr	1 km/hr = 0.54 nmi/hr
1 smi/hr = 1.61 km/hr	1 km/hr = 0.62 smi/hr
- Distance	
	1 u = 0.0000396 in = 10^{-6} m = .000001 m
	1 mm = 0.0396 in
1 in = 2.54 cm	1 cm = 0.396 in
1 ft = 0.3 m	1 m = 3.3 ft
1 nmi = 1.85 km	1 km = 0.54 nmi
1 smi = 1.61 km	1 km = 0.62 smi
- Weight	
1 lb = 0.45 kg	1 kg = 2.2 lb
1 ton = 2,000 lbs = 0.91 MT	1 MT = 1 tonne = 2,200 lbs = 1000 kg = 1.1 tons
- Area	
1 ft^2 = 0.092 m^2	1 m^2 = 10.89 ft^2
1 a = 0.4 ha	1 ha = 2.5 a
1 nmi^2 = 3.43 km^2	1 km^2 = 0.29 nmi^2
- Volume	
1 ft^3 = 0.0278 m^3	1 m^3 = 35.937 ft^3
1 U.S. gal = 3.78 l	1 l = 0.264 U.S. gal