Identification of Representative West Coast Areas for Manganese Nodule Processing Activities

by

James A. Henderson

Internship Report

Submitted to

Marine Resource Management Program
School of Oceanography
Oregon State University
1977

in partial fulfillment of
the requirements for the
degree of
Master of Science

Internship: National Oceanic and Atmospheric Administration
Office of Marine Minerals
Rockville, Maryland
1 November 1977

U.S. Department of Commerce  
NOAA/Office of Marine Minerals  
Rockville, MD 20852  

Attention: Mr. Karl Jugel

Contract T-35416  
Identification of Representative West Coast Areas  
for Manganese Nodule Processing Activities

Gentlemen:

With this letter we are transmitting five (5) copies of one (1) unbound electrostatically reproducible original of the report, "Identification of Representative West Coast Areas for Manganese Nodule Processing Activities."

We have enjoyed working with your office in completing this report. If you have any questions concerning this report, please contact us.

Respectfully,

School of Oceanography  
Oregon State University

Victor T. Neal  
Assoc. Professor

James A. Henderson  
Research Assistant
**TABLE OF CONTENTS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 INTRODUCTION</strong></td>
<td></td>
</tr>
<tr>
<td>1.1 Overview</td>
<td>1.1</td>
</tr>
<tr>
<td>1.2 NOAA Programs</td>
<td>1.1</td>
</tr>
<tr>
<td>1.3 Purpose of this Study</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>2.0 METHODOLOGY</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 Phase I Subsystems</td>
<td>2.1</td>
</tr>
<tr>
<td>2.2 Evaluation of Work</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>3.0 MANGANESE NODULE PROCESSING ACTIVITIES AND SCENARIO DEVELOPMENT</strong></td>
<td>3.1</td>
</tr>
<tr>
<td>3.1 Overview</td>
<td>3.1</td>
</tr>
<tr>
<td>3.2 Subsystem Descriptions</td>
<td></td>
</tr>
<tr>
<td>3.2.1 Marine Transportation</td>
<td>3.2</td>
</tr>
<tr>
<td>3.2.2 Marine Terminal</td>
<td>3.3</td>
</tr>
<tr>
<td>3.2.3 Onshore Nodule Transport</td>
<td>3.3</td>
</tr>
<tr>
<td>3.2.4 Processing Plant</td>
<td>3.3</td>
</tr>
<tr>
<td>3.2.5 Waste Treatment, Transportation and Disposal</td>
<td>3.6</td>
</tr>
<tr>
<td>3.3 Summary/Scenario</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>4.0 PHYSICAL CRITERIA CONSIDERATIONS</strong></td>
<td>4.1</td>
</tr>
<tr>
<td>4.1 Major Limiting Criteria</td>
<td>4.1</td>
</tr>
<tr>
<td>4.2 Physical Envelopes for Facility Location</td>
<td>4.2</td>
</tr>
<tr>
<td>4.3 Additional Criteria</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>5.0 REGUALTORY CONSIDERATIONS</strong></td>
<td>5.1</td>
</tr>
<tr>
<td>5.1 Categories of Regulatory Interest</td>
<td>5.1</td>
</tr>
<tr>
<td>5.2 Federal Environmental Regulations</td>
<td></td>
</tr>
<tr>
<td>5.2.1 National Environmental Policy Act</td>
<td>5.3</td>
</tr>
<tr>
<td>5.2.2 Federal Water Pollution Control Act Amendments</td>
<td>5.4</td>
</tr>
<tr>
<td>5.2.3 Marine Protection, Research and Sanctuaries Act</td>
<td>5.4</td>
</tr>
<tr>
<td>5.2.4 Resource Conservation and Recovery Act of 1976</td>
<td>5.5</td>
</tr>
<tr>
<td>5.2.5 Safe Drinking Water Act</td>
<td>5.6</td>
</tr>
<tr>
<td>5.2.6 Clean Air Act Amendments</td>
<td>5.6</td>
</tr>
<tr>
<td>5.2.7 Coastal Zone Management Act</td>
<td>5.6</td>
</tr>
<tr>
<td>5.3 Federal Regulation and Nodule Processing</td>
<td>5.7</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>6.0 GENERAL INFORMATION ON THE STUDY AREAS</td>
<td>6.1</td>
</tr>
<tr>
<td>6.1 Physiographic Overview</td>
<td>6.1</td>
</tr>
<tr>
<td>6.1.1 Topography</td>
<td>6.1</td>
</tr>
<tr>
<td>6.1.2 Seismic Activity</td>
<td>6.1</td>
</tr>
<tr>
<td>6.1.3 Climate</td>
<td>6.2</td>
</tr>
<tr>
<td>6.1.4 Oceanography</td>
<td>6.3</td>
</tr>
<tr>
<td>6.1.5 Ecological Classification</td>
<td>6.5</td>
</tr>
<tr>
<td>6.2 Physical Criteria Overviews</td>
<td>6.5</td>
</tr>
<tr>
<td>6.2.1 Alaska</td>
<td>6.5</td>
</tr>
<tr>
<td>6.2.2 Pacific Northwest</td>
<td>6.6</td>
</tr>
<tr>
<td>6.2.3 California</td>
<td>6.7</td>
</tr>
<tr>
<td>6.3 Regulatory/Attitude Overview</td>
<td>6.8</td>
</tr>
<tr>
<td>6.3.1 Solid Waste Disposal</td>
<td>6.9</td>
</tr>
<tr>
<td>6.3.2 Air Quality</td>
<td>6.10</td>
</tr>
<tr>
<td>6.3.3 Land Use</td>
<td>6.11</td>
</tr>
<tr>
<td>6.3.4 Permit Process</td>
<td>6.12</td>
</tr>
<tr>
<td>6.3.5 Public Attitudes</td>
<td>6.13</td>
</tr>
</tbody>
</table>

APPENDICES

A Alaska A 1
B Puget Sound B 1
C Grays Harbor C 1
D Columbia River D 1
E Coos Bay E 1
F Humboldt Bay F 1
G San Francisco Bay G 1
H Southern California H 1

LIST OF REFERENCES CONSULTED
<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>3.10</td>
</tr>
<tr>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>5.2</td>
<td>5.2</td>
</tr>
</tbody>
</table>

**Scenario of assumed West coast subsystems**

**West coast processing activities**

**Categories of regulatory interest**

**Regulatory impact relationships**
# List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Nodule mining area of maximum commercial interest</td>
<td>1.4</td>
</tr>
<tr>
<td>1-2</td>
<td>West coast of the United States and Alaska</td>
<td>1.5</td>
</tr>
<tr>
<td>3-1</td>
<td>Minimal whole nodule terminal</td>
<td>3.12</td>
</tr>
<tr>
<td>3-2</td>
<td>Single point mooring system</td>
<td>3.13</td>
</tr>
<tr>
<td>4-1</td>
<td>Valdez area</td>
<td>4.4</td>
</tr>
<tr>
<td>4-2</td>
<td>Pacific Northwest area</td>
<td>4.5</td>
</tr>
<tr>
<td>4-3</td>
<td>Humboldt/San Francisco Bay area</td>
<td>4.6</td>
</tr>
<tr>
<td>4-4</td>
<td>Southern California area</td>
<td>4.7</td>
</tr>
<tr>
<td>6-1</td>
<td>Seismic risk map of the United States</td>
<td>6.15</td>
</tr>
<tr>
<td>A-1</td>
<td>Valdez Harbor and vicinity</td>
<td>A 3</td>
</tr>
<tr>
<td>A-2</td>
<td>Average annual precipitation for Alaska</td>
<td>A 12</td>
</tr>
<tr>
<td>A-3</td>
<td>Maximum temperatures for January and July in Alaska</td>
<td>A 13</td>
</tr>
<tr>
<td>A-4</td>
<td>Mean annual evaporation from small lakes for Alaska</td>
<td>A 13</td>
</tr>
<tr>
<td>B-1</td>
<td>Puget Sound and vicinity</td>
<td>B 3</td>
</tr>
<tr>
<td>B-2</td>
<td>Mean annual precipitation - Oregon</td>
<td>B 14</td>
</tr>
<tr>
<td>B-3</td>
<td>Average January temperature - Pacific Northwest</td>
<td>B 15</td>
</tr>
<tr>
<td>B-4</td>
<td>Average July temperature - Pacific Northwest</td>
<td>B 15</td>
</tr>
<tr>
<td>B-5</td>
<td>Mean annual precipitation - Washington</td>
<td>B 16</td>
</tr>
<tr>
<td>B-6</td>
<td>Mean annual lake evaporation in inches - Pacific Northwest</td>
<td>B 17</td>
</tr>
<tr>
<td>B-7</td>
<td>Average annual lake evaporation in inches - West coast</td>
<td>B 18</td>
</tr>
<tr>
<td>B-8</td>
<td>West coast mean annual precipitation by district</td>
<td>B 19</td>
</tr>
<tr>
<td>C-1</td>
<td>Grays Harbor and vicinity</td>
<td>C 2</td>
</tr>
<tr>
<td>D-1</td>
<td>Columbia River and vicinity</td>
<td>D 2</td>
</tr>
<tr>
<td>E-1</td>
<td>Coos Bay and vicinity</td>
<td>E 2</td>
</tr>
<tr>
<td>F-1</td>
<td>Humboldt Bay and vicinity</td>
<td>F 2</td>
</tr>
<tr>
<td>G-1</td>
<td>San Francisco Bay and vicinity</td>
<td>G 2</td>
</tr>
<tr>
<td>H-1</td>
<td>Southern California area</td>
<td>H 2</td>
</tr>
</tbody>
</table>
1.0 INTRODUCTION

1.1 OVERVIEW

Manganese nodules are concretions which are widely distributed on the bottom of marine waters as well as on the bottom of some lakes. They vary in size, abundance, and to some extent composition, with location. The nodules are of potential economic value because of the nickel, copper, cobalt and manganese they contain.

The nodule deposits of greatest economic interest are found in the North Pacific Ocean, from the equator to about 30°N. The area extends from 100°W to 180°W (see Figure 1.1). The water in this region varies from about 7500 feet to 17,600 feet (2,300 m to 7,000 m) in depth with an average of about 16,400 feet (5,000 m). The region is mostly an abyssal plain; however, it is intercepted by the Clarion and Clipperton Fracture Zones.

Deep ocean mining of manganese nodules is anticipated by the early 1980's. First generation mining activities will consist of mining vessels, large bulk ore carriers and onshore processing facilities. The processing and associated activities will probably be located on the U.S. Pacific coast (including Hawaii and Alaska) or the Gulf Coast.

1.2 NOAA PROGRAMS

The mining and processing activities may be interpreted as major Federal actions under the National Environmental Policy Act (NEPA). Therefore, detailed assessments of the potential impacts will be required. The U.S. Department of Commerce, through its National Oceanic and Atmospheric Administration (NOAA), has initiated programs to assess these impacts.
The first of these programs, Deep Ocean Mining and Environmental Studies (DOMES), was designed to assess the potential marine environmental impacts associated with deep ocean mining in the Pacific. This study is now in progress. The basic objectives of DOMES are as follows: 1) obtain baseline data on selected environmental parameters in the mining region; 2) develop predictive capability to assess environmental consequences of ocean mining; and 3) establish preliminary environmental guidelines for the mining of manganese nodules. The second phase of DOMES is the monitoring of prototype mining operations to refine or modify the findings of Phase I.

In conjunction with DOMES, the NOAA Office of Marine Minerals has initiated a three-phase program to assess the environmental and socio-economic aspects of nodule processing activities. Phase I includes the description and characterization of the relevant activities associated with sea and land transportation of the nodules as well as potential processing methods and waste disposal. Phase II includes the identification and description of representative geographical areas on the west coast and Alaska (presented in this report) which might be suitable for the location of activities associated with onshore processing of manganese nodules. It is anticipated that Phase III will consist of environmental and socio-economic impact studies of one or more representative processing areas. The extent of Phase III studies will be determined on the basis of the Phase I and Phase II reports.

1.3 PURPOSE OF THIS STUDY

The objective of this study (Phase II-West Coast) is to identify and describe geographical areas on the west coast (including Alaska) which might be representative of areas where processing facilities will
might be located. To meet this objective, a methodology and set of criteria were formulated. The methodology allowed a logical sequence of data evaluation in the formulation of criteria and the description of geographical areas. The criteria were based on information obtained from the Phase I studies (Dames & Moore, 1977).

It should be noted that the areas described in this report are only representative of areas that may eventually be used. It is not the intent of this study to describe or delineate all areas where facilities may eventually be located — only selected areas that are representative enough that one or more of them might serve as the focus for subsequent Phase III impact studies. The areas are representative in the sense that they have many of the attributes that are desirable for processing activities (see Figure 1-2).

Specific sites for possible plant locations were not considered in this study.
Figure 1-1.
Nodule mining area of maximum commercial interest.
Figure 1-2 West coast of the United States and Alaska
2.0 METHODOLOGY

In order to identify, and then describe, the West Coast geographical areas with characteristics representative of those areas where industry might choose to locate manganese nodule processing facilities, the following methodology was used:

- review of the results of NOAA's Phase I studies in order to identify the most likely combination of subsystems for use on the West Coast.
- selection of representative values for these subsystems in order to develop a "scenario" providing physical criteria important to area identification.
- application of the physical criteria to the West Coast of the U.S. and Alaska in order to identify those areas which could physically support such facilities.
- identification of State and Federal regulations and attitudes relevant to the areas identified through the application of physical criteria.
- convening a broad-based workshop at Oregon State University in order to review the physical and regulatory/attitude criteria, review the areas identified, and elicit the views of persons who will potentially be involved in actual siting decisions.
- collection of needed additional information, description of the areas identified, and preparation of this final report to NOAA.

2.1 PHASE I SUBSYSTEMS

NOAA's Phase I Reports, "Description of Manganese Nodule Processing Activities for Environmental Studies" Volumes I & II (Dames & Moore,
provided an analysis of the alternative subsystems which could be used for marine transportation, marine terminals, onshore transportation, nodule processing waste treatment, and waste disposal. For each of the subsystems, the study included the physical requirements for its use. Because of the many combinations which could be used it was necessary to perform an evaluation of the various subsystem components as related to the requirements of a West Coast-oriented nodule processing operation. A scenario approach was utilized to describe the most likely combination of subsystems. In the identification of the most likely scenario, a series of assumptions were utilized to facilitate the selection process. In addition, each of the parameters associated with the individual segments of the scenario were assigned a range of values. The assumptions utilized and values assigned to the parameters were determined in consultation with representatives from the Phase I contractor (Dames & Moore) and the NOAA Office of Marine Minerals. It should be noted, however, that industry's specific choices may differ based both on regulatory considerations and total system economics.

This development of the scenario along with representative parameter values (e.g., land, electricity and water required) permitted the use of these physical criteria against which potential West Coast locations could be identified and described. Once done, applicable State and Federal regulations could be evaluated as related to a nodule processing operation. In addition, public attitudes were assessed, on a general scale, to evaluate their impact in relation to regulatory considerations and nodule processing in general.
2.2 EVALUATION OF WORK

The next step was an evaluation and verification of the work accomplished up to that point. The tool used for that evaluation was a workshop conducted at Oregon State University. The specific purpose of the workshop was to solicit recommendations and suggestions concerning:

1. the validity of the proposed methodology, developed scenario, and associated assumptions;
2. the comprehensiveness and direction of the regulatory/attitude assessment; and
3. additional information required to complete the study. The workshop was attended by private individuals (largely associated with environmental interest groups and university academic areas); representatives from federal, state and local governments; representatives of the deep-sea mining industry and of other industries (e.g., railroads and utilities) expected to be associated with the deep ocean mining.

The last step was to collect needed additional information identified at the workshop, to characterize and describe those areas on the West Coast which were identified, and to prepare the final report. The areas were described in relation to the criteria, both physical and regulatory, established according to the methodology. Special attention was given to those criteria (or considerations) which were identified at the workshop as being critical to a successful nodule processing operation.
3.0 MANGANESE NODULE PROCESSING ACTIVITIES AND SCENARIO DEVELOPMENT

3.1 OVERVIEW

The Phase I study concluded that it was most likely that in first generation systems, manganese nodules would be transported to shore for processing; although some partial processing at-sea may be possible. Three possible forms of nodules for transport were considered: naturally dried nodules and nodule fragments; ground and slurried nodules; and ground and specially dried nodules. This latter form was only considered practical if very long transportation distances are involved (e.g., such as from the Pacific area of commercial interest to the U.S. Gulf Coast). For each of two potential mine sites, marine transport requirements for each nodule form at two different production levels were estimated to Southern California, the Pacific Northwest and the Gulf Coast. Marine terminal requirements for each of the nodule forms were also described as were onshore port-to-plant and waste transportation systems. Based on a review of processing technology, Phase I identified five different processing techniques which are likely for commercial use. Production levels for each were then identified and the characteristic of each plant relevant to environmental and socio-economic impact studies were described. Phase I also described methods of treating wastes to make them "more disposable" and described the three waste disposal options (tailings ponds, landfill and at-sea disposal) likely to receive the greatest attention.

The general conclusions reached by OSU, in consultation with the Phase I Contractor and the NOAA Office of Marine Minerals, was that in
order to facilitate materials handling the most likely form of nodules
to be transported to the West Coast would be a slurry. Nodule throughput
for "three-metal" plants (those producing copper, nickel and cobalt)
would be approximately 2.0 million metric tons (dry weight) per year and
nodule throughput for "four-metal" plants (those producing copper,
nickel, cobalt and manganese) would be approximately 1.0 million metric
tons (dry weight) per year.

3.2 SUBSYSTEM DESCRIPTIONS

The following is a brief synopsis of the Phase I findings and also
describes the rationale used to select the alternatives for the West
Coast Phase II Study.

3.2.1 Marine Transportation

For a slurried form of nodules, the Phase I study estimated one to
five ore transports of different capacities could be used per deep
seabed mining operation for West Coast processing, depending on the
combination of mining rate and transportation distance. (It was concluded
that, in practice, two smaller ships would probably be used instead of
the one larger ship in order to provide redundancy so that mining would
not be interrupted by ore transport delays or breakdowns). Based on
this analysis it was concluded in consultation with the Phase I Contractor
and NOAA, that a "typical" ore transport servicing a West Coast processing
plant would nominally require a channel slightly over 12 meter (40 foot)
depth or roughly the same water depth at a single point mooring. The
depth corresponds roughly to the draft of a 60,000 DWT* to 70,000 DWT
ship.

* Long tons roughly correspond to metric tons for the purpose of this
study
3.2.2 **Marine Terminal**

For a slurried form of nodule, the Phase I report describes an onshore slurry terminal which could be used if the ore transport can be berthed at the terminal and a single point mooring terminal which could be used if the ore transport cannot berth at the onshore part of the terminal. The onshore slurry terminal and a single point mooring are illustrated in Figures 2-1 and 2-2 respectively. In general, industry would probably prefer the onshore slurry terminal. The Phase I reports also describe terminal configurations for naturally dried nodules and nodule fragments and for ground and specially dried nodules.

In general, use of the single point mooring system was considered practicable from about San Luis Obispo, CA, south to the Mexican border because of oceanographic conditions. Thus, north of San Luis Obispo ore transports would probably be constrained to unloading in existing harbors with the required channel clearances, while south of San Luis Obispo they could choose either suitable harbors or the use of single point moorings.

3.2.3 **Onshore Nodule Transport**

If received in slurried form, nodules would be transported from the marine terminal to the processing plant by a buried slurry pipeline. As will be discussed later in greater detail, the use of a slurry pipeline would make it practicable to locate the plant some distance away from the shoreline practicable.

3.2.4 **Processing Plant**

The Phase I study exhaustively reviewed the types of processes which could be used to extract the value metals from manganese nodules and identified five techniques which appear likely for possible commercial
use. Three of the processes are designed to remove copper, nickel and cobalt and two are designed to remove manganese as well. These processes are:

**Three Metal**
- Reduction/Ammoniacal Leach Process
- Cuprion/Ammonia Leach Process
- High Temperature Sulfuric Acid Process

**Four Metal**
- Reduction/Hydrochloric Acid Leach Process
- Smelting Process

For each type of plant (3 metal and 4 metal) the Phase I Contractor estimated a corresponding production level and then for each process used process engineering methods to estimate all inputs and outputs relevant to environmental and socio-economic impact studies. Thus, for each of the five processing techniques the Phase I report provides estimates of land, water and purchased electric power requirements, reagents consumed, and labor force required. An important assumption made by the Phase I Contractor related to siting was that the plant would depend on coal, instead of oil, for generating certain gases and the heat used in processing. The Phase I analysis included the use of scrubbers and other state-of-the-art devices (e.g., hooping) to control airborne emissions. Coupled with the reagents used and products produced, the quantity of coal used would essentially require such a plant to be within 24 km (15 miles) over level ground, of an existing, operating rail line. Furthermore, it should have convenient access to a highway.

The land area required for the plant, on-site storage, parking and so forth ranges from 40 hectares (110 acres) to 80 hectares (200 acres). In addition, there would probably be a buffer zone surrounding such plants. The actual plant site should be level and not subject to high
seismic activity. Most of the plant facilities (e.g., crushing, boiler and metal recovery equipment) and noise makers would be located inside of buildings (up to three or four stories). Stack heights will depend on local conditions. Noise at the plant-buffer zone boundary is expected to be roughly at the same level as that of auto traffic near a freeway.

Each process requires nearly the same order of magnitude of consumptive water. This water may be "used" water (i.e., from irrigation runoff, etc., or effluent from a sewage treatment plant) so it need not be a limiting factor in most areas. The amount of electrical power that probably would be purchased ranges from zero (for the cuprion process where all power could probably be generated internally) to 24 megawatts of purchased power for three-metal plants and may be nearly 100 megawatts for a four-metal process. The Phase I Study's assumption was that each plant would try to maximize its energy efficiency by generating electricity from what otherwise would be wasted heat or steam. The potential availability of purchased electrical power may be a significant factor, particularly for four-metal plants.

Processing plants are not expected to be labor intensive. Depending on the processing technique, there should be no more than perhaps 500 persons employed directly in processing activities. Additional persons will be employed at the marine terminal, for pipeline operations and maintenance, and for waste disposal operations. A reasonable socio-economic infrastructure, commensurate with anticipated plant activities, will be a siting consideration.

The Phase I Report also addresses "hazards" from spills and gaseous releases. In general, such plants were found not to be unusually hazardous provided modern industrial safeguards are taken.
3.2.5 Waste Treatment, Transportation and Disposal

Because the "tailings" (remainder of nodules after value metals have been removed plus ash, scrubber residues and other waste materials) may have both soluble toxic and soluble innocuous components which could raise concerns regarding disposal. NOAA also had the Phase I Contractor study waste treatment methods. This work concluded that it would be possible to wash the solubles from the tailings and thereby greatly reduce the quantity of material which would create disposal concerns. Additionally, the washed tailings could be dried, at a major energy consumption penalty, to further improve their "disposability."

If tailings are minimally treated or washed to remove solubles, they would be in slurry form and logically transported by slurry pipeline to the disposal area for onshore disposal. The capacity of such a pipeline would be nominally the same as that of the pipeline required from the marine terminal to the plant. Thus, for this study, it is possible to visualize a pipeline extending from the marine terminal to the disposal area; the plant could essentially be located at any point along that pipeline. In consultation with the Phase I Contractor and NOAA, it was assumed that the total length of this pipeline would be limited to 100 km (about 60 miles) or less and would not cross elevations of 900 meters (3,000 feet) or more. Industry may make tradeoffs of distance, height and total system economics which could change these parameters; however, it was agreed at the workshop that this was a "reasonable" constraint for considering processing areas.

With respect to waste disposal, the Phase I reports describe three methods:
(1) impoundment of minimally treated tailings in lined ponds where they are left to naturally dry as much as possible,

(2) landfilling washed and dried tailings in a lined disposal area,

(3) pumping treated slurried wastes back to the marine terminal for disposal far at-sea by outbound ore transports.

It should be noted that the choice of disposal methods will affect the pipeline length and plant location; if tailings are dried, the plant would most likely be located nearest the disposal area because of handling problems which would be expected with dried material and if washed tailings are pumped back to the marine terminal, the pipeline length limit would be roughly halved.

Lined "tailings ponds," which are common in the non-ferrous metals industry, but not in coastal states, depend on evaporation to sufficiently dry the tailings in order to permit subsequent reclamation of the disposal area. In practice, a system of ponds would be used so that some are in various stages of drying while one is in active use. Surface area and depth are traded off to facilitate drying; however, it should be noted that until actual information is available from industry it is impossible to predict if the drying time should be measured in days, weeks, months or years. The Phase I Study assumed tailings depth of about twelve meters (40 feet). Using this depth, about 40 hectares (100 acres) a year would be required for three-metal plants and about 8 hectares (20 acres) a year would be required for four-metal plants for waste disposal.

Washing and drying of the tailings would permit landfilling techniques, similar to those used for disposal of municipal solid waste, and would halve the disposal area requirements. Wash water would be reclaimed
leaving a solidified form of the solubles representing perhaps one percent of the original weight of tailings. These solids could be shipped considerable distances to "hazardous" material disposal areas. It should be noted, however, that the drying step increases energy consumption by about 60 percent.

As will be amplified later in this report, at-sea disposal of even washed tailings would require a federal permit under a current interpretation of the Marine Protection, Research and Sanctuaries Act. If permitted, the tailings would be returned to the marine terminal, loaded on outbound ore carriers, and released in a prescribed manner at a prescribed rate beyond a certain prescribed distance from shore. This at-sea disposal would require additional property at the marine terminal, require larger ore transports and may require large systems to expand the outgoing capacity.

3.3 SUMMARY/SCENARIO

Table 3-1 summarizes the major characteristics of the assumed subsystems which are relevant to identifying representative West Coast geographical areas for processing activities. (Table 3-2 provides these in English units). These characteristics were used as criteria for the identification of representative West Coast areas.
The scenario established is as follows:

- Marine Transport
- Slurry Line
- Rail or truck transport

Diagram:

- Mining Site -> Ships
  - Single Point Moorage
  - Port Capabilities
    - Pierside Moorage
  - Port Facility
    - At sea
    - Plant Requirements
      - Waste disposal
      - On land
      - Products from Plant
Table 3-2. West Coast Processing Activities Scenario

<table>
<thead>
<tr>
<th>Process Type</th>
<th>3-metal</th>
<th>4-metal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual Mining Rates (tons/year)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wet (as mined)</td>
<td>$4.1 \times 10^6$</td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>$2.5 \times 10^6$</td>
</tr>
<tr>
<td></td>
<td>Ore Transports (a)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of Ships</td>
<td>2-5</td>
</tr>
<tr>
<td></td>
<td>DWT (long tons) (b)</td>
<td>$44,000-70,000$</td>
</tr>
<tr>
<td></td>
<td>Salt water Draft (feet)</td>
<td>37-41</td>
</tr>
<tr>
<td></td>
<td>Crew size per ship</td>
<td>26-40</td>
</tr>
<tr>
<td></td>
<td>Marine Terminal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depth at berth/single point mooring (feet)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Pier/mooring dolphin length (feet)</td>
<td>800-900</td>
</tr>
<tr>
<td></td>
<td>Diameter for single point mooring (feet)</td>
<td>2,000</td>
</tr>
<tr>
<td></td>
<td>Area, inbound slurry only (acres)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Area, inbound/waste outbound (acres)</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Personnel (peak with ship in)</td>
<td>30-50</td>
</tr>
<tr>
<td></td>
<td>Port-to-Plant Pipeline (buried)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipe size (inches)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Right of way (acres/miles) (c)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Pump station area (acres/station)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Assumed maximum length (miles)</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Energy (KWH/month) at 60 miles</td>
<td>$2 \times 10^6$</td>
</tr>
<tr>
<td></td>
<td>Personnel (man-years/year)</td>
<td>6-12</td>
</tr>
<tr>
<td></td>
<td>Processing Plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purchased power (megawatts)</td>
<td>20-24</td>
</tr>
<tr>
<td></td>
<td>Consumptive water use (million gals/day) (e)</td>
<td>4.7-6.3</td>
</tr>
<tr>
<td></td>
<td>Land (acres)</td>
<td>180-200</td>
</tr>
<tr>
<td></td>
<td>Required level area (acres)</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Work force (f)</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Shifts per day</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Assumed max. distance to rail line (miles)</td>
<td>15</td>
</tr>
</tbody>
</table>

(a) For unbound slurry only; the combination of number of vessels and DWT will change to provide additional capacity if wastes are to be transported for at-sea disposal.
(b) DWT deadweight tonnage, the total weight capacity for fuel, supplies, and cargo.
(c) Land above the pipeline could be used for other purposes provided that these other uses do not preclude rare access to the pipeline from the surface.
(d) One three-metal process appears to need no purchased power.
(e) Does not necessarily have to be potable; therefore, could be reused or reclaimed water from other sources.
(f) Would be typical 1/3 skilled laborers, 1/3 unskilled laborers, and 1/3 professional management, clerical and support.
Table 3-2. (continued)

<table>
<thead>
<tr>
<th>Waste Disposal</th>
<th>Process Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-metal</td>
</tr>
<tr>
<td>- Liquid/solid volume (million gallons/year)</td>
<td>1,100</td>
</tr>
<tr>
<td>- Weight of solids (tons/year)</td>
<td>$4.1 \times 10^6$</td>
</tr>
<tr>
<td>- Disposal area</td>
<td></td>
</tr>
<tr>
<td>Tailings ponds (acres/year)</td>
<td>100</td>
</tr>
<tr>
<td>Landfill (acres/year)</td>
<td>50</td>
</tr>
<tr>
<td>At-sea</td>
<td>See Marine Terminal</td>
</tr>
<tr>
<td>- Work force (man-shift/day)</td>
<td></td>
</tr>
<tr>
<td>Tailings ponds</td>
<td>4</td>
</tr>
<tr>
<td>Landfill</td>
<td>20</td>
</tr>
</tbody>
</table>
ARROWS ON CONVEYORS INDICATE UPGRADE DIRECTION

Figure 3-1
From Dames & Moore 1977
vol II

MINIMAL WHOLE NODELE TERMINAL
(HIGH THROUGHPUT)
Figure 3-2
SINGLE POINT MOORING SYSTEM
from Dames & Moore 1977 vol II
4.0 PHYSICAL CRITERIA/CONSIDERATIONS

The identification of potential processing areas required the development of a first order set of criteria. These criteria were used to identify the ports on the west coast and Alaska which would be compatible with the nodule ore transport ships. In addition, these criteria were also used to delineate the actual area boundaries to be considered.

4.1 MAJOR LIMITING CRITERIA

The first criteria was a requirement for an existing or projected ship channel depth of approximately 12 meters (40 feet) as measured at mean lower low water. Those ports identified as meeting that criteria within each state are as follows (based on information provided by the U.S. Army Corps of Engineers):

Alaska - Valdez;
Washington - Puget Sound, Grays Harbor, Columbia River to Vancouver
Oregon - Columbia River to Portland, Coos Bay; and
California - Humboldt Bay, San Francisco Bay (as far east as Antioch)
San Luis Obispo south to San Diego (this area is suitable for single point moorage in addition to having ports which have a 40 foot depth).

Although neither Coos Bay nor Humboldt Bay have projected channel depths of 40 feet, they have been listed and described. Coos Bay is one of the estuaries in Oregon that has been designated for some industrial development in the Oregon Coastal Zone Plan. Humboldt Bay also appears to have potential for future development.
4.2 PHYSICAL ENVELOPES FOR FACILITY LOCATION

Using the ports having suitable projected channel depths in conjunction with slurry line assumptions, it was possible to delineate broad geographical areas where nodule processing and support facilities might be located. The boundaries were drawn using a 60 mile radius from the existing or projected 40-foot channel area except in those areas where the 3000-foot topographic contour was intercepted. The 3000-foot contour was followed while it remained within the 60-mile radius. There is some overlapping between areas. For the purpose of this study, it is assumed that activities associated with nodule processing would occur within the boundaries of the geographical areas described. A further restriction would locate the processing plant within 15 miles of existing rail facilities. It must be realized that the 60-mile and 3000-foot elevation restriction, while practical in theory, would not necessarily be applicable should economic considerations dictate their extension.

The broad geographical areas delineated and existing rail lines are shown in Figures 4-1, 4-2, 4-3 and 4-4, on the following pages.

Figure 4-1 Valdez is the only geographical area under consideration in Alaska due to harbor depth limitations.

Figure 4-2 Puget Sound, Grays Harbor and the Columbia River are all included in one large area which also includes a portion of northwestern Oregon. Coos Bay is the only other area in Oregon.

Figures 4-3 & 4-4 Humboldt Bay, San Francisco and the area from San Luis Obispo south to San Diego are included. The latter area would be suitable for both conventional pierside and single point moorage.
4.3 ADDITIONAL PHYSICAL CRITERIA

In addition to suitable port facility the study areas must also have those physical criteria such as power, land and water which are given in Table 3-2. The area must also have an infrastructure capable of supporting nodule processing activities. It was assumed that a community in excess of 10,000 people would be satisfactory.
Figure 4-1

Existing or projected 40 foot channel
Figure 4-3

- Humboldt Bay
- San Francisco
- Existing or projected 40 foot channel
- Railroad

North
SAN LUIS OBISPO

Existing or projected 40 foot channel depth or single point moorage capability

LOS ANGELES

SAN DIEGO

Railroad

FIGURE 4-4
5.0 REGULATORY CONSIDERATIONS

5.1 CATEGORIES OF REGULATORY INTEREST

One of the objectives of this study is to identify those areas of regulatory concern which are likely to significantly affect the design, construction and operation of nodule processing facilities on the west coast. Using the information presented in the Phase I reports, which describe the potential processing activities and their relative magnitudes, areas of important regulatory concern have been identified. Particular attention has been given to those regulations which come under the general categories listed in Table IV. The list is not intended to be all-inclusive; it includes only those categories which appear likely to have a significant influence on the location, development and operation of processing facilities.

TABLE 5-1
Categories of Regulatory Interest

1) Solid waste disposal  4) Water use
2) Air quality         5) Water quality
3) Land use           6) Environmental reviews

The relationship between categories of regulatory interest and where their impact might be influential in the developed scenario are depicted in Table 5-2.
Since no nodule processing facilities presently exist, information concerning operations is hypothetical and may be subject to large variations. Therefore, an identification of all applicable regulations is not practicable. Since our focus is on areas rather than on specific sites, we have concentrated on regional regulations and policies. We did not attempt to analyze those regulations requiring detailed knowledge of plant design and/or specific site characteristics. Regulations and policies of particular concerns are those which expressly prohibit construction and/or operation of the proposed processing facilities in an area. Some of those regulations at the federal level are identified and discussed in the following section.
5.2 FEDERAL ENVIRONMENTAL REGULATIONS

Future industrial processing facilities must be designed, constructed and operated as required by comprehensive plans. Part of this planning, especially that affecting discharges to the environment and waste storage, will be required by federal regulations or by approved local regulations. Presently there are at least a dozen federal environmental statutes implemented by seven different agencies. The purpose of this legislation is to check deteriorating environmental conditions, protect public health, reverse or reclaim areas of existing pollution, and to reduce the waste of resources and energy. The following are the major statutes, which, along with their resulting regulations, will affect coastal industrial plants such as the one under consideration:

1) National Environmental Policy Act of 1969 (NEPA);
2) Federal Water Pollution Control Act Amendments of 1972 (FWPCA);
3) Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA);
4) Resource Conservation and Recovery Act of 1976 (RCRA);
5) Safe Drinking Water Act (SDWA);
6) Clean Air Act Amendments of 1974 (CAA); and
7) Coastal Zone Management Act of 1972 (CZMA).

5.2.1 National Environmental Policy Act (NEPA)

This act is a declaration of general goals and policy for the environment. No specific plans or regulations on the maintenance of environmental quality and ecosystems resulted from NEPA although the Council on Environmental Quality (CEQ) was created. NEPA requires Environmental Impact Statements (EIS's) from Federal agencies managing projects or proposing regulations, etc., and projects requiring Federal loans or permits. It is expected that an EIS will be required for the manganese ocean mining and processing activities.
5.2.2 Federal Water Pollution Control Act Amendments (FWPCA)

This act created several programs to stop pollution and reclaim all the waters of this country by 1985. The first intermediate goal of "best practicable technology" by July 1977 has received 90% compliance by industry. FWPCA is administered by the Environmental Protection Agency (EPA) which issues permits and sets standards based on the quality and quantity of effluents. New potential sources of pollutants are required to use waste treatment technologies which are about at the 1983 goal of "very best available."

FWPCA also has provisions for the protection of wetlands. Under a permit program administered by the Corps of Engineers, the rate of wetland filling has decreased but remains at about 300,000 acres/year. A recent Presidential Executive Order (E.O. 1190, May 4, 1977) has further strengthened the act in the area of wetland protection. Federal agencies were instructed to refrain from activities on wetlands unless there is no alternative. An additional government action was the appropriation of $10 million for each of the next two years toward acquisition of wetlands by the U.S. Department of the Interior. Thus increased protection of wetlands will make future industrial siting there questionable. It is also likely that more coastal areas will be set aside as estuarine sanctuaries under the authority of the Coastal Zone Management Act.

5.2.3 Marine Protection, Research and Sanctuaries Act (MPRSA)

Restricted use and availability of land near the coast will make ocean dumping of wastes from industrial processing located in this zone more economically attractive. Ocean dumping, that is the release of
waste from a moving conveyance to the ocean waters, is controlled by MPRSA. It was the intent of Congress in passing this law that ocean dumping of toxic materials be eliminated; Congress has pressed for tough administration of this law by EPA. Thus present dumpers are on implementation plans with a phase-out deadline of 1981. Interim permits are being granted by EPA only where there is presently no alternative to ocean dumping (Ocean Dumping; Federal Register, Vol. 42, No. 7, January 11, 1977).

5.2.4 Resource Conservation and Recovery Act of 1976 (RCRA)

Another law which will discourage (if not eliminate) ocean dumping of the wastes from a future manganese nodule processing facility is the RCRA. This law is also administered by EPA. Regulations have not yet been published but the intent of the law is to control and manage on-land (and other) solid waste disposal in an environmentally sound manner and to increase the recovery of resources contained in wastes. Special attention will be given to hazardous wastes which have not yet been defined but which will probably include materials which may be present in manganese processing wastes. A permit will be required for disposal of these wastes with waste management plans developed to include storage methods, inventory control, and monitoring to prevent the escape of hazardous materials to the environment. RCRA calls for planning on the local and state levels and for the creation of regulations to give economic incentives to conservation. The "polluters pay" principal will probably be employed with the possibility that disposal charges will be imposed on certain consumer products and other sources of waste. RCRA will also control the underground injection of toxic materials and the seepage of leachate containing toxic materials into ground water.
5.2.5 Safe Drinking Water Act (SDWA)

This act protects public drinking water supplies. Part C, "Protection of Underground Sources of Drinking Water," is pertinent in its application to contamination of underground aquifers. EPA-proposed regulations state that underground injection includes any contaminant which may be put below the ground level and moves from the point of introduction. Seepage from waste disposal must not pollute sources of underground water supply.

5.2.6 Clean Air Act Amendments (CAA)

The Clean Air Act Amendments created local air quality control regions and implementation plans to attain a minimum standard of air quality. There is presently no permit system (on the Federal level) for stationary sources but local authorities have the power to bring civil action for non-compliance with emission standards. To achieve the latter, local authority can require emission standards more stringent than the national standards. This means that in heavily congested or polluted areas, emission standards may be very restrictive. New sources are expected to have the very best performance.

5.2.7 Coastal Zone Management Act (CZMA)

In response to a nationwide assessment of the intense pressures and conflicts in the coastal zone the Coastal Zone Management Act was passed by Congress in 1972. The Act affirms a national interest in the effective management, beneficial use, protection, and development of the coastal zone. As a result any incursion into the coastal zone by industry will be restricted by the local coastal plans.
5.3 Federal Regulation and Nodule Processing

Environmental regulations will definitely affect the siting of manganese nodule processing plants. On-site treatment of liquid wastes (as required by FWPCA), and on-land impoundment and storage of tailings (MPRSA and RCRA) will increase land requirements for the plant. At the same time, highly developed areas, because of existing air quality conditions (CAA), wetlands and other protected areas (FWPCA and MPRSA) might be excluded from siting. Lastly, the public review of EIS's (NEPA) and permit application (FWPCA, MPRSA and RCRA) will make public opinion, particularly local public opinion, very important.

5.4 Coastal States and Environmental Regulation

With the exception of NEPA the above public laws will result in separate bodies of regulations for implementation and setting of standards. The FWPCA, CAA and RCRA provide for multi-level environmental and resource planning. States are encouraged to develop plans, administer grants, set standards and take enforcement authority. Local pollution control agencies make urban-industrial or basin area plans to meet national (or locally developed) environmental quality standards, usually including an implementation schedule for phasing-in better treatment technology and insuring that new sources are based on environmentally sound design. In addition states are encouraged to develop management programs for their coastal zones with the authority to implement and enforce promulgated regulations.
6.0 GENERAL INFORMATION ON THE STUDY AREAS

This study has been restricted to the States of Alaska, Washington, Oregon and California. Each of these states has features that differ considerably from other states, at the same time there are some aspects and features which are common to the whole area. The purpose of the following sections will be to describe those features which are similar and disimilar with respect to manganese nodule processing.

6.1 PHYSIOGRAPHIC OVERVIEW

6.1.1 Topography

Each of the states under consideration is mountainous in nature and the mountains extend to the shoreline in several places. Detailed topographic information is included in each area description.

6.1.2 Seismic activity

The west coast states (Alaska, Washington, Oregon and California) are considered areas of frequent earthquakes. (The region composes part of the Pacific rim, which is the belt of greatest volcanic and seismic activity in the world). According to the seismic risk map (Figure 6-1), much of the coastal zone is in a very active area (zones 3 and 4). However, there are sections of the coast that fall into zones 1 and 2, and therefore are no more active than much of the rest of the United States.

The complexity of the geological environment strongly influences the effect of earthquake ground motion, therefore, evaluation of a site requires detailed information on subsurface conditions, distance from the energy release source, extent of the source mechanism, and character of the fault that produces the earthquake.
Additional information (which is not yet available) on active faults in the offshore zone should be considered for full evaluation of specific coastal sites.

6.1.3 Climate

The climate of the study area is influenced extensively by the North Pacific Ocean and the prevailing winds. The Aleutian low pressure system deepens and extends from the Aleutian area into the Gulf of Alaska during winter. The general air circulation is counterclockwise during this season and average winds are southerly along the coast, including Alaska, bringing relatively warm, moist marine air to the coastal areas. Large cyclonic disturbances then develop in the north Pacific and move inland bringing cyclonic rainfall to the coastal/mountainous belt. During this season, the rainfall is heaviest in Washington, Oregon and California coastal zones.

During the summer, the Aleutian low weakens and moves inland and/or decays. At this time, the Pacific high pressure system intensifies and moves northward. The air circulation associated with the high is clockwise causing northerly winds along the coasts of Washington, Oregon and California. During this season, precipitation is very low, but the moderating effects of the ocean maintains relatively cool temperatures on the coast. The northerly winds drive upwelling along the coasts of the states, bringing colder water to the surface along much of the coast. This water is also rich in nutrients, thus, productivity is high, making the area a very important fishery grounds. The cold upwelled water frequently causes considerable fog and/or low stratus along the coast in summer.
Seasonal changes in the atmospheric pressure system over the North Pacific have a pronounced effect on the climate of the west coast. Circulation causes wet but relatively warm winters and dry summers. In general, annual precipitation decreases with increasing distance inland from the coast, except on the west slopes of mountain ranges. Precipitation along the coastal zone tends to decrease from north to south (except for variations due to topography).

The regions of highest evaporation are east of the Cascades in Washington and Oregon, east of the Coast Range, and east of the Sierra Nevada Ranges in California and throughout southern California. In those areas, annual evaporation equals or exceeds annual precipitation.

6.1.4 Oceanography

The general surface circulation of the North Pacific Ocean is clockwise. The North Pacific Current flows eastward to the west coast, most of it turns southward as the California current, a fairly broad slow (maximum speed 0.2 knots in summer) current which extends to the Baja California area. During the summer, the plume from the Columbia River is swept in a southwesterly direction by winds and currents.

Some of the water from the North Pacific Current turns northward off the west coast and becomes part of the Alaska Current or Alaska Gyre which flows counterclockwise around the Gulf of Alaska. This flow brings relatively warm water to the coast of Alaska, moderating the climate.

During winter the same general circulation continues with the exception of the flow along the northern California, Oregon and Washington coasts. During this season the California current continues to flow southward offshore but near shore it is displaced by a northward flow,
the Davidson Current, which attains maximum speed of 0.5 to 0.9 knots. This current brings relatively warm water to the northern coasts in winter. The Columbia River plume is swept northward and generally held onshore during this season.

Sea surface temperatures are influenced by the circulation patterns. In winter, temperatures are about 60°F (15.6°C) near San Diego, decreasing to 45°F (7.2°C) in the Puget Sound area. In southern Alaska, the winter temperatures are near 40°F (4.4°C).

In the summer, the sea temperatures at San Diego are near 63°F (17.2°C) but become much colder nearshore and northward due to upwelling. The nearshore temperatures of northern California, Oregon, Washington and southcentral Alaska average between 55°F and 58°F (12.8°C and 14.4°C).

Surface salinity in summer ranges from about 33.5‰ at San Diego to about 32‰ in southcentral Alaska. Local variations occur due to river runoff and/or upwelling. Locally, the nearshore salinity may be reduced by high precipitation and runoff in winter along the northern California, Oregon and Washington coasts.

The stormiest season, winter, produces the roughest sea conditions. Highest seas are experienced through the northeastern Pacific and Gulf of Alaska during winter. Winds may reach hurricane proportions offshore, generating heavy seas. Sea and swell tend to approach the west coast (Washington, Oregon, California) from the west. In winter the wave approach shifts more to the southwest and south, while in summer the trend is from the northwest.

Since the Pacific rim is an active tectonic belt, tsunamis are occasionally generated. Their effects may be felt along the coastal zone of the study area.
Tides along the entire study area are mixed semidiurnal tides. They increase in range from about five feet (1.5 m) at San Diego to about 10 feet (3 m) in Puget Sound. In Prince William Sound, the tidal range is about 12 feet (3.7 m) while in the upper reaches of Cook Inlet, it is greater than 20 feet (6.1 m).

6.1.5 Ecological Classification

From central California to southcentral Alaska, the coastal belt is classified as a humid temperate marine ecological zone. Within this broad classification, precipitation is seasonal (maximum in winter and minimum in summer) and the temperatures during the coldest months average between -3°C and 18°C and are less than 22°C during the warmest month. Precipitation is seasonal--rainy winters and dry summers. Vegetation is typically coniferous forest, ranging from Sitka spruce-cedar, hemlock forests through redwood forest, cedar-hemlock-Douglas fir forests, California mixed evergreen forests, to silver fir-Doublas fir forest. The Southern California coast is a temperate mediterranean zone being mostly California chaparral.

6.2 PHYSICAL CRITERIA OVERVIEW

The physical criteria, energy and infrastructure, were identified as being critical to the success of a nodule processing venture. The other physical criteria (i.e., railroads, water, flat land, etc.) were assumed to be available within the study areas. The following sections will address both energy and infrastructure on a state by state basis.

6.2.1 Alaska

Alaska has the potential to develop untapped energy resources, specifically coal. For example, if the Beluga coal field in Cook Inlet area is developed in the near future that area would have a source of
relatively cheap electrical power. Preliminary plans for development include the possibility of constructing a coal-fired generating plant at or near Tyonek. The power generated would be for use in industrial facilities that require large amounts of electrical energy, such as certain metal processing industries.

In general it could be said that certain sections of the Alaska coast will have a source of relatively cheap power in conjunction with deep water marine access. However, port and navigation facilities are not developed at this time in most of those areas. Since the OSU workshop considered an infrastructure capable of supporting a population of at least 10,000, this would have to be developed in most areas. It should be noted that future plans for the Tyonek area include infrastructure development.

6.2.2 Pacific Northwest

The State of Washington receives about 94% of its electric power from hydro-electric plants. The hydroelectric systems have provided the state with the lowest cost replenishable supply available in the U.S. The sources of power in the Puget Sound area are not adequate to serve the local demand. Therefore, most of the peak demands are generally met by power generated by hydroelectric plants on the Columbia River system.

The state is reaching the limits of hydroelectric development so other sources must be tapped such as coal and nuclear energy. A coal-fired plant is operating near Centralia. Construction of several nuclear plants in the state are being planned.

The existing electrical energy system does not have a large reservoir of unused capacity. Scheduled completion of new plants will barely keep up with projected increases in demand. However, projections do allow for some industrial growth.
Oregon appears to be nearing the end of an era of relatively inexpensive energy. Important factors in determining the cost and availability of energy are petroleum supply, natural gas supply and electricity available from hydroelectric or other sources. Although electrical energy has been cheap and plentiful, it is now influenced by regional considerations.

Energy consumption is expected to increase during the coming years. Electrical energy supply will have to be increased by either coal or nuclear plants. Officials of Bonneville Power Administration (BPA) are pessimistic about future availability of electrical energy in the state.

Perhaps the most crucial and controversial energy issue in the state is the timetable on which new thermal electric generating plants will be built. There is little agreement of the forecasts for future needs. Timing is further confused by licensing procedures and impact assessments required. Therefore, the availability of electrical power in the future in Oregon is not clear.

The infrastructure situation in the Pacific Northwest is such that those areas which would be suitable for the location of a nodule processing facility possess the required services. These locations are determined both by physical and regulatory considerations.

6.2.3 California

Energy availability at present and in the future depends upon location in California. In the northern coastal portion of the state any large increase in demand would require construction of additional transmission lines from sources inland.
The central coastal area would probably have the electrical power available in the mid-1980's. This of course depends upon the construction of additional facilities in conjunction with expansion of present generating capacity.

The south coastal area power outlook depends upon the construction of nuclear power plants due to the increased costs of oil and natural gas. Coal-fired generating plants would probably not be acceptable in the Southern California area. In general the power outlook in this portion of the state is unclear at this time, especially when considering consumption on the scale of a nodule processing operation.

The infrastructure for a nodule processing operation exists in the California study area.

6.3 REGULATORY/ATTITUDES OVERVIEW

The area of solid waste management, air quality and land use were identified as having the greatest potential impact upon a nodule processing operation. In addition, general public attitudes towards heavy industrial type development were also considered. The areas of water quality and availability were not considered critical from a regulatory point of view. This judgement was made because there was no foreseeable degradation of the freshwater environment as outlined by Dames & Moore. The availability of water for processing was considered a minor factor because of the ability of the system to utilize waste water. Biological impacts were not treated here because they would be treated under the Environmental Impact Statements which would be required. The following sections are a general overview of those significant areas of regulatory concern and public attitudes as they pertain to each of the states in question.
6.3.1 **Solid Waste Disposal**

The disposal of the wastes generated by a nodule processing operation would seem to be the most critical phase relative to regulatory concerns. It is assumed that the wastes would be classified as hazardous under the Resource Conservation and Recovery Act of 1976 which would require containment and isolation from the environment. Although each of the states in question has disposal sites for hazardous wastes, it is questionable if the wastes generated could be absorbed by existing facilities.

Solutions to the problem of wastes disposal consist of three alternatives. The first alternative would be the construction of a longer pipeline to transport the wastes over the Cascade Mountain Range in the Pacific Northwest. This would facilitate the drying of the slurried waste, thus allowing reclamation of the land used. In addition it would also make available the hazardous materials disposal sites in both Washington and Oregon. However, it is still unknown if the sites would be able to absorb the expected volume of wastes generated. Waste disposal in California might also be affected by an extension of the pipeline, especially if the wastes could be pumped to a disposal site in an isolated area.

Alternative number two is to dry the wastes at the processing plant. Prior to drying the wastes those constituents which are considered hazardous to the environment would be removed. The dried waste products could then be disposed of in a landfill or lined tailings enclosure which would facilitate land reclamation. Those constituents removed prior to drying, a very small percentage of the total waste volume, would then be disposed of in such a manner as to ensure their isolation from the surrounding environment. The drying process would be a very energy intensive operation.
Alternative number three was to dispose of the waste tailings in the deep ocean after treatment to render them relatively innocuous to the marine environment. The technology required for ocean dumping is available to the industry with minor modifications. The major factor relating to this method of disposal are legal rather than technical. The trend, as mandated by federal regulations, is away from ocean disposal in favor of confinement of waste products on land.

6.3.2 Air Quality

Each of the states in the study area has air quality standards which are in line with the Federal Clean Air Act Amendment of 1974. Within the study area it was noted that large metropolitan areas are having difficulty in maintaining air quality standards (Southern California, San Francisco, Portland and parts of Puget Sound). In addition there are non-deterioration air quality standards being developed which will impose restrictions upon industrial development in underdeveloped areas.

This study determined that there are various approaches to the problem of air quality maintenance and improvement. These approaches range from best available technology, to no significant emissions, to no significant deterioration, or a combination of the above depending upon region.

The State of California probably has the strictest overall air quality program from a standpoint of emission standards. These standards combined with the interpretation of how they should be enforced make the location of new industry in the state a long and involved process. The authority for enforcement is at the regional rather than state level. This difference in authority creates differences in policy within the state depending upon location.
The level of enforcement in both Oregon and Washington is at the state level. The actual air quality standards are lower in Washington which would probably make the state a more desirable processing location in relation to required air pollution abatement technology.

6.3.3 Land Use

The States of Washington and Oregon and the San Francisco area have federally approved coastal zone management land use programs. Alaska and the remainder of California will soon have approved programs. Certain trends in land use regulation have been identified which will affect the location of nodule processing facilities on the West Coast.

One of those trends is proposed legislation in the form of state industrial planning laws, California being the farthest along in this category. The result of state level planning for industrial siting would be to identify those areas which would be available for development. This would probably benefit industry in terms of knowing where to locate but at the same time would also restrict development to only those identified locations.

The Coastal Zone Management Program has placed emphasis on planning at the rural and local government level. The result of this emphasis has been a greater involvement and an increase in importance of the local government in the industrial siting process. Consequently industry has been mandated to work within land use planning and zoning regulations. The next step for industry would be to become involved in the actual planning process in areas where growth may be anticipated.
6.3.4 Permit Process

The permit process has become a source of controversy due to the requirements of the various federal and state regulations concerning both environmental impact reviews and statements. Some of the trends identified in the permit review are:

1. A movement towards a "one stop" permit process on the state level which would decrease the time and effort required. The "one stop" would require the permit applicant to have all impacts analyzed rather than going one step at a time which is less expensive but requires more time.

2. Preemption of some of the permit problems through land use planning. The concept is to accomplish some of the basic permit requirements for development as a part of the planning process. This would eliminate the need for redundancy between various permit applications.

3. Regionalized permit planning and review to include the federal, state and local requirements. This action would tend to decrease the amount of time and effort required in the review process by combining all requirements into one regional review system. This could be accomplished through joint notices, joint hearings and sharing the same kinds of information, rather than a sequential series of isolated events.

4. Tightening the requirements for permit review times which would in turn decrease the whole permit application and review process.
In addition, the large segments of federal land on the west coast might impose unique siting problems in relation to the remaining U.S. coastline.

6.3.5 Public Attitudes

Public attitudes within an area are a subjective factor, and conflicting opinions can be gathered. Indicators which can be used to "measure" attitudes include environmental and economic development group activities, recent elections and referenda, local resolutions and ordinances, and specific comments from local officials.

In Alaska the recent completion of the oil pipeline and the associated impacts of construction have generated questions about the desirability of continued industrialization. However, there are still efforts being made to attract industry to Alaska. Examples would be the proposed development of the Beluga coal field at the state level and proposed expansion of port facilities at Valdez on the local level. In contrast there are also citizen action groups which are generally opposed to industrial development.

In the coastal areas of the Pacific Northwest industrial development would probably have local government acceptance if not encouragement. This would be especially true in those areas zoned for industrial growth in the coastal zone plans. On the state level, referring to state regulatory agencies and possibly the state public as a whole, the attitude would be much more cautious.

In Southern California the attitude might be towards continued industrial development but environmental regulations would probably severely limit such growth. The same could probably be said for the central California coastal region as evidenced by the recent permit
difficulties of the Dow Petrochemical Project. The northern coastal portion of the state has numerous well-organized environmentally conscious citizens groups. The recent rejection of a hydroelectric project in the Humboldt County area would seem to indicate an anti-development trend.
Figure 6-1
Seismic Risk Map of the United States.

Zone 0 - No damage.
Zone 1 - Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the M.M.* Scale.
Zone 2 - Moderate damage; corresponds to intensity VII of the M.M.* Scale.
Zone 3 - Major damage; corresponds to intensity VIII and higher of the M.M.* Scale.
Zone 4 - Those areas within Zone No. 3 determined by the proximity to certain major fault systems.

*Modified Mercalli Intensity Scale of 1931.
The region of greatest interest to the processing industry is the southcentral region, which includes Cook Inlet and Prince William Sound. This region is characterized by rugged, mountainous terrain with some exceptions such as the lowlands around Cook Inlet, the lower Susitna Valley, the Copper River plateau, and intermittent strips along the coast.

The coastal section of this region is complex. It varies from the islands and fjords of the Prince William Sound area to the wide, shallow Cook Inlet basin. The mountains, in many places, rise abruptly from the sea.

The climate of the region is marine; precipitation and temperatures reflect the marine influence. Precipitation is generally greater along the coast and in the mountains. Temperature ranges are generally not as extreme along the coast as inland. Annual precipitation is about 60 inches (152 cm) and temperatures usually reach upper 50's (F) for mean maximum during summer and the low 20's (F) for mean lows during winter. Occasionally extreme temperatures result from outbreaks of air from the interior - very cold in winter and relatively hot in summer. Evaporation patterns vary along the coast but values are generally less than total rainfall (Figures A-2 and A-3).

Strongest surface winds are in the coastal area. Speeds average from 12 to 18 knots, offshore, decreasing onshore. Extremes of 50 to 70 knots are common in winter, and can exceed 100 knots locally due to topographic effects.

Air pollution is an area of concern in southcentral Alaska, even though it is not a serious problem yet. For air pollution to reach...
serious levels, it is necessary to have a source, proper topography, and air conditions that favor accumulation. The Anchorage area comes closest to having these conditions. Other areas may have all the conditions at present except the source. The potential for pollution in Anchorage is greatest in winter when temperature inversions are strongest and winds are weakest.

Sea ice is found mostly in the upper portion of Cook Inlet. Sometimes, small icebergs break off coastal glaciers and drift along the rim of the Gulf of Alaska. However, they do not persist since the water temperature is about 40°F (4.4°C).

Tidal ranges in Cook Inlet have been as great as 38.9 feet (11.8 m). Tidal currents range from about six knots or more at the narrowest point. Near Valdez, tidal ranges are much less (on the order of 10-12 feet or 3-3.7 m).

Southcentral Alaska is one of the most active seismic areas in the world, the coastal belt being in the greatest seismic risk zone (zone 4). Severe damage resulted at several locations from the earthquake of 27 March 1964 and the tsunami it generated. The following is a detailed description of the one area in Alaska, Valdez, which was considered representative for a manganese nodule processing operation.

2.0 VALDEZ

2.1 General Description

Valdez is located in the Lowe River Valley at the east end of Port Valdez on the northeastern most extension of Prince William Sound (Figure A-1) at an elevation of 15 feet (4.6 m). It is 120 miles (192 km) east of Anchorage. Port Valdez is a three mile (4.8 m) wide steep-walled fjord which extends east-west about 14 miles (22.4 km). It is closely
Figure A-1
Valdez Harbor and vicinity.
surrounded by the Chugach Mountains. At the west end, the fjord turns
toward the southwest and narrows to less than one mile at Valdez narrows,
before joining Valdez arm of Prince William Sound. The fjord's flat
bottom is 400 to 800 feet (122 to 244 m) deep. The shores are rocky
except where inflowing streams and glaciers have built deltas and mor-
aines.

Valdez is the northernmost ice-free port in the United States. It
is on the southern end of the Richardson Highway and the Trans-Alaska
Pipeline. It is on the shortest and most direct route between tidewater
and the Alaskan interior.

About the only relatively flat areas are the large alluvial and
 glaciofluvial deposits which are poorly consolidated. These areas are
about the only places where docks, yards and other facilities could be
built in support of a nodule processing facility.

A 2.2 Oceanography/Climatology

The ocean is most important for its climatic influence on the
Valdez region. However, the effect of tsunamis (especially those gener-
atated by local earthquakes) is one that has to be considered very important
also. Otherwise, the port is fairly well isolated from the open ocean
phenomena (such as wind waves) except for tides. The tides at Valdez
are mixed semi-diurnal, having a mean range of 9.17 feet (2.9 m) and a
diurnal range of 12.0 feet (3.7 m).

The climate of the region is marine, characterized by heavy precipi-
tation and relatively mild temperatures. Local variations in the
region are produced by topography. In general, the climate at a given
location is determined by the following: a) its exposure to moist winds
from the Gulf of Alaska; b) its proximity to a mountain barrier; and, c)
its elevation.
The climate of the area is strongly influenced by the Aleutian low. The low is best developed in winter when it extends southward and into the Gulf of Alaska. The cyclonic flow of the system causes a flow of moist air onto the coastal region of southern Alaska. In summer, the low weakens and moves northward, and the North Pacific high advances further north. Summer heating in the interior generates low pressure which induces an inflow of moist air from the south. The average air flow in the area is from the south or southwest. Locally, the winds will vary in response to the rugged mountainous terrain. The channeling effects of mountain gorges and valleys may cause winds up to 80 knots (148 km/hr) locally. The annual winds average 5.7 knots (15.6 km/hr).

The average annual sea level air temperature in the Valdez area ranges from 39°F to 43°F (3.9°C to 6.1°C). The extremes recorded at Valdez are -28°F and 87°F (-33°C and 30.6°C).

Average annual precipitation is about 62 inches (157 cm) including 144 inches (366 cm) of snowfall; it exceeds annual average evaporation. The precipitation is mostly cyclonic resulting from frontal systems which move inland from the Gulf of Alaska. The flow of moist air over the mountains produces additional precipitation. Rainfall is usually of moderate intensity but long duration; precipitation of five inches (12.7 cm) or more per day is rare. The record 24-hour rainfall at Valdez is 5.10 inches (12.9 cm). Precipitation is fairly well distributed throughout the year. Maximum monthly precipitation is in September and/or October and the minimum usually occurs April through June.

Maximum possible hours of sunshine varies from six hours per day in the winter to 19 hours in summer. Due to frequent cloud cover, Valdez probably receives only about 30% of the amount possible.
A 2.3 Seismicity

Southern Alaska and the Aleutian chain are one of the world's most active seismic zones. It is part of the circum-Pacific earthquake and volcanic belt. It includes the mountains and the continental shelf and slope in much of the region. The northwest seismic zone extending from South America, turns sharply westward in the Valdez area.

About 70 earthquakes of magnitude 5 or greater (Richter scale) have been reported from Valdez since 1898. Five of these have caused submarine landslides.

The Alaskan earthquake of 27 March, 1964 had a magnitude of about 8.3-8.4 on the Richter scale. The epicenter of this earthquake was 45 miles west of Valdez. The loss of life and damage at Valdez resulting from the associated submarine slides and tsunami was greater than in many other sectors of Alaska. A complete discussion of the disaster may be found in Wilson and Trum (1968).

The earthquake of 1964 also triggered many subaerial landslides and avalanches in the mountains, causing considerable damage to roads.

A 2.4 Ecology

Vegetation of the region varies with elevation, soil conditions and exposure. Sitka spruce (Picea sitchensis), up to 18 inches (45.7 cm) in diameter, predominates on the slopes upward to about 350-400 feet (107-137 m) in elevation. Underbrush in the spruce area consists of blueberries (Vacciniaceae), devils club and sparse alders (Alnus crispa). Above 400 feet, alder predominates but there are scattered patches of salmon berries (Rubus spectabilis) and blueberries interspersed with squirrel-tail grass (Hordeum jubatum).
Flood plains tend to dense covers of willow shrubs (Salix alaxensis). Cottonwood (Populus trichocarpa) also grow on the flood plain.

There are about 30 species of mammals that use the land area around Port Valdez. Some of the species are brown bear, black bear, mountain goat, coyote, snowshoe hare, red squirrel, weasel and meadow vole. About 150 species of birds are found in the area. Water fowl are numerous. Many of them are diving ducks. Mallards are the only dabbling duck found year around in significant numbers while pintails are probably the most common breeding dabblers. Several other species are spring migrants. Geese are uncommon breeders in the area. Bald eagles congregate in the Port Valdez area during the salmon spawning season. The Prince William Sound area is an important migration route for birds of the Pacific flyway, the Copper River Delta being a key feeding and resting point for many species.

Alaska is famous for fish. Fishery resources are an essential part of the subsistence for many Alaskan natives. The fisheries are also important for sport, hence have potential value for tourism and recreation. It is one of the few places in the United States where sport fishing has not been maintained by hatchery operations. The native fish population in the sparsely populated wilderness area has a strong attraction for the outdoorsman.

Marine sport fishing has developed in the Valdez area because of the abundance of salmon and its relatively easy access from the Alaskan interior. The fishery is mostly pink and coho salmon. Pink salmon are taken in early June through August. Coho appear early August to early September.
Marine fauna of southcentral Alaska have been only poorly surveyed. Prince William Sound represents a protected fjord coast that supports one of the major salmon fisheries of the northern Gulf of Alaska. Prince William Sound is also a major herring spawning area and a productive fishery for tanner and Dungeness crabs.

The streams flowing into Port Valdez are typically turbid in the summer because of silt from melting glaciers in the headwaters. The streams usually run clear in fall and winter. The Lowe River system has resident populations of Dolly Varden. It also is an important stream for production of sockeye, pink and chum salmon. Other streams in the area support turbot, lake trout, grayling and some steelhead.

Even though traces of human activities are found, mostly transported by the atmosphere from other regions of the world and local construction of roads, buildings, pipeline, etc., the natural conditions are relatively undisturbed. The marine environment has been used by man since early times; even so, his inroads are not very evident and the area remains relatively primitive.

2.5 Socioeconomics

Being the northernmost ice-free port in Alaska, Valdez is the center of trade and commerce for most of the people in the adjacent area. With the exception of the oil industry (activities such as pipeline operations and associated tanker traffic) the town subsists mostly on fishing, trans-shipment activities, government service and tourism. The 1970 census listed the population at 1,005. Estimates of population in the vicinity during peak months of pipeline construction reach about 10,000. It is estimated that about 6,700 lived within the city limits as of December 1975.
The old town was almost completely destroyed by the 1964 earthquake. The town has been relocated about four miles west of the old position on a geologically more stable area. The town is backed by steep, picturesque mountains and, being in a relatively pristine area, it has considerable potential for tourism and recreation (especially hunting and fishing).

Keystone Canyon of the Lowe River and Thompson Pass are very scenic areas. The mountains around the Valdez area are also very scenic. The scenic areas coupled with the excellent sport fisheries, make a potentially strong future for the tourist industry.

Natives of the Prince William Sound area are descendents of Alaskan Eskimos (Chugachigmiut, now called Chugach). Many of them are commercial fishermen and due to the seasonal nature of fishing, they rely heavily on subsistence use of fish and game resources.

There is no rail service between Valdez and the interior, although there are rail barge facilities. Several truck lines operate over the Richardson Highway which connects with the major roads of the state. The port is serviced by regularly scheduled airlines. Bus service is available to Anchorage.

The community has two hospitals and a medical clinic. In addition to elementary educational facilities, the community has a senior high school. There is a public library in Valdez.

Communication facilities include a local radio and television station and cable TV. The local newspaper is published weekly. The telephone system is operated by Copper Valley Telephone Co-op, Inc.

The principal economic base in the area is the oil industry. In addition to tourist related activities, the State of Alaska, particularly in health, social services and highways, employs a substantial number of people.
The "permanent" labor force is small. The pipeline labor force came primarily from other areas.

It is estimated that about 3,000 acres (in lots up to a full section) may be available for industrial siting within the city limits. Water and sewage services are supplied to industry by the City of Valdez. The water is drawn from wells. Real property is taxed at 10 mills. There is a city sales tax of 4%. The city maintains a police department and a volunteer fire department.

A 3.0 RESOURCE AVAILABILITY FACTORS

A 3.1 Energy

There is a hydroelectric plant being proposed for the area, the Solomon Gulch Hydroelectric Project by Copper Valley Electric Association, Inc. The Katalla coal field (between Valdez and Cordova) may eventually be developed, thus, there is potential for power of the amount required for a nodule processing operation in the region.

A 3.2 Water

Streamflow in the Prince William Sound area remains high during June and July from snow melt, and August and September from rain and glacial melt. Maximum flows result from heavy rains in August, September and October. The general streams in the area provide an ample supply of water. The average flow of the Lowe River is estimated at 1,160 cfs. As a result, water would be available in the area for processing requirements.

A 3.3 Waste Disposal

Solid waste disposal in the immediate Valdez area may be difficult to arrange since the terrain is rugged with poorly consolidated alluvial deposits. The excess of precipitation over evaporation, both along the
coast or east of the adjacent mountain range, would make contained disposal of wet tailings and subsequent land reclamation difficult.

A 4.0 REGULATORY/ATTITUDES

A 4.1 Land Use

Land is zoned for specific uses, including industrial, in Valdez. Seismic risk has caused prohibition of permanent structures in some areas. The port does not yet have firm development plans. One of Alaska's primary assets is an unspoiled environment with an abundance of clean water, pure air and pleasing scenery. Regulations concerning protection of the environment generally are under jurisdiction of the Department of Environmental Conservation. Regulations have been developed for wastewater disposal, water quality, solid waste management and air quality control. All development is subject to the environmental constraints defined in these regulations. The Federal Clean Air Act is probably the most stringent regulation that would have to be satisfied in Alaska.

The Alaskan Coastal Zone plan is still in the formative stage.

A 4.2 Attitudes

At the present time the general attitude towards development in Alaska is in a state of flux. There are two groups those who favor and those who oppose continued development of "heavy" industry. The community of Valdez is generally sympathetic to industry due to the areas' dependence on the oil pipeline. Evidence of an attitude towards continued growth would be the effort of the Valdez Port authorities to encourage more marine transportation and related activities in the area.
Precipitation values include the water equivalent of the snow.

Adapted from National Weather Service and U. S. Geological Survey

Figure A-2

Average annual precipitation (cm) for Alaska. From Alaska Regional Profiles - Southcentral Region.
Mean annual evaporation from small lakes (cm) for Alaska.

Figure A-3
Maximum temperatures (°F) for January and July in Alaska. From Alaska Regional Profiles - Southcentral Region.
B 1.0 PACIFIC NORTHWEST

Four areas have been identified in the Pacific Northwest: two in Washington (Puget Sound and Grays Harbor); one in Oregon (Coos Bay); and one shared by the two states (the Columbia River). These areas have many things in common, particularly topographic, oceanographic, climatic and biotic regimes.

The major physiographic features of the region include the Coast and Cascade Mountain ranges, Puget Sound, the Columbia River, and the Willamette Valley. The Columbia River is the boundary between the two states from near McNary Dam to the Pacific Ocean.

The Coast Mountain Range is characterized by high precipitation, in excess of 100 inches (250 cm) per year. To the east of these mountains is an area of valleys or rolling hills which have a lower annual rainfall of about 30 to 40 inches (75-100 cm). East of this low lying zone are the Cascade Mountains, which extend from the Canadian border to the Siskiyou Mountains along the Oregon-California border. Precipitation increases going up the west slope of the Cascades, ranging from 70 to 100 inches (175-250 cm). East of the Cascades are high semi-arid plateaus with annual precipitation as low as six inches (15 cm) in certain areas. Evaporation generally exceeds precipitation east of the Cascades (see Figures B-1, 2, 3, 4, 5, 6 and 7).

Population, agricultural and general economic activities are concentrated in the Willamette Valley and Puget Sound lowlands, as well as in some of the larger river valleys. One of the major economic bases for the region has traditionally been forestry and related wood products.
B 2.0 PUGET SOUND

B 2.1 General Description

The Puget Sound area has several lowland regions backed by the Cascade Range to the east and the Olympic Range along the coast to the west. The area is bounded on the south by a range of low hills that separate the drainage area of the Sound from the Chehalis River basin. The Sound extends northward into Canadian waters. It is, in effect, an inland sea having numerous channels, bays and inlets (Figure B-8). There are two main branches: the western one in Hood Canal, a long narrow channel extending southward about 50 miles (80.4 km); the much larger eastern branch is where the deep-water harbors are located.

The lowland areas are alluviated river valleys. These valleys are where most of the population, industry and agriculture are located. The valleys are separated by gently rolling areas and include terraces, lakes and marshy depressions. The transition from lowlands to mountains is rather abrupt in most of the area.

The Cascade Range has high ridges 8,000 feet (2,438 m) in the north and lower ridges of 5,000 feet (1,524 m) in the south. Several inactive volcanic peaks are located in the region: Mt. Baker, Glacier Peak and Mt. Rainer. The Olympic Mountains are not as high as the Cascades but are nonetheless rugged and scenic.

Puget Sound is one of the few natural protected deep water harbor areas in the world. There are several cargo handling ports on the Sound: Bellingham, Anacortes, Everett, Seattle, Tacoma, Olympia, and Port Angeles. From Olympia, the southernmost port, to Canada is about 171 nautical miles (316.8 km). Depths range from 70 to 200 feet (21.3 m to .60.9 m) as close to shore as 500 feet (152.4 m). Therefore, the area
Figure B-1
Puget Sound and vicinity.
is navigable by the larger tankers or bulk carriers. Most harbors have
berth side depths of 35 feet (10.7 m), but depths up to 80 feet (24.4
km) are available here.

B 2.2 Oceanography/Climatology

The Sound is part of a large marine complex which extends to and
includes the Strait of Georgia. The system is stratified—relatively
fresh water lies on saltier water. The surface layer moves seaward,
while the lower layer water flows landward.

Minimum and maximum annual surface salinities observed in the
southern reaches of the Sound are approximately 17%/oo and 31%/oo,
respectively. Salinities decrease to zero upon entering an estuary
system. Surface water temperatures in the southern reaches have the
following annual minimum and maximum: 43°F and 62°F (6.1°C and 16.7°C)
(except in shallow protected areas when the maximum may reach 70°F
[21.1°C] or more). In the northern reaches, conditions are somewhat
moderated in that the maximum annual temperature is near 55°F (12.9°C)
and the minimum annual temperature is 45°F (7.2°C) while salinities
range from nearly 15%/oo to 31%/oo.

The climate is mid-latitude west coast marine over most of the
area. The region experiences wet but relatively mild winters and dry
moderate summers. Factors exerting major influence on the local climate
are distance from the ocean, topography and prevailing winds.

Average annual precipitation varies from 35 to 50 inches (88.9 cm
to 127 cm) over most of the lowlands (except in the rain shadow of the
Olympic Mountains where it may be as low as 15 inches [38.1 cm]) to 75
inches (190.5 cm) in the foothills and from 100 to 200 inches (254 cm to
508 cm) on the seaward slopes of the Olympic and Cascades. Most of the
rainfall is cyclonic and/or orographic. Much of the precipitation in the mountains falls as snow. Thunderstorms do occur but are not common except in the mountains in summer. Tornadoes are practically unknown in the region.

Average annual precipitation exceeds evaporation in the area. To the east of the Cascades, the evaporation may equal or exceed precipitation.

Prevailing wind direction in summer is west or northwest. In winter, winds are generally from the south or southwest. In winter the low pressure system off the coast and cold airflow through the Fraser River Valley (Canada) may cause strong northeasterly winds especially over the northern section. Summer winds are normally light. Maximum winds are associated with storms moving inland from the coast. Hurricane force winds are rare but winds up to 55 miles per hour (88.5 km/hr) can be expected about once in two years.

Maximum summer temperatures over the area range from low 70's°F (21.1°C) along the water, to 100°F (37.8°C) in lower valleys. However, the average July temperatures range from 60-65°F (15.5 to 18.3°C) in most of the area. Winter temperatures average 30-40°F (-1.1 to 4.4°C) in January (except in the mountains).

B 2.3 Seismicity

Most of the Puget Sound is in seismic risk zone 3. The only area of seismic risk less than 3 is the Olympic Peninsula which is zone 2. The tsunami generated by the Alaskan earthquake of March 1964 was observed in the Sound area. Water rose 5.3 feet (1.6 m) above predicted tide level at La Push on the Olympic Peninsula. However, only minor damage was reported in the Sound area. Some of the damage was caused by seiching
in Lake Union. The seiching was not caused by the tsunamis but by the 
earthquake.

B 2.4 Ecology

Environments found in the region include marine, forest, stream and 
mountains. Due to the wide range of environments, the area supports a 
wide and abundant variety of fish, shellfish, game animals and wildlife.

Terrestrial wildlife includes the following big game animals: 
black-tailed deer, elk, black bear, mountain goat, and mountain lion. 
Many species of valuable fur animals are also found in the area: beaver, 
muskrat, mink, river otter, marten, lynx, weasel, skunk, bobcat, red 
fox, coyote, and raccoon.

Game birds of the area include the following upland species: blue 
grouse, ruffed grouse, ring-necked pheasant, California quail, mountain 
quail, cottontail, snowshoe rabbit, and band-tailed pigeon. Major 
species of waterfowl include mallard, pintail, canvasback, ruddy duck, 
harlequin, ring-necked duck, wood duck, redhead, oldsquaw, bufflehead, 
whidgeon, scaup, goldeneye, green-winged teal, shoveler, black brant, 
Canada goose, lesser Canada goose, snow goose, cackling goose, and 
white-fronted goose.

Numerous shorebirds and seabirds are found in the region. Songbirds, 
predators and wading birds are also found throughout the region.

Endangered species found in the area include trumpeter swan and the 
bald eagle.

Natural vegetation of the area is predominantly dense coniferous 
forests. The lowlands have some natural grass covered areas. At higher 
elevations, alpine flora are found.
The principal forest tree of the region is the Douglas fir. Other important species are western hemlock, western red cedar, western white pine, lodgepole pine and Sitka spruce. Hardwoods found in various locations at lower elevations include red alder, big-leaf maple, Oregon ash, willow, and black cottonwood. Near the grass covered areas, Oregon white oak is found.

Undergrowth and shrubs of the area may include various ferns, huckleberries, oceanspray, elderberry and Oregon grape.

The most important fish are salmon and searun trout. They are valuable to both the commercial and the sport fishery. Salmonids of importance include chinook, coho, pink, chum, sockeye, steelhead and trout. Salmon spawn in several of the streams that drain the Puget Sound basin. The fish are harvested inside the Sound and in the ocean off the west coast of Vancouver Island and along the Washington coast north of La Push.

Other major marine food fish harvested in the general area include Pacific halibut, Pacific ocean perch, petrale, sole, flounder, lingcod, true cod, herring, surf smelt, and many rockfishes. Other species are harvested for fish meal and/or animal food and include dogfish, skate, ratfish, and hake.

The Sound supports a wide variety of shellfish. The most abundant clams are littleneck, butter, horse, and Japanese littleneck. Other less abundant species are geoduck, softshell, cockle, and piddock. There are three species of oysters that are abundant: Olympic, Pacific and Kumanmoto. Other mollusks present include abalones, scallops, mussels, squid, and octopi.
Crustaceans found in the Sound include the Dungeness crab and 
several species of shrimp.

B 2.5 Socioeconomics

Population in the Puget Sound region has grown rapidly, especially 
since the 1940's. The major center for land, air and sea transportation 
is Seattle, population 530,831. The second largest city of the area is 
Tacoma with 154,581 people. The populations of other cities are as 
follows: Everett - 52,100; Bellingham - 39,375; Olympia - 23,111; 
Bremerton - 35,307; Port Angeles - 16,367; and, Anacortes - 7,701. The 
total metropolitan population is greater than indicated by these figures. 
The area comprises nearly two-thirds of the population of Washington.
Seattle and Tacoma are the major industrial and commerce centers of the 
region. The region serves as an important center for sea and air traffic 
to the Far East and Alaska. The Puget Sound area is served by the 
following major railroads: Burlington Northern, Milwaukee Road and 
Union Pacific. There are two major interstate freeways serving the 
area: I-90 (to the east) and I-5 (north-south). Other Federal highways 
serving the area are U.S. 2 (east from Everett) and U.S. 101 serving the 
Olympia area from the south. There are numerous state highways connecting 
the various ports of the region. Several major truck lines connect the 
area with other west coast and inland centers. The major airport is 
Sea-Tac which is between Seattle and Tacoma. Direct passenger and 
freight service is available to most major U.S. cities and several major 
foreign cities.

There are several private and public universities and colleges in 
the region. The largest, University of Washington (enrollment 34,500), 
is in Seattle.
The economy of the northern sector of the Sound has a broad base including forest products, oil refining, aluminum production, manufacture of logging equipment, electronics, food processing and boat building. Tourism and agriculture are also important economic factors.

In the central Puget Sound region, manufacture of transportation equipment, forestry related industry, metals and machinery related industries constitute the principal economic activities. Foreign trade, transportation, warehousing and tourist oriented services are an increasing source of employment. Government employment is high because of the shipyard at Bremerton, as well as Ft. Lewis and McChord Air Force Base near Tacoma. In addition, there are many regional federal offices in the area.

Economic activities of the southern sector of the Sound are dominated by forest products and agriculture, as well as state government and administrative services.

The area has a large skilled labor force, and educational facilities geared for training of new skills. The region has traditionally been dependent for employment on several key industries exporting raw, partially processed and finished products to foreign and U.S. markets. In the past few years unemployment has been relatively high.

The major port is Seattle, which is 124 nautical miles (229.8 km) from the open ocean via the Strait of Juan de Fuca. It has two deep water harbors. The Outer Harbor is in salt water and includes Elliott Bay, Harbor Island east and west waterways, and the Duwamish Waterway. Most Elliott Bay facilities can handle vessels with 50 feet (15.2 m) draft. The Inner Harbor is all fresh water: Lake Union and Lake Washington. The lakes are connected to each other and are accessible from Puget Sound through a dredged channel and navigation locks.
The Port of Seattle handles over 40% of the import cargo bound for the northwestern states (of the lower 48) from Pacific Rim countries. Leading imports are limestone, lumber, gypsum, newsprint, sand, automobiles, metal sheet and plate, and electronic equipment. Major exports include grain, flour, wood products, peas, hay, and tallow.

The Port of Tacoma is 18 nautical miles (33.3 km) south of Seattle, and 142 nautical miles (259.8 km) from the Pacific Ocean. It is the second largest port on the Sound. Channels and berths have depths from about 30 to 50 feet (9.1 m to 15.2 m). One of the port's major activities is importation of minerals. It has facilities for transshipping bulk ores to a smelter in Idaho. Major imports include salt, wood products, aggregate, ores, rubber, iron, steel, and meat products. Leading exports are wood products, grain, alumina, scrap iron, copper alloys, tallow and vegetables. Salt and limerock are import cargos handled at private docks.

Bellingham Harbor is 80 nautical miles (148.2 km) north of Seattle and 108 nautical miles (200.1 km) from the Pacific Ocean. The channel depths are maintained at 30 feet (9.1 m) or less. Major types of cargo handled are logs, pulp, aluminum, salt, general cargo and chemicals. Private facilities include pipelines for handling petroleum, lignosite, and alcohol. Alumina is also an important cargo handled at private facilities in the area between Cherry Point and Sandy Point.

The Port of Anacortes is about 17 nautical miles (31.5 km) south of Bellingham and 93 nautical miles (172.3 km) from the open ocean. The harbor can be reached via Guemes Channel, a three mile long and one-half mile wide (4.8 m and 0.8 m) waterway in excess of 60 feet (18.3 m) depth. Pierside depths, however, are not more than 35 feet (10.8 m) at
present. Forest products and fish products are the major commodities handled at the port.

The Port Angeles Harbor, 56 nautical miles (103.8 km) east of Cape Flattery, is the port closest to the open ocean of all the ports in Puget Sound. However, it is farther from the major industrial centers than any other harbor in the Sound. It is a large volume forest products export port. The port is on the Strait of Juan de Fuca, the main route for ocean shipping entering the Sound. Pierside depths range from 31 feet to 45 feet (9.4 m to 13.7 m).

Other ports on the Sound are Bremerton and Port Townsend. However, they do not have deep-water public terminals.

B 3.0 RESOURCE AVAILABILITY FACTORS

B 3.1 Energy

The state of Washington receives about 94% of its electric power from hydroelectric plants. The hydroelectric systems have provided the state with the lowest cost replenishable supply available in the U.S. The sources of power in the Puget Sound area are not adequate to serve the local demand. Therefore, most of the peak demands are generally met by power generated by hydroelectric plants on the Columbia River system.

The state is reaching the limits of hydroelectric development so other sources must be tapped such as coal and nuclear energy. A coal-fired plant is operating near Centralia. Construction of several nuclear plants in the state is being planned.

The existing electrical energy system does not have a large reservoir of unused capacity. Scheduled completion of new plants will barely keep up with projected increases in demand. However, projections do allow for some industrial growth.
B 3.2 Water

The greatest consumptive users of water in the area are for municipal and industrial purposes. Other uses are irrigation, power, fish hatchery operations, forest product mills and recreation. Greatest water consumption is in the Tacoma-Seattle and Everett metropolitan areas.

The river basins with the largest average runoff that drains into the Sound are the following:

- Nooksack River
- Skagit River
- Stillaguamish River
- Green River
- Puyallup River
- Nisqually River
- Snohomish River
- Cedar River
- Skykomish River
- Elwha River

Together these rivers receive 84% of the total runoff in the Puget Sound area. There are several other small rivers, however.

The total runoff into the area averaged about $39 \times 10^6$ acre feet per year from 1931-60. Seasonal flows may be very high in winter and very low in late summer (usually July-November). Most major floods occur when warm rainstorms hit the area from October to March. The runoff is increased when the warm rains cause snow melt.

B 3.3 Waste Disposal

Disposal of waste tailings in slurry form may be a difficult problem in the Puget Sound area due to the annual rate of precipitation being much greater than evaporation. If it were possible to slurry the wastes east of the Cascades the disposal problem may be much easier to solve.

B 4.0 REGULATORY/ATTITUDES

B 4.1 Land Use

Competition for land use comes from agriculture, forestry, urbanization and industrialization. Within the area there are limited amounts
of land owned by port districts which may be available for future marine industrial development. These areas are generally zoned for industrial use. The Washington Coastal Zone Plan has an impact on land use within the Sound.

B 4.2 Attitudes

The general attitudes toward new industry in the area are subject to change and therefore are difficult to assess. At present the conflict over supertanker traffic on the Sound and the associated industrial development indicate attitudes both for and against development in the area.
Figure B-2
Mean annual precipitation (inches) - Oregon.
From Pacific Northwest River Basins Commission,
The Regional Appendix II, 1969.
Figure B-3
Average January temperature.
Isotherm interval = 4°F.

Figure B-4
Average July temperature.
Isotherm interval = 4°F.
Figure B-5
Mean annual precipitation (inches) - Washington.
From Pacific Northwest River Basins Commission,
The Regional Appendix II, 1969.
Figure B-6
Figure B-7
Average annual lake evaporation in inches (period 1946-1955).
Figure B-8
West coast mean annual precipitation by district. From U.S. Department of Commerce Environmental Science Services Administration Weather Bureau.
C 1.0 GRAYS HARBOR

C 1.1 General Description

Grays Harbor (Figure C-1) is located at the mouth of the Chehalis River in southwestern Washington, about 45 miles (72.4 km) north of the Columbia River. Aside from the ship channel, the harbor is shallow, predominantly less than 20 feet (61 m) deep. There are six rivers that empty into Grays Harbor.

The harbor entrance is about 2.5 miles (4.0 km) wide. At the entrance, the channel is about 70 feet (21.3 m) deep at mean lower low water. At present, the 600 foot (182.8 km) wide navigation channel is maintained at 30 feet (9.1 m). The projected depth is 40 feet (64.4 m). Ship loading facilities of the upper harbor are in the Chehalis River.

Several marshes surround the bay and several small creeks drain the local area. There are about 44 square miles (26 km$^2$) of tidal flats that are exposed at mean lower low water. The area around Grays Harbor is generally of low relief, with a few of the Willapa Hills to the south reaching 600 feet (182.8 m). The rugged Olympic Mountains to the north have a maximum elevation of 7,965 feet (2,427.7 m) (Mt. Olympus). The Olympic Mountains provide a substantial drainage area, including the Humptulips, Hoquiam, Wishkah, Wynoochee, and portions of the Chehalis River basin which empty into Grays Harbor.

C 1.2 Oceanography/Climatology

Waves over 40 feet (12.2 m) high may be generated offshore by winter storms along the coast. Seas and swells approach predominantly from the northwest to west throughout the year. Local seas may approach from the southwest and south-southwest during fall and winter, and from the north-northwest during spring and summer. Ocean swells may pass
Figure C-1
Grays Harbor and vicinity.
into the harbor entrance. Occasionally winter storms cause closure of
the bar.

Tides are mixed semidiurnal. The mean range varies from 6.4 to 7.9
feet (1.6 to 2.4 m) depending on location in the estuary. The dirunal
range varies from 8.1 to 10.1 feet (2.5 to 3.1 m).

Grays Harbor is classified as a positive partially mixed coastal
plain estuary. The salinity varies with position in the estuary as well
as seasonally. Surface salinity increases from 0°/oo in Chehalis River
to oceanic values (approximately 30°/oo in summer) at the mouth. It is
influenced seasonally by the Columbia River plume in winter and by
upwelling in summer. The Columbia plume is fresher than adjacent ocean
surface waters while the upwelled water may have higher salinity.

Water temperatures in the bay may vary from 37.4°F to 39.2°F (3°C
to 4°C) in December to a high of 69.8°F (21°C) in July and August.
Diurnal fluctuations in temperature are influenced by tides and upwelling.

The area has a typical marine climate with relatively mild winters
and cool and relatively dry summers. Average air temperatures range
from 39.7°F (4.3°C) in January, to 60.8°F (16°C) in August. Local winds
are influenced by the surrounding Willapa Hills and the Olympic Mountains.
Along the coast, the winds are predominantly southerly in winter, and
northerly in summer. Annual average precipitation varies from 70 to 100
inches (177.8 to 254 cm) generally decreasing from Aberdeen westward.
Annual precipitation exceeds evaporation throughout the area.

The seasonal changes in winds coincide with the deepening and decay
of the Aleutian Low and the building and decline of the Pacific High.
The strongest winds are out of the south and southwest during winter.
Storm winds of hurricane force are reported occasionally in the offshore
and coastal areas.
1.3 Seismicity

Grays Harbor is in seismic risk zone 2, indicating a region of very moderate seismic activity. There have been two epicenters in the region: one, an earthquake of magnitude between 3.7 and 5.0, and one equal to or less than 3.7. The tsunami generated by the Alaskan earthquake in March 1964 was observed along the Washington coast. However, no damage was reported in Grays Harbor.

1.4 Ecology

The mild wet marine climate along the coast supports dense coniferous forests. Species vary locally and with elevation and logging practices. Trees commonly found include: Alaska cedar, western red cedar, Sitka spruce, western hemlock, and Douglas fir. Deciduous trees also occur especially along streams and in disturbed areas. The most common is red alder, but big leaf maple, Oregon ash, black cottonwood and golden chinkapin also occur.

Underbrush may be especially dense in the wettest zones. It is generally made up of various ferns, huckleberries, creambush, oceanspray, elderberry, Oregon grape and salal.

Large animals that may be found in Grays Harbor area include Roosevelt elk (Olympic mountain region), black-tailed deer, black bear and mountain lion. Fur-bearing animals include muskrat, raccoon, skunk, fox and beaver. Game birds include several species of waterfowl, grouse and pigeon.

Many other forms of wildlife are found in the area. Included are amphibians, non-game birds and animals, insects, spiders and other invertebrates.
The region is noted for the salmonid species that occur. These species are important to the commercial fishing and sports fisheries. Species included are chinook, coho, sockeye, chum and pink salmon. Dolly Varden, steelhead and cutthroat trout are also found. Other fish in the area are white sturgeon and Pacific lamprey. Commercial marine species landed also include herring, halibut, flounder, rockfish, greenling, lingcod, seaperch, sole and hake.

Red and Dungeness crab are found in coastal waters including estuaries. Ocean beaches produce razor clams while bays may produce horse, littleneck, cockle, softshell, butter and other clams. These shellfish are important to the sports fishery. The Pacific oyster is produced commercially in North and South Bays.

C 1.5 Socioeconomics

There are three cities at the head of Grays Harbor: Aberdeen, Hoquiam and Cosmopolis. These cities are served by U.S. Highways 101 and 12, and State Highway 105. They are about 109 miles from Seattle. Population within the cities (1970 census) is 30,554 and within Grays Harbor County, 59,553.

The area is served by three railroads: Burlington Northern, The Milwaukee and Union Pacific. Major west coast truck lines serve the area. There is no major air service, but commuter air service is available to and from Seattle. Two 5,000 foot runways are suitable for executive aircraft.

Each of the three cities has a municipal water and sewage system. They also offer police and fire protection. There are 12 elementary, 3 junior high schools, and 2 high schools in the area. In addition, Grays Harbor College (2 year) is in Aberdeen. The area has two hospitals.
Each of the cities has mayor-council forms of government. Each has zoning ordinances and building codes.

The major sources of employment (in decreasing order) are manufacturing, retail trade, and services. There are seasonal fluctuations in employment in construction, logging, cranberry and seafood packing. Unemployment has been a continuing problem in recent years. For example, in 1975 unemployment was 12.4%.

There are 243 manufacturing firms in Grays Harbor County. Most of them are involved in forestry related activities.

Industrial sites are available in the area.

C 2.0 RESOURCE AVAILABILITY FACTORS

C 2.1 Energy

Washington receives about 94% of its electric power from hydroelectric plants. Power from the projects in Washington is also exported to other western states. The hydroelectric systems have provided the state with the lowest cost replenishable supply available in the U.S. However, the state is reaching the limits of hydroelectric development so other sources must be tapped such as coal and nuclear energy. A coal-fired plant is operating near Centralia. Two nuclear plants are in the application/construction process in Grays Harbor County. They are scheduled for completion in 1982 and 1984. If the scheduled completion of new power sources are realized there should be power available in the Grays Harbor area.

C 2.2 Water

Fresh water enters Grays Harbor from the Chehalis, Hoquiam, Wishkah, Wynoochee and Humtulips Rivers. Annual input by the major rivers averages 10,500 cfs. Additional inflow from smaller streams varies between 125
and 599 cfs. The lowest flow is in the summer months; estimates have placed the flow as low as 1,000 cfs. During winter the flow may exceed 65,000 cfs. The water supply in the area seems more than adequate for a nodule processing operation.

C 2.3 Waste Disposal

The Department of Ecology has established a comprehensive statewide program for solid waste management. Each county, in cooperation with its cities has established a coordinated, comprehensive solid waste management plan. Permits are required to operate new or existing solid waste disposal sites to insure that they comply with comprehensive plans.

Normal waste disposal in the Grays Harbor area is through one of the municipal systems. Large volumes of tailings would be difficult to handle, especially if they are wet as precipitation exceeds evaporation in the area.

C 3.0 REGULATORY/ATTITUDES

C 3.1 Land Use

The Washington Coastal Zone Plan includes strict zoning and planning requirements in relation to land use. Grays Harbor is one of those areas identified for further industrial growth. This classification would facilitate the locating of a nodule processing industry in the area.

C 3.2 Attitudes

The general attitude in the Grays Harbor area is pro-industry. The economic base for the area is the wood products industry which, if the trend continues, is decreasing in importance. The local port commissions and Chambers of Commerce have been actively soliciting industry in an
effort to broaden the economic base and lessen the impact of fluctuations in demand for wood products.
D 1.0 COLUMBIA RIVER AREA

The Columbia River, the largest stream on the Pacific Coast of North and South America, is the boundary between Oregon and Washington from just upstream of McNary Dam to the Pacific Ocean. The major tributaries are the Okanogan, Kootenai, Clark Fork, Snake and Willamette Rivers. The total drainage area of the system is nearly 259,000 square miles (670,810 km²), most of which lies between the Rocky Mountains and the Cascade Mountains. In the lower regions (the area of prime interest) the following rivers empty into the Columbia: Cowlitz, Lewis, Clatskanie, Youngs, Lewis and Clark, and Skipanon.

The estuary has many winding channels separated by low islands, bars and shoals. Its overall width ranges from less than one mile (1.6 km) (50 miles [80.4 km] from the mouth), to about nine miles (14.5 km) (20 miles [32.2 km] inland). Depths vary from shoal areas to over 100 feet (161 km) below mean lower low water.

The estuary is just seaward of the Coast Range and south of the Willapa Hills. Elevations are generally less than 2,000 feet (3,218 m).

The navigational channel depth is 40 feet (64.4 m) as far up river as Vancouver, Washington (about 106 miles [170.6 km]) and up the Willamette River to Portland, Oregon (Figure D-1). Therefore, the entire section is considered as a potential site.

D 1.1 Oceanography/Climatology

The tide is mixed semidiurnal with mean tidal range at the mouth 6.5 feet (2.0 m) and the range from mean lower low water to mean higher high water 8.5 feet (2.6 m). Tidal effects are observed as far upstream as 140 miles (225.3 km) during low river stages.
Figure D-1
Columbia River and vicinity.
Salinity intrusions vary with the stage of tide and with river flow. During low river flow and lower low water, the seawater intrudes less than 15 nautical miles (27.8 km) but at higher high water, it may extend to nearly 20 nautical miles (37.1 km). At high river flow, salinity intrusions may vary from less than five to about 13 nautical miles (24.1 km) depending on the stage of tide.

The estuary is a positive coastal plain estuary. It varies from well mixed to stratified depending on location, tidal stage, and river flow.

The prevailing direction of winter storm winds is southwest. Frequently the storms last for several days and are accompanied by very heavy seas, mostly from the southwest. Occasionally coastal winds reach hurricane proportions. A study of wave conditions over a 20 year period revealed that the most severe conditions produced waves having a significant height of 33.5 feet (10.2 m) and a period of 13 seconds, approaching the entrance from 234°T. Most sea and swell approach from the northwest to southwest. Severe storms have caused temporary closure of the bar.

The Columbia River area lies in the zone having a marine climate characterized by relatively mild, wet winter, and relatively cool, dry summers. The changes in the Aleutian low and Pacific high produce the wet winter and dry summer precipitation cycles. As one crosses the Cascade Mountains going inland the climate shows greater continental effects, becoming much drier. The net evaporation begins to exceed net annual precipitation in this area. Precipitation ranges from above 78 inches (198.1 cm) at Astoria, to about 37 inches (94 cm) at Vancouver, and about 14 inches (35.6 cm) at The Dalles, Oregon. The precipitation reflects the topographic effects of the Coast Range and the Cascade
Range, as well as distance from the ocean. The annual rainfall on the high western slopes of the Coast Range and the Cascade Range is up to 120 inches (204.8 cm) and 80 inches (20.3 cm), respectively.

Temperatures may range from about 105°F to -10°F (40.5°C to -26°C). The extremes and ranges both tend to increase with distance upstream. The average temperature in July ranges from 60°F (15.6°C) along the coast to 72.5°F (22.5°C) at The Dalles. The January averages are 40°F (4.4°C) and 32.7°F (0.4°C), respectively.

Winds are seasonal throughout the area, generally being from the north in the summer and from the south or southwest in winter. The channeling effect of the mountains influences wind speed and direction, especially in the Columbia Gorge.

Cyclonic storms move inland during the winter. Winds accompanying these storm systems may reach hurricane force just offshore and on the open coast. Inland the maximum winds are usually less than 60 miles per hour (96.5 k/h) (except in mountain passes and the Columbia Gorge).

D 1.2 Seismicity

The seismic risk map of the U.S. shows the lower Columbia River area is all in zone 2. Epicenters of earthquakes of magnitude 3.7 to 5.0 mostly lie in the Portland-Vancouver area. One epicenter for an earthquake of magnitude between 5.0 and 6.3 was located a few miles downstream from Vancouver.

The tsunami generated by the Alaskan earthquake of March 1964, was noted on tide records up the Columbia River, at least as far as Vancouver. However, no significant damage was reported in the area except at Cannon Beach, Oregon (on the open coast, about 25 miles [40.2 km] south of the Columbia River estuary).
D 1.3 **Ecology**

The lower Columbia River (below Vancouver) including its banks and islands is biologically rich and is a substantial recreational resource. About 175 species of birds have been identified in that section. There are several areas of good waterfowl habitat. The lower Columbia is in the Pacific flyway for migratory waterfowl. Several species winter in the area and some (mallard, cinnamon, blue-winged teal, wood ducks and Canada geese) also nest there. Upland game birds include ring-neck pheasant, California quail, mountain quail, blue grouse, ruffed grouse, bobwhite and band-tailed pigeons.

Zooplankton in the system consists mostly of cladocerans and copepods. The benthos in the lower reaches consists largely of amphipods, both freshwater and marine types. The Dungeness crab, sand shrimp and blacktail shrimp are found in the lower portion of the estuary. Crayfish are found above salt water intrusion, nearly everywhere in the system.

Rare or endangered species frequenting the area include the Aleutian Canada goose and the osprey (rare in Oregon but common along the lower Columbia). Other species rare in Oregon but not on the national list are found in the region.

Large animals include deer and elk. The black-tailed deer is common on the east side of the Cascades; mule deer are also common east of the Cascades. The Columbian white-tailed deer, which is found in the lower Columbia River region, is an endangered species.

Forest areas along the lower Columbia consist of mixed hardwoods and conifers. Species found include: willow, cottonwood, red alder, big leaf maple, ash, Douglas fir, red cedar and western hemlock. Shore pine occurs near the mouth. Dense underbrush may be found throughout,
including elderberry, thimbleberry, Pacific service berry, wild rose, blackberry, red flowering currant, gooseberry, snowbush, gorse and scotch broom.

Amphibians include red-legged, spotted, tree, bull and tailed frog, as well as several salamanders. Reptiles include painted turtle, northern alligator lizard, and rubber boa, racer, gopher, common garter and northwestern garter snakes. None of the reptiles or amphibians are on the rare or endangered species list.

Fur-bearing animals present include beaver, muskrat, mink, raccoon, nutria, foxes, rabbits, squirrels and black bear.

Dungeness crab and shrimp occur in commercial quantities in the lower reaches of the estuary. Crayfish have been harvested commercially in the lower Columbia region for many decades.

Anadromous fish in the system include salmon (pink, chum, sockeye, coho and chinook), steelhead, shad, smelt and lamprey. Freshwater species of interest are white sturgeon, white fish and trout. Warm water game fish also exist in the system. The most important commercial and sport species are salmon, sturgeon, steelhead, smelt and shad. Trout are of considerable interest to sportsmen, especially in some of the tributary streams.

Other species resident in the estuary include: flounder, sculpins, surf smelt, tom cod, blennies, perch, sole, peamouth, sticklebacks, dogfish, skates, hake and rockfish.

D 1.4 Socioeconomics

The lower Columbia is bordered by Columbia, Multnomah, Clackamas and Clatsop counties in Oregon, and Pacific, Wahkiakum, Cowlitz and Clark counties in Washington. Communities along the river having popula-
tion over 2,000 are Astoria, 10,740 (1974); Longview/Kelso, 28,373/10,296 (1970); St. Helens, 6,855 (1974); Vancouver, 42,493 (1970); and Portland, 373,200 (1974).

Manufacturing and trade employ the largest number of workers in the area. These two fields are followed by construction and agriculture. Commercial fishing is also important. In 1974, the commercial catch by fishermen in the Astoria area was $13.7 \times 10^6$, the ninth largest catch for any U.S. port.

There are three major east-west transportation modes--road, rail and water. One major railroad (Burlington Northern), two highways (U.S. Highway 30 and U.S. 26) an inland water route, and a natural gas pipeline serve the area. Most follow the Columbia from Portland to the Coast. The major north-south highway along the coast is U.S. 101. Interstate 5 is the major north-south route of the region. Interstate 80N, U.S. Highways 26 and 30 serve Portland from the east, while State Highway 14 serves Vancouver from the east.

Barge traffic is extensive all along the lower Columbia and extends past several dams into the interior. Barge traffic consists mainly of logs, grain, paper, petroleum products and fertilizer.

The area is an important center for the production and movement of goods in both regional and international trade.

Fishing, boating, swimming, water skiing, hunting and camping are principal recreational activities along the river.

D 2.0 RESOURCE AVAILABILITY FACTORS

D 2.1 Energy

Oregon appears to be nearing the end of an era of relatively inexpensive energy. Important factors in determining the cost and avail-
ability of energy are petroleum supply, natural gas supply and electricity available from hydroelectric or other sources. Although electrical energy has been cheap and plentiful, it is now influenced by regional considerations.

Energy consumption is expected to increase during the coming years. Electrical energy supply will have to be increased by either coal or nuclear plants. Officials of Bonneville Power Administration (BPA) are pessimistic about future availability of electrical energy in the state.

Perhaps the most crucial and controversial energy issue in the state is the timetable on which new thermal electric generating plants will be built. There is little agreement on the forecasts for future needs. Timing is further confused by licensing procedures and impact assessments required. Therefore, the availability of electrical power in the future in Oregon is not clear.

The energy predictions for Washington are a little more optimistic since the coal-fired plant has been placed in operation near Centralia, and several nuclear plants (six) have been approved or are nearing approval, and at least one is scheduled for completion in 1978. However, as in Oregon, the expansion of hydroelectric generating capacity is no longer feasible. Thus, the end of relatively inexpensive electrical energy is rapidly approaching. However, projections for future supply and demand in Washington do allow for some industrial growth.

D 2.2 Water

Although some communities do take their water from the lower Columbia, most do not. Water from the river is used for irrigation and industry (principally pulp and paper mills). The river is used extensively for navigation, recreation, fish and wildlife and dilution of industrial waste.
The flow of fresh water through the estuary varies seasonably. Even though the lower tributary streams, where runoff is highest in winter, peak during winter months, the discharge through the system normally peaks in May, June or July. The peak discharges normally are associated with snow melt in the higher elevations of the watershed. The maximum discharge of record was estimated at 1,200,000 cfs (June, 1894) and the lowest has been estimated at 65,000 cfs. Low flows are from September through March. The normally wide range of flows is now decreased by the many dams on the system.

The quantity and quality of water required for nodule processing activities would be available from the Columbia River system.

D 2.3 Waste Disposal

Disposal of tailings may be difficult in the Columbia River area, especially if they are wet. Net precipitation exceeds evaporation throughout the lower Columbia River region. The problem of tailings disposal could be solved in the northwest by dumping at sea. If dumping at sea is not possible, it will be difficult to arrange disposal, especially in an area where precipitation exceeds evaporation by a substantial margin. An alternative is to transport the tailings to possible disposal sites east of the Cascade Mountains. There is a general feeling that it would be easier to get approval for locating the entire processing facilities east of the Cascade Mountains. In either case, transport of nodules or wastes would be required. It is conceivable that transshipment could be made near Vancouver to barge, rail or pipeline. The general area of processing could then be in the vicinity of Dallesport, Washington or The Dalles, Oregon, some 80 to 90 miles up river from Vancouver. Since this distance exceeds the boundaries of the area delineated, we have not prepared a description of the area.
D 3.0 REGULATORY/ATTITUDES

D 3.1 Land Use

Washington and Oregon have obtained Federal approval of coastal zone management programs. In addition, Oregon is developing comprehensive land use plans in all counties. A nodule processing facility would have to be planned and operated within the constraints of the respective land use plans.

D 3.2 Attitudes

In general, there is apprehension to large industrial development in western Washington and western Oregon, but there are local exceptions. Some of the coastal communities are anxious to improve their economic status and to relieve the high unemployment rates that have persisted over the past few years.
E 1.0 COOS BAY

Coos Bay is the largest natural harbor between the Columbia River and San Francisco Bay (Figure E-1). It is about 13 miles (21 km) long and has a mean width of 1,200 feet (366 m) at low tide. The channel is maintained at 40 feet (12.2 m) over the bar. Congressional authorization has been received to deepen the channel over the bar to 45 feet (13.7 m) and to deepen the channel to 35 feet (10.7 m) to mile 15. Channel width varies from 40 feet (12.2 m) to 300 feet (9.4 m) wide.

The Coos River and the endless streams that empty into Coos Bay rise in the Coast Range just east of Coos Bay. The drainage basin is about 605 square miles (1,567 km$^2$). The maximum elevation in the Coast Range near Coos Bay is 1,700 feet (518 m).

The bay is a coastal plain estuary which varies from well mixed to stratified, depending on distance from the mouth, river flow and tidal stage.

Coos Bay is in seismic risk zone 1, the lowest risk zone of the entire west coast and Alaskan areas under consideration.

E 1.1 Oceanography

The area is strongly influenced by the Pacific Ocean and the Pacific high and Aluetian low. The California current brings relatively cold water from the north Pacific during summer. At this time, the water temperature is reduced even more by upwelling induced by northerly winds. In winter, the Davidson Current brings relatively warm water along the coast from the south.

The mixed semi-diurnal tides have a mean range of about seven feet (2.1 m) and an estimated entrance range of nearly 11 feet (3.4 m).
Prevailing wave direction is from the west. Waves generated by winter storms can cause closure of the bar.

Surface salinity varies from zero in the rivers to ocean salinity near the jetties. There is some season variability, primarily induced by upwelling.

The climate at Coos Bay is typical of the Pacific Northwest Coast—wet winters and relatively dry summers. Annual precipitation varies in the area from 50 to 100 inches (127 to 254 m) depending on elevation. At North Bend, the average is 61 inches (155 cm). Annual precipitation exceeds evaporation throughout the area. Average temperature in January at Coos Bay is 44°F (6.7°C); the minimum of record is 16°F (-8.9°C). The highest average temperature is in August, about 59°F (15°C). Average winds are 11 miles per hour (17.6 km/h), from the northwest in summer and the southwest in winter. Winds associated with winter storms may approach or reach hurricane force at times.

### 1.2 Seismicity

Coos Bay is in seismic risk zone 1, the lowest risk zone of the entire west coast and Alaska areas under consideration. The tsunami generated by the March 1964 earthquake in Alaska was observed at Coos Bay. Damage reported was slight, being estimated at $20,000.

### 1.3 Ecology

Vegetation in the region, with the exception of dune areas north of the bay is similar to other coastal areas in the Pacific Northwest. The active dunes have little vegetation while the stabilized dunes have a succession of plant communities dominated first by grasses, then shrubs and trees. Inland from the dunes, the natural vegetation becomes typical of coastal valleys and coastal forests. The forests generally include
the following species: cedar, fir, spruce, hemlock and red alder. Port Orford cedar also occurs in the area.

The estuarine area includes several salt marshes. South Slough has been designated a National Estuarine Sanctuary under the Marine Protection, Research and Sanctuaries Act of 1972. The tidal flats and salt marshes have an abundance of benthic organisms. Marine mammals are observed in the estuary and include sea otter, harbor seal and California and Stellar's sea lions.

The marshes provide excellent habitat for insects, amphibians and birds. About 250 species of birds use the estuarine area. The area is an important resting, feeding and wintering ground for birds using the Pacific flyway. Of the birds found in the area, the bald eagle, osprey, snowy owl, common egret and brown pelican are listed as rare, endangered, threatened, or peripheral species. The only mammals in these categories are the white-footed mole and the sea otter. Major game animals are black-tailed deer and elk. Fur-bearers include black bear, mountain lion, rabbit, squirrel, badger, raccoon, bobcat, coyote, fisher, fox, mink, muskrat, nutria, skunk and weasel. Game birds are pigeon, grouse, quail and waterfowl.

Commercial fishing is an important part of the local economy. Species landed include salmonids, shrimp, tuna, groundfish and crab. Species making up the sport fishing are clams (both softshell and hardshell), Dungeness crab, salmon, steelhead, cutthroat trout, shad and striped bass.

E 1.4 Socioeconomics

The principal communities on Coos Bay are North Bend and Coos Bay. Of the 56,515 people (1970 census) living in Coos County, 14,130 lived
in Coos Bay and 8,980 in North Bend (1974 census). The area suffers from high seasonal unemployment, superimposed on a perennial high unemployment base.

The economy of the area is centered on forest products. Other important segments are fishing, tourism and recreation, and other trades and services.

Coos Bay is an important shipping center for exportation of logs, wood chips, lumber and plywood.

Since about one fourth of all its employment involves the wood products industry, Coos County endures important social and economic impacts during times of extremely adverse, or extremely favorable conditions for that industry. It appears that the downward trend in employment in the wood production industry will continue.

Although commercial fisheries represent an important aspect of the economy, it and tourism, recreation and services all rank far below forestry related activities, both in employment and in total value of products.

Coos County has six school districts. Coos Bay School District has 13 elementary schools, two junior high schools and one high school. North Bend has seven elementary schools, one junior high school and one high school. Southwestern Oregon Community College is in Coos Bay.

Municipal services include police and fire protection as well as water and sewer service.

Coos Bay is served by the Southern Pacific Railroad. The line comes from Eugene to Coos Bay via Florence and Reedsport. It also extends past Coos Bay up the Coquille Valley.

Trucking service has been essential in moving wood products in the region. Other types of truck freight are increasing between the coast and the Willamette Valley.

The one means of transportation that the area has been historically dependent upon, due to relative isolation, is water. At the present time, the major cargo handled at the port docks is wood products. Waterborne trade has continued to increase since the 1940's. The major waterborne import is petroleum products.

E 2.0 RESOURCE AVAILABILITY FACTORS

E 2.1 Energy

The problem of energy at Coos Bay is about the same as elsewhere in Oregon. With the end of hydroelectric expansion essentially here, the alternative appears to be coal and nuclear plants. Coal has been mined in the area in the past; however, we have not seen plans to reactivate the coal operation for electric power generation. Power of the magnitude required for nodule processing might be difficult to obtain in the region.

E 2.2 Water

Average summer inflow of fresh water is probably not more than 100 cfs. Winter and spring freshets may increase the flow to over 100,000 cfs. Water is being used for irrigation and other uses so that salinity intrusion is increasing. Since the water requirements are small there should be no problem obtaining the desired amount of water required.
E 2.3 Waste Disposal

Since the area is one where net annual precipitation exceeds evaporation, disposing of wet tailing on land becomes a serious problem.

E 3.0 REGULATORY/ATTITUDES

E 3.1 Land Use

Curry County (to the south) and the principal cities of the area have comprehensive plans and zoning. Coos County is developing a complete comprehensive plan. The Coos Bay Estuary Plan was adopted 16 May 1975 as an element of the Coos County comprehensive plan. The estuary plan clearly indicates a concern for valuable estuarine resources. However, it reflects a balance of land use between industrial and commercial activities in the bay and the need to preserve and enhance estuarine resources.

E 3.2 Attitudes

The community feeling is assessed as being favorable toward development at present. The problems of decreasing employment opportunities in the major industry of the area is probably an important factor. The outlook for the future has not been good, hence a fairly large percentage of the young workers leave the area to seek employment elsewhere. New industry may elevate the problem.
F 1.0 HUMBOLDT BAY

Humboldt Bay is about 225 nautical miles (417 km) north of San Francisco and 156 nautical miles (289 km) south of Coos Bay, Oregon (Figure F-1). A narrow sandspit which varies in width from 0.2 km to 1.6 km (1/8 to 1 mile) separates the Bay from the ocean. An entrance channel of approximately 2,000 feet (610 m) in width, separates the spit into north and south sections. The width of the spits vary with location, the average being about 3,000 feet (1,000 m). The channel entrance is stabilized by two rubble-mound jetties which extend from the tips of the spits.

The city of Eureka and the Humboldt Bay area lie in the Northern Coast Range physiographic province of California. The Humboldt Bay area is relatively flat and is characterized by the bay tidal flats rising to slightly elevated flats or rolling terraces. The bay is bordered on the south by a narrow ridge, Table Bluff, and is bordered on the east and north by mountains.

The width of the bay varies from 14 miles (0.8 km) to about 4 miles (6.4 km), and is 14 miles (22.53 km) in length. The total surface area of the bay during high tide and low tide is about 25 miles (64.7 km²) and 8 miles (20.7 km²), respectively.

The bay is shallow so channels for fishing boats and shipping vessels are maintained by dredging. The southern portion of the bay extends about 4 miles (6.4 km) south from the entrance. A dredged channel is maintained for 2 miles (3.2 km) from the entrance to Fields Landing, which is about midway along the east side of the South Bay.

A fairly deep natural channel follows the north spit for about 4 miles (6.4 km) to the junction of Samoa and Eureka channels. The Samoa
Figure E-1
Humboldt Bay and vicinity.
channel is dredged for almost 1 mile (1.6 km) at which point it intercepts a natural channel leading to Arcata Bay. There is no commercial traffic on this waterway. The Eureka channel is dredged for almost 2 miles (3.2 km) along the waterfront of the city of Eureka. The bar and entrance channels are presently maintained at 40 feet (12.1 m), with the North Bay, Samoa and Eureka channels being dredged to 30 feet (9.1 m). The Corps of Engineers is recommending that the North Bay, Samoa, and a portion of the Eureka channels be deepened to 35 feet (10.7 m) below mean lower low water.

F 1.1 Oceanography/Climatology

The tidal range between mean lower low water and mean higher high water is 6.4 feet (1.9 m) at the south jetty, and 6.7 feet (2.0 m) at Eureka. The average tidal discharge through the channel entrance is 2,831 m³/sec (100,000 cfs). Tides of more than 2 feet (0.6 m) below mean lower low water have been recorded. In 1885, a high tide inundated the lower sections of the Eureka water front. The entrance channel is directly exposed to high waves generated by high winds of local coastal storms, and to long period waves generated by distant offshore Pacific storms. Both types of waves usually occur between November and April, the critical area of approach being from the southwest through northwest. During severe winter storms wave action causes closure of the entrance channel.

The Humboldt Bay climate is characterized as coastal in nature with cool summers and very wet winters. The Coastal Mountains and the Pacific Ocean are the main factors influencing the region's weather. Warm, moist air moving onshore is forced up over the mountains, causing it to cool and the moisture to condense, resulting in heavy rainfall on the
coast and windward slopes. Snow occurs in the mountain peaks in the winter.

About 90 percent of the annual precipitation occurs between October and April. Rainfall may average slightly less than 50 inches (127 cm) along Humboldt Bay, but more than 100 inches (254 cm) per year may fall in the mountains to the southwest.

The maritime coastal climate has only a 10°F (-12.2°C) average daily temperature variance between winter and summer. Maximum temperatures on the coast rarely exceed 80°F (26.6°C), but 100°F (37.8°C) readings in the mountain valleys to the east are not uncommon. Freezing temperatures are experienced nearly every winter. Annual average precipitation exceeds evaporation.

Severe storms, winds and squalls occur frequently along the coast, particularly during the winter season. Heavy fogs occur in this area most frequently during July, August and September, while December and January are relatively free of foggy weather.

F 1.2 Seismicity

Humboldt is located near one of the most seismically active regions in California. The majority of the earthquakes recorded occur on active faults in the ocean floor off the coast of Cape Mendocino and extend seaward along the Gorda escarpment which is 50-80 miles (80 to 128 km) southwest of Eureka. An active branch of the San Andreas Fault Zone extends inland 50 miles (80 km) southwest of Eureka. The Freshwater Fault is south of Arcata and is projected to run under Arcata Bay.

The region experiences three or four 4.0-4.9 magnitude events per year; one 5.0-5.9 magnitude event per year; one 6.0-6.9 magnitude event every five years; and one major event greater than magnitude 7.0 every
28 years. Because Humboldt Bay is located within a seismically active region, it is assumed that the area will continue to be subjected to periodic shocks of varying intensity.

The most recent tsunamis to impact on the northern California coast occurred in the years 1960 and 1964. Humboldt Bay suffered little or no damage from these seismically induced waves. Potentially damaging currents did occur within the bay as a result of the rapid changes in water level.

F 1.3 Ecology

A variety of vegetational habitat types are found in the Humboldt Bay area. Dominant among these are the redwood forest area located along the mountain ranges and lands to the east of the Bay. Another prominent habitat type is urban-agricultural land. This area is composed of urban and suburban developed lands and those lands which are being utilized for agricultural purposes. The maritime climate also supports Douglas fir forest and woodland prairie types of vegetation.

Humboldt Bay is a major wintering area for over 100 species of migratory water birds and the adjacent shorelines provide habitats for many additional land and semi-aquatic species. The bay supports three species of loons, five kinds of grebes, twenty varieties of ducks, three kinds of cormorants, pelicans, three species of geese, black brant, ten types of gulls, terns and seabirds. The area is able to support this large variety of bird life primarily due to the broad selection of food organisms including snails, clams, worms, fish and other marine organisms. The bay eelgrass beds are a source of food for brant and ducks. The bay also offers a resting area for other birds.
Within the Humboldt Bay area eight general animal habitat types have been identified. These habitat areas provide various species of wildlife with suitable food, resting or escape cover and nesting areas.

The waters of Humboldt Bay provide habitat for 95 species of fish representing 41 families.

More than half the fish consumed in California are landed at the Port of Eureka, a leading fish and shellfish producer on the California coast. The annual fresh fish and shellfish catch of local vessels is more than 30 million pounds. The value to the economy of the fishing and associated industries has been estimated in excess of $15 million.

The most important commercial fish are salmon, sole, rockfish and crab. Shrimp are also landed and processed locally. Oysters are farmed commercially in Humboldt Bay and account for almost 90 percent of the oysters consumed in California.

Trawling operations are year-round with nearly 200 commercial vessels registered locally. In addition another 500 commercial boats from other West Coast parts utilize the Port of Eureka facilities.

There are two fish hatcheries operating on the bay. One of the hatcheries is operated by the California Department of Fish and Game, which specializes in silver and king salmon production. The other hatchery is owned and operated by Humboldt County and specializes in silver and king salmon, steelhead, cutthroat and rainbow trout.

F 1.4 Socioeconomics

The relative remoteness of the Humboldt Bay area and the nature of the rugged terrain separating it from the rest of the state makes transportation an important factor in the area's societal and economic existence.
Approximately 250 miles (460 km) of state highways exist in Humboldt County. The most important highway system is the north-south U.S. Highway 101. More than half of its 135 mile (216 km) county length is four lanes or more. Future plans of the California Department of Transportation call for the upgrading of the highway to full freeway between San Francisco and Eureka.

Branches off Highway 101 are state sign routes (SSR) 36 and 229. SSR 36 branches to the east at Alton, 24 miles south of Eureka, and continues east to Red Bluff and Interstate Highway 5. It is a narrow scenic route and used primarily for minimal local transportation. SSR 299 branches east at Arcata, traversing the state, crossing Interstate 5 at Redding. It is a wide, two-lane road and carries most of the west bound traffic into the area.

There are two rail lines serving the Humboldt Bay area; the inter-county Northwestern Pacific and the intra-county Arcata and Mad River. The Northwestern Pacific (NWP) with classification yards and servicing facilities in Eureka is the area's main rail carrier. The NWP serves all major docks and forest products facilities in the county and connects with other rail facilities at the Southern Pacific yards at Schellville in Sonoma County, California.

Forest products account for almost 90 percent of all revenue traffic from Humboldt County. Nearly 98 percent of the freight traffic is southbound. Passenger service does not exist at this time.

Arcata Airport, the area's main landing field, is located at McKinleyville. The runway is 6,000 feet (1,829 m) long, has air crash service and 24-hour fuel availability. Hughes Air West and Golden Pacific serve the area with scheduled jet flights. The city of Eureka also maintains its own airport.
Waterborne commerce has been utilizing Humboldt Bay for more than a century. The Port of Eureka imports mainly fuels such as gasoline and oil. Chemical products are also important (from domestic sources) to serve the wood pulp industry.

Historically forest products have been the major export commodity in the bay's waterborne commerce. These products currently include logs, wood pulp, wood chips, staves, mouldings, lumber, plywood, veneers and miscellaneous wood products. Lumber products and wood pulp have accounted for an average of approximately two-thirds of waterborne commerce from 1964 to 1974.

Approximately 0.5 percent of California's population is in Humboldt County. The 1970 census listed county population as 99,642. This number has increased by about 1,000 each year since. Fifty percent of the population clusters in the towns and cities around Humboldt Bay. Approximately 80 percent live along the length of U.S Highway 101.

According to the 1970 census, 25 percent of the people in the county live in Eureka, population 24,377. Another 23 percent live in the six other incorporated cities: Arcata, 8,985; Blue Lake, 1,112; Ferndale, 1,352; Fortuna, 4,203; Rio Dell, 2,817; and Trinidad, 300. Estimates for 1975 indicate Eureka has grown 0.6 percent, while Arcata has increased from 8,085 to 11,650, or 30 percent.

A high percentage of the work force in the proximity of Humboldt Bay and in Humboldt County is classified as laborers, other than farm laborers. This is a key element in the economic activity of the Humboldt Bay area.
F 2.0 RESOURCE AVAILABILITY FACTORS

F 2.1 Energy

The Pacific Gas and Electric Company operates a nuclear power plant four miles south of Eureka at King Salmon on Humboldt Bay. In addition to nuclear energy the plant also uses gas/oil (two generators) to supply the region with electric power. The PG & E plant can produce a total of 172,000 kilowatts from its three generators. The county is also tied into PG & E's grid system which can provide additional power when needed. The county's daily peak demand averages 110,000 kw.

Humboldt County has two active natural gas fields: Tompkins Hill field and Table Bluff field. These fields are connected to the PG & E gas pipeline system and contribute about 25 percent of the natural gas requirements of the county. The remainder is brought in via a 12-inch main from Red Bluff.

Local PG & E officials have expressed the opinion that the electrical power requirements of a manganese nodule processing facility, either three or four metal extraction, is not presently available in the Humboldt Bay area. To supply the amount of power required would necessitate the construction of new power transmission lines from PG & E sources outside the area.

F 2.2 Water

Although Humboldt County has access to approximately one third of the state's total surface water runoff, only a small portion of this water is available on a sustained basis. The Humboldt Bay Municipal Water District is the only major supplier of industrial water. The district is presently capable of supplying 75 million gallons of water per day. Of this amount, 60 million gallons are supplied to industrial
users and the remaining 15 million gallons are sold or reserved for municipal and domestic use.

The water required for the processing of manganese nodules is not large when compared with present industrial consumption. Water availability should not be a problem in the Humboldt Bay area.

F 2.3 Waste Disposal

At the present time, there are no existing class I disposal sites in the Humboldt area. The nearest sites are located in Solano and Contra Costa Counties in the San Francisco Bay area. Class I disposal sites are required for environmentally dangerous waste which is defined as "a waste material containing substances which are hazardous or toxic, or which could seriously impair the quality of usable waters, as a result of any disposal of such wastes." The wastes produced would probably have to be considered hazardous.

F 3.0 REGULATORY/ATTITUDES

F 3.1 Land Use

Humboldt County's growth and land use have developed around the Bay area. Large public and private land ownerships have helped to contain the sprawl and leap frog development which was common in other areas prior to extensive development of land use plans. Out of 2,287,000 acres (3,573 square miles) approximately 24 percent of the county's land use is forest, 10 percent is agriculture, 6 percent is in public use, 4 percent is residential, 3 percent water resources, 2 percent is industrial and one percent is commercial. Within the land zoned for industrial use there is probably a site suitable for a nodule processing facility.
F 3.2 Attitudes

The general attitude towards industrial development in the Humboldt Bay area is negative. This attitude is reflected in the county plan and by such authorities as Port District Planners, Chamber of Commerce officials, County planners, and local environmental group representatives. Another indicator of an anti-development attitude would be the recent rejection of a hydroelectric project by the voters. The increasing attractiveness of the area as a retirement community has also contributed to anti-industrial sentiment.
G 1.0 SAN FRANCISCO BAY AREA

San Francisco Bay is located on the western coast of the United States, in the State of California, at 38° latitude and 122° longitude. The watershed of the bay extends through the Sacramento and San Joaquin Valleys of central California. There are nine counties bordering the bay which encompasses 6,949 square miles (17,922 km²). Of this area, 400 square miles (1,036 km²) are covered by the bay. This makes San Francisco Bay one of the world's largest estuaries, approximately 55 miles (88.5 km) long on a north-south axis, and 2-13 miles (3.2-21 km) wide on an east-west axis (Figure G-1).

The Bay area includes approximately 65 separate municipalities of which four (San Francisco, Oakland, San Jose and Berkeley) are over 100,000 in population, 12 exceed 50,000, 33 exceed 10,000 and 16 have less than 10,000 (1970 census). These urban areas constitute eight percent of the region's total land surface area.

San Francisco Bay is connected to the Pacific Ocean by a deep narrow channel between Marin Peninsula on the north and San Francisco Peninsula on the south. The Golden Gate channel and much of the bay consists of drowned valleys of the Sacramento River and tributaries. The Bay area lies completely within the Coast Range that forms the western border of the Sacramento-San Joaquin Valley. The Coast Range with its included valleys comprises a general northwest-southwest belt nearly 400 miles (643 km) long with an average width of 50 miles (80.4 km).

The mountains consist of steep-sided hills, the highest elevation being 3,489 feet (6.943 m) on the East Bay and 2,604 feet (4.190.7 m) in north Marin County. The other elevations are generally below 2,000
feet (521 m). The main ridges are Santa Cruz to the southwest of the bay, Bolinas to the northeast, Sonoma to the north, and Diablo and Berkeley Hills to the east.

G 1.1 Oceanography/Climatology

Tide volume in San Francisco Bay is almost ten times the average volume of freshwater input. At mean tide, the system contains 235 billion feet$^3$ ($6.65 \times 10^9$ m$^3$) of brackish water. South San Francisco Bay is the largest of the four sub-bay systems and contains about 90 billion feet$^3$ ($2.55 \times 10^9$ m$^3$) of water or 38 percent of the total mean tidal volume of the Bay.

The tidal cycle of the bay is mixed semidiurnal, consisting of two high and two low tides. The mean tidal range at the Golden Gate is 5.8 feet (1.7 m) while at Suisan Bay the range is 5.6 feet (1.6 m).

Currents in the bay system are primarily induced by the tides. Non-tidal currents also occur; they are caused by wind stress, salinity or density gradients, and river inflow. The large-scale pattern of the currents in the bay is influenced by bottom topography and depth.

There are wide contrasts in climate in the area surrounding San Francisco Bay. In the city of San Francisco, fog and low stratus clouds are typical, especially in summer. During the summer months the temperature of the Pacific Ocean is usually low near the coast (due to upwelling) and atmospheric pressure is low. This situation tends to intensify the landward movement of air and to make the prevailing westerly winds brisk and persistent, especially from May to August. This steady sweep of air from the Pacific results in a climate with few extremes of heat or cold within the Bay area. Another characteristic of the climate is a pronounced wet and dry season. On the average, 85 to 90 percent of the
total annual rainfall, 8–30 inches (20.3–76.2 cm), occurs between November and April. The climate of Oakland and other east bay cities is similar to that of San Francisco except that the daily mean temperatures are about 4°F (2.2°C) higher, at maximum, and 4°F (2.3°C) lower, at minimum. Annual precipitation at Oakland Airport is about 3 inches (7.6 cm) lower than at San Francisco, 20.5 inches (52.1 cm).

Areas to the east and north of the bay experience warmer and sunnier weather. The amount of annual rainfall is influenced by the extent of sheltering provided by the coastal mountains. On the east side of the coastal mountains, average temperatures increase while annual rainfall decreases.

The amount of annual evaporation increases with distance moving from west to east within the San Francisco study area. Within a few miles of the coast, the annual evaporation may exceed precipitation.

G 1.2 Seismicity

Three major active fault zones transverse the area in a northeast-southeast direction. These are the San Andreas Fault, the Hayward Fault, and the Calaveras Fault. All but the Calaveras have experienced earthquakes of seven or greater on the Richter Scale.

Earth tremors are frequent although usually not severe. Earthquakes severe enough to cause serious damage since 1850 occurred in 1865, 1868 and 1906. Each time the most extensive damage was done in areas of artificial land fill and tidal marshes. Major design, engineering, construction and maintenance problems should be anticipated for any type of slurry pipeline that crosses the fault and mud fill area. Processing and port facilities would need to be designed and constructed to withstand earthquakes.
Within the Bay area, damage to vessels and harbor facilities is possible due to the swift currents which could be generated by tsunamis. The tsunami generated by the Alaskan earthquake of March 1964 was greatly attenuated after passing through the Golden Gate. Even so, some damage to pleasure boats did occur at some marinas. The open coast, especially south of the entrance to San Francisco Bay, is very susceptible to damage from large waves generated by seismic activity.

G 1.3 Ecology

The San Francisco Bay area represents the largest estuary on the California coast. The estuary originally had 476 square miles (1,237 km²) of water and about 300 square miles (777 km²) of marsh. Some of this area has been filled in.

The waters of the bay are generally turbid, reducing area suitable for attached and rooted plant growth to only the very shallow water and the marsh area. Large algae, kelp and higher plants, such as eel grass, are found in some portions of the system.

The natural terrestrial vegetation east of the bay consists of a mosaic of grasslands and shrub areas. The grassland areas are a mixture of annual grasses and forbs. The grassland areas are used for grazing throughout the year, even though the green season is late fall, winter and early spring. On hilly terrain, grasses occupy the more xeric sites while the most mesic sites are occupied by dense stands of broadleafed evergreen shrubs and trees.

The Coast Range is covered by mixed conifer forests, mostly Douglas fir. Redwood is found mixed with the Douglas fir in some areas.

Shorebirds are by far the most abundant group of birds found in the bay system and their principal feeding habitat is in the tidal flats.
Each year thousands of these birds migrate to their wintering grounds around the bay. Aerial surveys conducted by the California Department of Fish and Game, from 1965 to 1968, tallied average daily totals of nearly 100,000 shorebirds. Rough estimates projected from these data indicate a total bay area population of some 400,000 birds.

Food habitat studies indicate that the principal food items of shorebirds were small clams, worms and snails. All three of the groups of food organisms abound in the shallow tidal flats.

San Francisco Bay, including San Pablo and Suisun Bays, provides habitats which encourage both diversity and abundance of marine, freshwater and terrestrial animals. The deeper saline portions of the bay are inhabited by marine animals which require protected marine waters while the shallow San Pablo and Suisun Bays provide less saline water for true estuarine organisms. The marshes and freshwater streams provide spawning areas for anadromous species and nursery grounds for their young.

The anadromous fish probably contribute more to the fishery of the bay than any other group. Adults must pass through the bay to reach their spawning grounds and the young utilize it as a nursery grounds and during their movement back to the sea. Species that utilize the bay in this manner are king salmon, steelhead trout, striped bass, shad and sturgeon. Approximately 70 percent of the king salmon landed in California area are from the Sacramento-San Joaquin River system.

G 1.4 Socioeconomics

A massive complex of highways, arterials, local roads, bridges and parking areas serve automobile and truck traffic. Mass transit modes
include bus, rail, air and ferry. Rail systems include the Bay Area Rapid Transit (BART) system, AMTRAK and the Southern Pacific, Union Pacific and Western Pacific Railroads. Nationwide rail service is through terminals in Oakland.

Passenger air service is provided at San Francisco and Oakland International Airports and San Jose Municipal Airport. More than 20 airlines have regularly scheduled service from San Francisco and Oakland to major cities throughout the United States. Several overseas flights originate in San Francisco.

The San Francisco Bay area is one of the major west coast port systems in the United States. The predominate commodity shipped is petroleum. International trade is an important aspect of bay area shipping. Most of the foreign commerce is with the Far East; imports from Japan predominate.

The population of the San Francisco Bay area is estimated at 5,906,600 and includes the nine Bay area counties and the three counties of the Sacramento Delta area.

G 2.0 RESOURCE AVAILABILITY FACTORS

G 2.1 Energy

The energy required for a manganese nodule processing operation would probably be available in the mid-1980's. This forecast depends upon the construction of additional facilities in conjunction with expansion of present generating capacity.

G 2.2 Water

The water required for a manganese nodule processing operation could be available in the San Francisco Bay area. The net delta inflow into the bay is estimated to be about 16,800,000 acre-feet per year.
under present upstream development conditions. Since the quality of the water required is not a significant factor there should be adequate waste water available, especially in the quantities required.

G 2.3 Waste Disposal

There are currently three Class I disposal sites in the San Francisco Bay area. These are the Pacific Reclamation and Disposal Site, Sierra Reclamation and Disposal Site, and West Contra Costa Disposal Site. It is questionable if any of these existing disposal sites would be able to absorb the quantity of solid wastes generated by a nodule processing operation. It may be necessary to transport tailings to as far as the desert in Nevada where disposal areas could probably be arranged.

G 3.0 REGULATORY/ATTITUDES

G 3.1 Land Use

The location of major industrial facilities are significantly impacted by local planning. There are a limited number of deep water access sites in the bay area and such areas as Suisun Marsh and the Delta have important regional, if not national, environmental values. Any industrial development will have to be consistent with regional planning goals. This approach was recently strengthened by the Federal 208 water quality planning program for the Bay area to be conducted by the Association of Bay Area Governments, the State Air Quality Maintenance Plan and other regional environmental management programs.

G 3.2 Attitudes

Attitudes towards industrial development in the Bay area reflect a continuum from pro- to anti-development. There are many influential environmentally conscious groups in the Bay Area which would probably be opposed to new industrial growth of the manganese nodule processing
category. However, there are also economic development organizations which are attempting to attract new industry to the Bay area. A general attitude towards manganese nodule processing activities in the Bay area would probably be negative, judging from recent developments concerning the proposed Dow Chemical Plant in Solano County.
H 1.0 SOUTHERN CALIFORNIA

The following counties could be affected by manganese nodule processing activities in the Southern California area: San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange and San Diego. This includes an area of roughly 8,000 square miles (20,720 km²) (Figure H-1).

The southern California area has a highly varied landscape with valley lands, rolling hills, and rugged mountains. The Los Angeles basin consists of all the lowlands between the San Gabirel and San Bernadino Mountains on the north, the San Jacinto and the Santa Ana River on the south and the Pacific Ocean on the southwest. The Santa Clara River feeds the Ventura Basin in the Santa Inez Mountains to the north which extend from Santa Barbara west for 60 miles to Point Conception. The Sierra Madre is the major range of mountains to the east of Point Conception. The Lucia Range is inland of the coastal plain, east of San Luis Obispo.

H 1.1 Oceanography/Climatology

The southern California Bight is defined as the open embayment of the Pacific Ocean bounded on the northeast by the reach of the north American coastline extending from Point Conception, California to Cabo Colonet, Baja California. To the west, the California Current is the major oceanographic factor in the area. The area is dominated by the Southern California countercurrent and the complex weather systems that move in from the Pacific Ocean. These two systems interact to produce highly variable oceanic conditions in the bight.

The coastal climate of the Southern California area is known as a subtropical mediterranean type with warm, dry summers, and mild, rainy winters. The higher mountain areas receive intermittent snow in the winters.
Figure H-1
Southern California Area
The seasonal rainfall is approximately 10 inches (25.4 cm) in the coastal segments of this area and increases with elevation and distance from the coast. About 75 percent of the rainfall occurs from November through March, but wide variation takes place in monthly and seasonal totals depending upon location.

Along most of the coastal area, a dominant characteristic of spring and summer is the nighttime and early morning stratus which usually dissipates before noon. Considerable fog occurs along the coast; the fall and winter months usually being the foggiest.

The area has long periods of light winds and frequent sunshine. Surface wind conditions are characterized by a daily reversal in direction. During daylight hours winds blow from the coast toward the interior areas and at night they reverse. Occasionally, strong, dry northeasterly winds (the "Santa Ana Winds") descend the mountain slopes in the fall, winter and early spring, developing speeds in excess of 50 miles per hour (80.45 km/h) over localized sections of the area. The annual average temperature for the area is 60.9°F (16.1°C). Strong winds associated with winter or spring storms occasionally exceed 40 miles per hour (64.4 km/h). In the southern portion of the area, winter storms or gales are infrequent and wind velocities over 30 miles per hour (48.3 km/h) occur on the average only about once a year.

January is usually the coolest month with an average temperature of 50.7°F (10.4°C) and July/August the warmest time with an average temperature of 71.6°F (22.0°C).

H 1.2 Seismicity

The Los Angeles area is in seismic risk zone 4 with a potential for major damage from earthquakes. Earthquakes are frequent and tend on the
average to be of greater magnitude than those which occur in the central
California region. The Point Conception and San Diego areas are in
seismic risk zone 3, which also has the potential for major damage from
earthquakes. Epicenters appear to be concentrated in the Santa Barbara,
Burbank and Long Beach area. However, the San Fernando earthquake
February 9, 1971, demonstrated that destructive seismic activity can
occur almost anywhere in the region. During earthquakes the greatest
damage generally occurs to structures founded on thick alluvial fill or
where the fault traces intersect the surface.

There are several major active faults which traverse the area,
including the San Andreas, San Gabriel, Newport-Inglewood and San Fernando
Faults. Major engineering design, construction and maintenance problems
should be anticipated for any slurry pipeline that crosses the faults or
the thick alluvial fill at the mountain bases. The actual processing
and disposal facilities could probably be designed to withstand most
earthquakes expected in the region.

Locally generated tsunami waves have been reported several times in
the area around Santa Barbara but they rapidly dispersed and did little
damage. At Long Beach and San Pedro major damage to shore and harbor
facilities has occurred and can be expected in the future. Potential
harbor damage is possible throughout the coastal areas, particularly if
high tide and a tsunami are coincident.

H 1.3 Socioeconomics

The Southern California area produces a great quantity of agricul-
tural goods. Water is transported for hundreds of miles to irrigate
large areas of land. Citrus and subtropical fruits are the major crop,
others of importance include forest crops, nuts, alfalfa, pasture and
beans. Forestry is not a major activity in the region, although there are large areas of national forest land.

Large quantities of crude oil and petroleum products originate in the area. Other minerals include peat, clay, sand and gravel, magnesium compounds, salt, stone, gold, silver, natural gas, lead, copper and zinc. Important industries in the area are automobile assembly, movie and television production, food processing, petroleum production and refining, and manufacturing of aircraft, tires, apparel and furniture. The tourist industry is also important.

A massive transportation system including railroads, highways and ocean-going ships, has developed to move the raw materials and products in and out of the area.

The population of the southern California area exceeds 10 million people.

H 2.0 RESOURCE AVAILABILITY FACTORS

H 2.1 Energy

Higher fuel costs, combined with already escalating plant construction and operating costs, have escalated electricity rates. With today's oil prices and the natural gas shortages, emphasis on new generating plants has shifted to coal and nuclear power. Continuing debate over environmental, siting and safety issues, and financial problems in the utility industry have introduced significant uncertainties into the outlook for electricity growth. It is not clear at this time if the power requirements for a manganese nodule processing facility would be available in the southern California area.
H 2.2 Water

The water requirements, both quality and quantity, for a manganese nodule processing operation should be available in the southern California area.

H 2.3 Waste Disposal

There are seven Class I waste disposal sites located in the study area. It is questionable if any of the existing disposal sites could accommodate the volume of waste generated by a nodule processing facility.

H 3.0 REGULATORY/ATTITUDES

H 2.4 Attitudes

The general feeling towards industrial development in the Southern California area is difficult to determine. As in most industrially developed areas, there are both pro- and anti-development factions. In the southern portion of the area, Los Angeles basin and south, state air quality standards may preclude additional heavy industrial growth contrary to some local attitudes. The northern portion of the study area, being less developed, may be more favorably located in relation to air quality but anti-industrial development factions are also quite well organized in this area.
REFERENCES

Association of Bay Area Governments, 1976, Environmental Management Plan - San Francisco Bay Region Work Program.


California Governor's Office of Planning and Research, 1976, Onshore Impact of Offshore Southern California OCS Sale No. 35.


Climate Atlas of the United States, 1962, Environmental Data Service, Department of Commerce.


Dames and Moore, Inc. and B. V. Andrews II, 1977, Description of Manganese Nodule Processing Activities for Environmental Studies, Volume II, National Oceanic and Atmospheric Administration, Department of Commerce.

Dames and Moore, Inc. and EIC Corporation, 1977, Description of Manganese Nodule Processing Systems for Environmental Studies, Volume I, National Oceanic and Atmospheric Administration, Department of Commerce.
Environmental Science and Engineering, University of California, Los Angeles, 1976, Southern California Outer Continental Shelf Oil Development: Analysis of Key Issues.


Humboldt County, 1974, Atlas of Humboldt County.


Shannon and Wilson, Inc., 1972, Seismic Regionalization Studies, Bonneville Power Administration Service Area.


