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The Marine Components of the Cohasset Development Plan

Conceptual Production Engineering Studies for Cohasset and Panuke Oil Developments

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SECTION 1. PROJECT OVERVIEW

1.1

INTRODUCTION

The project to develop the Cohasset and Panuke condensate fields off the coast of Nova Scotia is called the Cohasset/Panuke Development Project.

LASMO Nova Scotia Limited as Operator for the joint venture, is proposing to develop and produce the hydrocarbon resources of these two fields. Figure 1.1-1 shows the location of the fields off the Nova Scotia Coast approximately 41 km west-southwest of Sable Island.

LASMO Nova Scotia Limited is a wholly owned subsidiary of LASMO PLC. From its formation in 1971, LASMO PLC of London England, has grown to become the United Kingdom's second largest independent oil and gas exploration and production company. With operations in 17 countries, production has already been established in the U.K., Indonesia, Gabon, the U.S.A., Canada, Australia and Colombia. LASMO's expansion program has yielded very positive results and the company is determined to remain the best diversified independent exploration and production company in the world.

The following elements comprise the project:

- drilling of development wells and production of condensate and associated natural gas from the two independent fields, Cohasset and Panuke

- complete processing at the offshore field facilities

- transfer of stabilized condensate to a moored storage tanker during the primary production period from April through October
LOCATION OF COHASSET-PANUKE DEVELOPMENT PROJECT

- PRINCE EDWARD ISLAND
- CAPE BRETON ISLAND
- STRAIT OF CANSO
- SABLE ISLAND
- CANADA
- NOVA SCOTIA
- HALIFAX-DARTMOUTH

FIGURE 1.1-1
- Transportation of the stabilized condensate via shuttle tanker to market destinations.

All components of the project will meet or exceed Canadian and Nova Scotia design, safety and environmental standards and regulations.

1.1.1 PURPOSE OF DEVELOPMENT APPLICATION

This Development Application (DA) is a submission to the Canada Nova Scotia Offshore Petroleum Board (CNSOPB) indicating the Operator's specific plans for developing the Cohasset and Panuke fields. Submission of the DA is the first phase in the process through which CNSOPB approvals will be obtained before the Operator proceeds with the project. Early consultation and exchanges of information with the CNSOPB, the Canada Oil and Gas Lands Administration (COGLA), the Nova Scotia Department of Mines and Energy, and other government departments should preclude unnecessary delays in project implementation.

This DA is based on technical information, and environmental data and analyses available to the Operator up to March 1, 1990. Final engineering information, specific project specifications, and complete environmental assessments will be completed during the next several months. Additional and supplementary information will be made available to the CNSOPB as it is completed during the DA approval process period.

1.1.2 REGULATORY REQUIREMENTS

During the final engineering phase, the Operator will interact with the CNSOPB and seek to obtain approvals for various aspects of the project. Certain of these approvals are required pursuant to the Canada - Nova Scotia Offshore Petroleum Resources Accord Implementation Act, the Canada Oil and Gas Installation Regulations, and the Canada Oil and Gas Drilling Regulations.

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1.3
The Canada–Nova Scotia Agreement on Offshore Resource Management and Revenue Sharing, effective March 2, 1982, governs the development of hydrocarbon resources in Nova Scotia's offshore region (Figure 1.1-2). The CNSOPB, representing both the federal and provincial governments, is the joint agency designated to administer oil and gas exploration and development activities, regulations, and legislative requirements in the Nova Scotia offshore area.

The Canada Oil and Gas Installation Regulations (latest draft) require that government approvals be obtained for all development plans. The Operator will be applying for other specific approvals for offshore structures, drilling rigs, production facilities, interfield flowlines and tanker transportation systems in accordance with current and pending regulations. Drilling approvals will be applied for in accordance with the Canada Oil and Gas Drilling Regulations.

1.1.3 APPROVAL PROCESS

For scheduling purposes, from the date of initial submission of the DA, seven months have been allocated for CNSOPB technical and environmental reviews, public viewing and hearings, and the receipt of final recommendations and ministerial approvals.

IASMO will provide all necessary engineering documentation and supporting environmental impact studies to facilitate project review by the CNSOPB and other government departments. IASMO has been working and will continue to work closely with both private and public interest groups to solicit their views and address their concerns prior to submission and during the DA review period.

An independent environmental and economic review panel will be established by the CNSOPB to set-out the terms of reference and guidelines for the public review phase of the project.
Supplementary information will be provided by the Operator as required.

As part of the Canada Certificate of Fitness Regulations, IASMO will select and contract an approved Certifying Authority (CA) to conduct independent engineering design checks and technical audits of all of the components of the development drilling and production systems and facilities. The CA will eventually issue various certificates of fitness which will be submitted to the CNSOPB for final approvals.

1.1.4 SCHEDULE

The proposed development schedule is shown in Figure 1.1-3. It indicates the various major activities prior to the start of production and the intended six production seasons.

1.1.5 COMPONENT OVERVIEW

The major equipment components for the Cohasset/Panuke Development Project are as follows:

- steel piled well jackets
- production processing and water injection facilities
- year-round jack-up drilling and production unit
- subsea control and flowlines
- offloading system
- storage tanker and shuttle tanker

Figure 1.1-4 is a schematic of the proposed offshore facilities arrangement.

1.1.6 RESERVES

This section presents the estimated reserves for both Cohasset and Panuke and the combined recoverable reserves for the total project.
# OVERALL MASTER SCHEDULE

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**FIGURE 1.1-3**
Cohasset Reserves

The total condensate-in-place based on volumetric calculations is estimated to be $10.0 \times 10^6$ m$^3$ including all the major and minor sands. However, the reservoir simulations for the main sands assessed total condensate in-place to be $8.1 \times 10^6$ m$^3$. The total simulated recoverable reserves from Cohasset are estimated to be $2.9 \times 10^6$ m$^3$. Table 1.1-1 summarizes the calculated recoverable reserves for the Cohasset reservoirs based on the reservoir simulation results.

**TABLE 1.1-1**

**ORIGINAL AND RECOVERABLE CONDENSATE-IN-PLACE COHASSET RESERVES**

(RESERVOIR SIMULATION RESULTS)

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<th>Sand</th>
<th>Original Condensate in-Place ($10^3 m^3$)</th>
<th>Recovery Factor (%)</th>
<th>Recoverable Condensate in-Place ($10^3 m^3$)</th>
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**Panuke Reserves**

The total simulated condensate-in-place at Panuke is $7.2 \times 10^6 \text{ m}^3$, the total recoverable reserves from the two sands are estimated to be $2.7 \times 10^6 \text{ m}^3$. Table 1.1-2 summarizes the calculation of recoverable reserves for the Panuke reservoirs based on reservoir simulation results.

**TABLE 1.1-2**

ORIGINAL AND RECOVERABLE CONDENSATE-IN-PLACE
PANUKE RESERVES
(RESERVOIR SIMULATION RESULTS)

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<th>Recovery Factor (%)</th>
<th>Recoverable Condensate in-Place ($10^3 \text{ m}^3$)</th>
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**Combined Reserves**

The total simulated condensate-in-place for the combined Cohasset and Panuke reservoirs is estimated to be $15.4 \times 10^6 \text{ m}^3$. The total recoverable reserves simulated for the combined fluids are $5.6 \times 10^6 \text{ m}^3$. Table 1.1-3 summarizes the calculated combined recoverable reserves based on simulation results.
1.2 HISTORY OF PROPOSED DEVELOPMENT

This section outlines the drilling history in the Cohasset and Panuke areas and describes pre-development studies and evaluations.

1.2.1 DRILLING HISTORY

Drilling for hydrocarbons in the Sable Island area has been ongoing since 1967. The first good indication of hydrocarbons occurred in 1969 in Shell's Onandaga E-84, the second well drilled on the Scotian Shelf. This location is approximately 30 km southeast of the Cohasset and Panuke fields. Although no successful tests were run, log analysis suggested that there were 54 m of gas-bearing Lower Cretaceous Sand. The first important discovery with recovery of hydrocarbons was the Mobil-Tetco Sable Island E-48 well, completed October 15, 1971. The E-48 well encountered 247 m of net oil, gas, and condensate pay from several Upper Cretaceous Sandstones.

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1.11
The initial Cohasset D-42 discovery well was drilled and abandoned by Mobil in 1973. Mobil also drilled the Cohasset P-42 delineation well in 1978. This well was an aggressive step-out to the northeast and proved to be a dry hole. A second delineation well, Petro-Canada/Nova Scotia Resources Limited (NSRL) Cohasset A-52 was drilled, tested, and suspended in 1986. No further Cohasset wells have been drilled since 1986.

The initial Panuke B-90 discovery well was drilled and abandoned by Shell in 1986. Petro-Canada/NSRL drilled the Panuke F-99 delineation well in 1987. This well was extensively tested and, for the first time on the East Coast, produced condensate was safely loaded into a tanker moored alongside the drilling and testing jack-up unit. No further Panuke wells have been drilled to date. Figure 1.2-1 shows the Sable Island Area and many of the wells drilled to date.

1.2.2

PRE-DEVELOPMENT EVALUATIONS AND STUDIES

During 1985-86, Nova Scotia Resources (Ventures) Limited (NSRVL) conducted internal evaluations to determine the technical and economic merits of Cohasset development on a stand-alone basis. A joint Petro-Canada-NSRVL Task Force completed additional detailed technical and economic evaluations from November 1987 to January 1988. A specific 3D seismic survey was run over the Cohasset structure. Petro-Canada concluded that the Cohasset field alone would be a marginal development based on an intensive capital investment approach.

NSRVL, with a working interest in both fields, continued with further studies in 1988 to evaluate the combined development of Cohasset and Panuke. Since May 1989, various specialist studies have been completed to establish baseline technical and environmental data. IASMO and NSRVL have brought together technical data from these sources and compiled the preliminary development plan for the combined development of the Cohasset and Panuke fields.
1.2.3 PARTNERS AND LAND POSITIONS

The working interests of partners in the combined development of the Cohasset and Panuke significant discovery areas (SDAs) are as follows:

(1) IASMO Nova Scotia Limited (Field Operator) 50.0%
(2) Nova Scotia Resources (Ventures) Limited 50.0%

100.0%

IASMO Nova Scotia Limited is a wholly owned subsidiary of IASMO PLC. IASMO PLC is an international oil company with head offices in London, England. It employs approximately 700 persons on a worldwide basis and has a daily oil production of approximately 13,500 m³/d. A partially owned subsidiary, IASMO Canada, is listed on the Toronto Stock Exchange.

Nova Scotia Resources (Ventures) Limited was formed in 1982 as a wholly owned taxable subsidiary of Nova Scotia Resources Limited, a Crown Corporation of the Province of Nova Scotia. NSRVL has participated in previous exploration and pre-development programs on the Scotian Shelf.

These two working interest partners bring together an excellent combination of private and public sector technology, offshore experience, and financial strength to undertake the first field development on the Scotian Shelf.

1.3 OVERVIEW OF THE DEVELOPMENT PROJECT

The components comprising the production and transportation facilities include the following:

- a jack-up drilling and production unit to be located at the Cohasset location
- two steel piled well jackets, one at Panuke and one at Cohasset
- production facilities located on the jack-up unit at Cohasset
- subsea production and water injection flowlines and control lines between Panuke and Cohasset
- a tanker mooring and loading system to be located adjacent to Cohasset
- a storage tanker to be moored adjacent to Cohasset
- a shuttle tanker travelling from the field to market destinations

Figure 1.3-1 shows the relative positions of the two fields and the major production components. The tanker mooring and loading system will be located approximately 2 km on the prevailing leeward side of the jack-up drilling and production unit at Cohasset. A brief description of the components is provided in the following sections.

1.3.1 JACK-UP DRILLING AND PRODUCTION UNIT

A year round jack-up drilling and production unit will be used to drill the wells at both Panuke and Cohasset, and then to support the production facilities until project completion. The selected drilling unit will provide all required production support utilities such as seawater, compressed air, drains, electrical power, and safety systems, as well as the accommodations required for drilling and/or production personnel. Figure 1.3-2 shows a typical jack-up drilling unit that could be used for the project.

1.3.2 WELL JACKETS

Two structural steel well jackets are proposed, one located at Panuke and one at Cohasset. The Panuke well jacket, located in 46 m of water, will be unmanned and will be equipped with a boat landing and helideck for access to the Panuke wellheads. The well jacket will be designed for a minimum deck load including the helideck loads, the weight of the production and injection
PANUKE FIELD LOCATION MAP

FIELD LOCATION MAP

COHASSET FIELD

PRODUCTION JACK-UP

INTERFIELD FLOW & CONTROL LINES

VESSEL SAFETY ZONE

PANUKE JACKET COORDINATES

\[ \begin{align*}
60^\circ 44'00'' \text{ W} & \quad X \\
43^\circ 48'40'' \text{ N} & \quad Y \\
& \quad Z
\end{align*} \]

COHASSET JACKET COORDINATES

\[ \begin{align*}
60^\circ 37'40'' \text{ W} & \quad X \\
43^\circ 50'45'' \text{ N} & \quad Y \\
& \quad Z
\end{align*} \]

FIGURE 1.3-1
manifolds, and aids to navigation. The Cohasset well jacket, located in 40 m of water, will be adjacent to the jack-up drilling and production unit. Four wells, including three production wells and one water injection well, will be drilled through the Panuke well jacket. Seven wells, including five production and two water injection wells will be drilled through the Cohasset well jacket. Figure 1.3-3 is a schematic view of a typical steel piled well jacket.

Structural steel tubular frames secured by piles driven into the seabed will comprise the well jackets. They will provide lateral support to the well conductors between the seafloor and the water surface. The structural design will provide for the combined wind, wave and current loads associated with the 100 year storm conditions.

The well jackets will be fabricated onshore, transported offshore, and installed using either a medium-sized derrick barge or the jack-up drilling unit.

The use of well jackets at both locations will allow personnel access to all wellheads, manifolds, and surface valving. Artificial lift pumps (either electric or hydraulic) will be used in the Cohasset and Panuke production wells to increase overall condensate recovery.

The Panuke wellheads and manifold will be remotely operated from the jack-up located at Cohasset. Electric and/or hydraulic control lines will be selected for this purpose. Line-of-sight telemetry is also being considered as a primary or secondary control system.

1.3.3 PRODUCTION FACILITIES

Production facilities will be provided to process produced well fluids from both the Panuke and Cohasset fields to achieve
STEEL PILED WELL JACKET

(TYPICAL ONLY)
stabilized condensate for tanker storage and transport. To support the process, the following systems will be provided:

- condensate, gas and water separation
- water injection
- produced water disposal
- associated gas flare and fuel system
- integrated safety and control systems

The production facilities will be manufactured and assembled, installed on the jack-up inshore, and commissioned before the jack-up unit completes drilling the initial development wells. Once the Panuke wells have been drilled and completed, the jack-up will be positioned at the Cohasset location.

A detailed description of the production facilities is provided in Section 5.

1.3.4 FLOWLINES

Two flowlines will be installed between the Cohasset and Panuke well jackets. One 153-mm ID production line will carry commingled, untreated, three-phase produced fluid from Panuke to the facilities at Cohasset. The second 153-mm ID water injection line will carry treated seawater from Cohasset to the Panuke water injection well. In addition, a control bundle will be installed to provide communications to control and monitor the wells at Panuke from Cohasset. A power cable may be installed for artificial lift and navigation aids.

Two designs are being considered for the interfield flowlines:

- steel line pipe with conventional installation
- flexible pipe using a special purpose reel vessel
The final selection will depend on design, operational and economic factors.

1.3.5

**CONDENSATE EXPORT**

The loading system will be a catenary anchor leg mooring (CALM) system consisting of a cylindrical steel buoy held in place by catenary mooring lines. Each line will consist of approximately 700 m of 89-mm chain with anchors or steel piles. A flexible steel riser will connect the export flowline end manifold to the buoy. The buoy will be equipped with a turntable arrangement containing the connection point for the mooring hawser and the floating transfer hoses. The storage tanker will be permitted to "weathervane" around the buoy.

One 153-mm ID flowline will be installed from the Cohasset wellhead jacket to the seafloor and manifold as part of the interfield flowline installation program. Figure 1.3-4 shows a typical CALM loading system.

The CALM system will remain in place throughout the entire year even though tanker operations will be conducted primarily on a seasonal basis (April through October).

1.3.6

**STORAGE TANKER**

A 120,000 to 140,000 DWT tanker will be moored to the CALM buoy throughout the operating season. Studies are in progress to optimize the storage tanker size consistent with shuttle tanker size and offtake patterns. During producing operations the storage tanker will use on-board power to assist with weathervaning and reducing the mooring system loads.
TYPICAL CALM OFFLOADING SYSTEM

FIGURE 1.3-4
The primary operating season will be seven months (April through October). The storage tanker will not be moored at location continuously during the winter season. Production during the more severe winter months will be confined to periods with good weather forecasts. Operating procedures will define the practical winter loading limits which minimize the risk of accidents and small condensate spills.

1.3.7 SHUTTLE TANKER

A 60,000 to 80,000 DWT shuttle tanker(s) will be used to transport the stabilized condensate to market destinations. The shuttle tanker(s) would be released during the winter months when the field is not producing on a continuous basis. The storage tanker may be used during the winter period, during suitable weather windows, to transport additional condensate to market.

1.4 CONSTRUCTION AND INSTALLATION SCHEDULE

Figure 1.4-1 shows the time required for each component to be designed, fabricated, and installed. The installation of all offshore components is targeted for the summer months in 1991, with production beginning after completion of the initial Cohasset wells. To meet the proposed schedule, it will be necessary for detailed engineering to be complete by mid-1990 in order to select and order long-delivery items.

Design engineering activities are scheduled to be completed approximately when CNSOPB approvals have been received. The time from CNSOPB approval to first condensate production is estimated to be 21 months.

Well jacket fabrication contracts would be awarded in the third quarter of 1990 with loadout and installation in the spring of 1991. The production equipment will be manufactured and assembled during the last half of 1990 and scheduled for installation on the
# Construction and Installation Schedule

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FIGURE 1.4-1
A jack-up drilling unit during 1991. The flowlines will be installed during the summer of 1991. The CALM mooring and loading system will also be installed during the summer of 1991. The initial Cohasset wells will be drilled and the production facilities commissioned during the winter months, so that all systems will be completed and tested for first condensate production in the second quarter 1992.

**OPERATIONAL CONSIDERATIONS**

The Operator recognizes some of the practical aspects of dealing with winter storm conditions in the East Sable Bank area. Due to the relatively shallow water near the Cohasset location, the loading buoy chain mooring system will have reduced limits when compared with deeper water systems. This will cause increased tanker and production down-time during the severe winter months of January, February and March.

IASMO intends to restrict primary producing operations to the months of April through October, and utilize the winter months for well maintenance, workovers and any recompletions or new wells that may be proposed. By using this approach several advantages may be realized:

- Continuous water injection, in the absence of continuous production, should maintain reservoir pressures at more optimum levels and may improve overall reserves recovery.

- Adequate time will be available to maintain and service the components of the artificial lift system. Downtime will be reduced during the primary producing period.

- Adequate time will be available to service wells prior to the start of continuous production each April.
- Additional wells may be drilled as needed. Additional Cohasset well slots are under consideration in the well jacket design.

- Winter production and offshore loading will be limited to periods of forecastable good weather conditions which can occur on a seasonal year by year basis. Only with direct operating experience at the location can operational procedures and limits be optimized, however safe operations will be maintained.

1.6 POTENTIAL IMPACTS

The physical location of the Cohasset/Panuke Development Project falls within the previous Venture study area surrounding Sable Island. In order to build on this collection of data and knowledge, LASMO has adopted the environmental baseline data prepared by Mobil Oil Canada, Ltd. as part of the Venture Project Environmental Impact Statement (EIS) 1983/84. Any new additional data relating to fisheries, marine wildlife and mammals, and biophysical data, has been updated where available.

1.6.1 ENVIRONMENTAL CONSIDERATIONS

1.6.1.1 Condensate

Preliminary studies (further studies are in progress) have indicated the following:

- The Cohasset and Panuke condensates have an unusually low specific gravity (API 50°-52°). Only 0.5% of the world's production is of a similar nature.

- The condensate, if spilled at the offshore location, would dissipate very rapidly and would be unlikely to contaminate the seafloor or to foul fishing equipment in the area. Computer trajectory simulation of surface slicks for larger spills indicates that the condensate would not reach Sable Island.
- Condensate released into the water column from subsea flowlines would also rapidly dissipate. Lethal concentrations for marine life would extend over a small area. Fish tainting could occur during larger spills, but exposure times would be short.

1.6.1.2 **Routine Discharges**

All routine discharges into the water column from the drilling and production jack-up unit, including produced water, drilling mud, and sewage will be treated to meet regulated levels. A small gas flare for the associated produced gas not used for fuel would be controlled at less than \(85 \times 10^3\) m\(^3/d\). Solid wastes will be transported to shore for disposal.

1.6.2 **ECONOMIC IMPACTS**

1.6.2.1 **Fishing Industry**

Preliminary discussions have been held with several private fishermen and with the Nova Scotia Seafood Producers Association. The fishing activity in the vicinity of the Cohasset and Panuke sites is low. No shellfish spawning areas have been identified in the immediate project area. Several groundfish fall and winter spawning areas are located to the north and east of the field area. IASMO recognizes the importance to fishermen and fleet operators of unlimited access to all stock areas. However, for safety reasons, the Canadian Coast Guard will specify a vessel traffic management zone around the drilling, production and tanker facilities. The extent of this exclusion zone will be defined in consultation with the fishing industry representatives. Safety of joint operations will be the primary consideration.

IASMO is committed to the principle that the fishermen should not be disadvantaged as a result of the company's activities. Fishermen's compensation for this project will be based on the mutually acceptable Canadian Petroleum Association (CPA)
non-attributable compensation plan. IASMO will discuss with fishermen the modifications necessary to the CPA approach and address the project-specific requirements.

1.6.2.2 Socio-Economic Impacts

The economic and social impacts resulting from the Cohasset/Panuke Development Project are expected to be minor due to the small size of the project. However, IASMO does expect that this new level of activity will provide a revitalization of the offshore support services industries with company relocations back into the Halifax area.

Some new employment and permanent positions will be created locally. A more comprehensive analysis of the project benefits is provided in Section 9. IASMO is preparing a specific benefits and opportunities plan which will be reviewed with the CNSOPB and provincial government departments. IASMO encourages the use of local suppliers and contractors and will take positive steps towards early identification and early communication of project information to all potential suppliers, contractors and service companies.

1.6.3 CONTINGENCY PLANNING

IASMO strongly believes that prevention and preparedness are the key elements of the project contingency planning policy and procedures. Any emergency situation at the Cohasset and Panuke field facilities will be handled responsively to reduce damages to the facilities, prevent loss of life, to protect the marine environment, and to protect the livelihood of the fishing industry. During the next several months, IASMO will be preparing specific plans and procedures covering areas of safety and training programs for itself and all contractors involved in the project; contingency plans for hypothetical emergency situations; live drills and field exercises in co-operation with various government agencies;

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and environmental monitoring programs. These various programs will be designed for the construction, drilling, production, and tanker transportation phases of the project.

1.7

PROJECT MANAGEMENT

As of October 28, 1989, IASMO has established an office in Halifax to conduct new exploration work on recently awarded lands and also to implement the Cohasset/Panuke Development Project. Management, operations, engineering, and support staff will be experienced in all phases of offshore drilling, production operations and tanker transportation. Specialized engineering and environmental consultants will be contracted as required. Staff levels are expected to reach 30 persons by the fall of 1990.

IASMO Nova Scotia Limited will be headed by an executive vice president who will be directly responsible for all Nova Scotia activities. He will report directly to IASMO's senior management and directors in London.

The levels of project management and design personnel required will be determined by IASMO's particular contracting philosophy formulated for the project. An approved certification agency will be retained by IASMO to provide technical certification of all components of the offshore field facilities.

1.8

CAPITAL AND OPERATING COSTS

The total capital cost for the Cohasset/Panuke Development Project is estimated to be $160 million Canadian dollars (1990), excluding land acquisition costs and excluding previous discovery and delineation wells.

The operating costs have been estimated to be an average $68 million Canadian per year over the six production years.

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A more detailed description of both capital and operating costs is presented in Section 13.

1.9 ABANDONMENT

It is expected that economic recovery limits will be reached at the end of the sixth production year. At that time the offshore site at both Cohasset and Panuke will be restored on the following basis:

- Wells will be plugged with cement and the casing removed to a depth of 6 m below seafloor.

- Wellhead jackets will be removed by severing the piles below the seafloor.

- Interfield flowlines will be purged and retrieved from the seafloor.

- The jack-up drilling and production unit will be demobilized and removed from location.

- The CALM mooring and loading buoy will be removed and all anchors and chains retrieved. The export loading line will also be recovered with the interfield flowlines.

- Tankers will cease operations at the field facilities.

1.10 ORGANIZATION OF DEVELOPMENT APPLICATION

The Development Plan is presented in the following sections:

SECTION 1  Project Overview
SECTION 2  Geology, Geophysics, and Petrophysics
SECTION 3  Reservoir Engineering and Reserve Estimates
SECTION 4  Drilling and Completions

MARCH 7, 1990
# SECTION 4
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SECTION 2. GEOLOGY, GEOPHYSICS AND PETROPHYSICS

2.1 OVERVIEW OF COHASSET AND PANUKIE FIELDS

The Cohasset and Panuke condensate fields are located on the western margin of the Sable Sub-basin on the Scotian Shelf. Figure 2.1-1 shows the wells that have been drilled in the vicinity of the two fields.

The discovery well for the Cohasset field was D-42, drilled in 1973. It was abandoned as a gas condensate well, having been drilled to a depth of 4428 m. Two step-out wells have since been drilled: P-42, located approximately 1800 m northeast of D-42 and which was drilled to a total depth of 2591 m in 1978; and A-52, located approximately 1400 m to the southwest of D-42 and which was drilled to a total depth of 2496 m in 1986. Fifteen sandstone reservoirs containing condensate have been identified in the Cohasset field.

The discovery well for the Panuke field was B-90, drilled in 1986 and located at the northeast end of the structure. It was abandoned as a gas condensate well drilled to a total depth of 3425 m. A step-out well, Panuke P-99, was drilled to 2507 m in 1987. Five condensate bearing sandstone reservoirs have been identified in the Panuke field, with two of these reservoirs containing the bulk of the expected recoverable condensate.

The field geology, consisting of the regional setting, depositional environment, and lithology, and the net pay determinations for the two fields are described in the sections that follow.

2.2 FIELD GEOLOGY

This section discusses in some detail the regional setting, tectonic history, stratigraphy, and lithology of the Cohasset and Panuke reservoirs.

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2.1
WELL LOCATIONS

LEGEND
- WELL LOCATION
- DRY AND ABANDONED
- SUSPENDED OIL WELL
- SUSPENDED GAS WELL
- ABANDONED GAS WELL
- SUSPENDED COND. WELL

FIGURE 2.1-1
2.2.1 REGIONAL SETTING

The Cohasset and Panuke reservoirs are located within an Early Cretaceous section (Logan Canyon and Missisauga Formations) comprised of sandstone and shale which developed on the seaward edge of a relatively stable platform of earlier Cretaceous and Jurassic clastics and carbonates. It is believed that an earlier (Jurassic) carbonate shelf-edge build-up (Abenaki Formation) helped to create the stability necessary for the development of the depositional settings for the reservoir sands. This stable area is, in essence, the hinge-line, with numerous growth faults occurring in a south to southeast or seaward direction.

2.2.1.1 Cohasset Field

The Cohasset Field consists of a series of stacked reservoir sandstones located within the Lower Logan Canyon Formation (Sands 0-9), through the Naskapi Formation (Sands 9a and 9b), and the Upper Missisauga Formation (Sands 10 Upper and 10 Lower).

2.2.1.2 Panuke Field

The Panuke Field also consists of a series of stacked reservoir sandstones located entirely within the upper part of the Missisauga Formation (Sands 1 through 5).

The Panuke Sand 1 correlates to Cohasset Sand 10 Upper. Panuke Sand 2 is the principal producing horizon in this field and occurs stratigraphically below Cohasset Sand 10 Lower.

2.2.2 TECTONIC HISTORY

The Sable Basin is characterized by apparently continuous deposition from the Middle Jurassic to the Tertiary. The tectonic history for the Scotian Shelf is generally one of subsidence, the only variation being differential subsidence. During the Late
Jurassic and Early Cretaceous periods, subsidence of the basins occurred, and uplift of the source area supplied the rapid influx of terriginous clastics. This is the case for the Sable Basin, where subsidence and rapid sedimentation have produced the down-dropped fault structures along the Late Jurassic - Early Cretaceous hinge line.

Four unconformities on the Scotian Shelf have been identified by King et al. (1974) from high-resolution seismic data: Early Cretaceous, Late Cretaceous, Early Tertiary, and Late Tertiary - Pleistocene. Only the fourth is known to extend over the shelf while the earlier unconformities are confined to the Inner Shelf margins and over local structural highs. There does not appear to be any significant regional unconformity on the Scotian Shelf.

2.2.3 DEPOSITIONAL ENVIRONMENT

During late Missisauga and early Naskapi times, sandy deltaic deposition was overwhelmed by a regional transgression (Jansa & Wade 1974). During this period, large flat coastal plains and fluvial systems were onlapped by shallow marginal marine shale deposition (Naskapi Formation). It is suspected that fluvial valleys were inundated by the sea, and estuarine type environments were established shoreward of the Cohasset and Panuke area. Thus the stage was set for deposition of Cohasset Sands 7 through 10 and Panuke Sands 1 through 5, as variations on the estuarine theme, i.e., shallow shelf bars, tidal and distributary channels, and storm deposits.

Many subaqueous bars were developed as sand ridges on large estuarine distributary mouth bar sheets. Both the bars and adjacent tidal channels were placed randomly, but sub-parallel to shore due to longshore drift effects in outer portions of the sheet.

The upper Cohasset reservoir section (Sands 0 to 6) represents a more traditional estuarine system, with complex micro-environments.
of deposition, dominated by the formation of numerous barrier beaches with associated lagoons, flood-tidal deltas, intertidal creeks, and tidal rivers.

In short, the whole sequence seems to be regressive, with the proximal lagoonal-estuary system overlying the various pulses of proximal to distal estuarine mouth bar sheets. Each fluvial pulse was dominated and eventually overwhelmed by marine influences, until Cohasset Sands 5 and 6 were deposited, at which time the shoreline essentially moved seaward. Later marine transgressive periods appear to be brief and not as widespread.

The result of this depositional cycle is a series of stacked reservoir sands from 2 to 20 m thick, with varying geometric configurations.

2.2.4 RESERVOIR STRATIGRAPHY

The trapping mechanism for both the Cohasset and Panuke fields is both stratigraphic and structural in origin.

In the underlying Jurassic, a thick carbonate section (Abenaki Formation) was deposited near the shelf edge. This carbonate developed in the form of a linear bank trending roughly southwest to northeast, west and north of the present-day Sable Island (Eliuk 1978). This bank formed a high, which dips sharply downward in a southeasterly direction and more gradually downward toward the northwest. The bank is believed to have been a shallow shelf and shoreline area during reservoir sand deposition.

The Cohasset feature is an elongated structural anticline, parallel to the underlying Abenaki reef trend. Closure is provided by steep dip (partially fault bounded) to the southeast, plunge to the critical northeast direction, plunge to the southwest and, to the northwest by a paralleling low structural trend.
The Panuke high is also an elongated anticline offset to the southwest of Cohasset and separated from it by a low saddle. It is closed by the same factors as Cohasset. The structure extends about 4 km to the southwest of the F-99 well, but possible deterioration of sand quality may limit the extent of the field in this direction.

The reservoirs of the Logan Canyon Formation (Sand Units 0-9) in Cohasset and Panuke range in composition from well-sorted very fine grained lithic arkose, feldspathic litharenite and litharenite to very poorly sorted upper medium to very coarse grained subarkose. In general, the quartzose rock types are coarser grained than more lithic rock types. The overall mean grain size range for the sand units is mid to uppermost fine sand. Minor amounts of chamosite and glauconite are common. The Upper Mississauga Formation (Sand Unit 10) is similar but finer grained, has a lower feldspar content, and a significant amount of detrital mica.

The main porosity type in the more permeable sections is secondary intergranular porosity formed by partial to complete dissolution of an earlier pore-filling ferroan calcite cement. This secondary intergranular pore system mimics the primary intergranular pore system, and thus varies with sedimentary facies, depositional energy and clay content. This "pseudo-primary" pore system has been further enhanced by secondary dissolution porosity resulting partly from dissolution of unstablefeldspars, but mainly from dissolution of ferroan calcite which had replaced bioclastic debris and microporous detrital matrix. Local pore throat enlargement has resulted from dissolution of displacive ferroan calcite cement. Core plug porosity and horizontal permeability to air varies from 16 to 26 percent, and 100 to 5300 millidarcies respectively (after Haverslew 1986).
2.2.5 DETAILED LITHOLOGY

The lithology, probable depositional environment, geometry, and condensate-water contact for each of the sands in the Cohasset and Panuke fields are described in the sections that follow.

2.2.5.1 Cohasset Field

Sand 0

Sand 0 is best developed at Cohasset A-52, where it is 9 m thick, fine-grained, fossiliferous, and clean. Porosity is up to 29 percent. Sand 0 shales out toward the northeast at Cohasset P-42, where it consists of a very fine- to fine-grained, coarsening-upward, shaly sand. At Cohasset D-42, the upper portion of the sand is shaly, cemented with calcite, and tight.

This sand was probably deposited in a complex lagoonal environment consisting of subtidal sand bars (Cohasset D-42 and P-42), and tidal bar-channel hybrids (Cohasset A-52). The latter hybrids may have developed within an estuarine-delta distributary mouth bar, or a barrier-bar-related, flood-tidal delta.

The geometry of Sand 0 is unknown, but it is suspected to be rather lenticular in nature and, because of shaling out and calcite cementation, it is uncertain whether there is field-wide lateral reservoir communication.

Sands 1, 1a, 1b, 1c

Sands 1, 1a, 1b, and 1c are grouped together because of similarities in texture, composition, paleoenvironment, and geometry. When well-developed, the typical sand is very fine- to medium-grained, subrounded, and well-sorted, and may be either coarsening- or fining-upward. Shaliness is a common feature, and quite often the sand may shale out completely (Sand 1a in Figure
2.2-1). Tight bioclastic zones occur frequently. Sand thicknesses vary from 0 to 6 m in an apparently random fashion.

Sands 1 to 1c were probably deposited in a lagoonal setting consisting of tidal channels, bars, and associated flood-tidal deltas landward of a barrier bar system. This paleoenvironment suggests that, in many cases, the geometry of the sands is quite irregular and lenticular.

Sand 2

Sand 2 has a fair degree of variability across the Cohasset field. At Cohasset A-52, there is a fine- to coarse-grained, subrounded, fining-upward zone overlying a section of interbedded, lenticular, very fine sandstone and shale. At Cohasset D-42, only the cleaner, fine- to coarse-grained sand is present. At P-42, the sand is a coarsening-upward, poorly sorted, very fine- to medium-grained sand, with abundant tight shelly zones.

The thickness of the sand is similar at the A-52 and D-42 locations (8.5 - 9.0 m), but it thins to 6.5 m at Cohasset P-42. Porosity is best developed at Cohasset A-52 (27 percent), but correlatable tight shelly zones increase in abundance toward the northeast, where the sand also becomes more shaly.

Sand 2 was deposited in very shallow water possibly at, or near, a barrier bar system, and components were subjected to both fluvial (estuarine) and open marine processes. The geometry is probably linear (northeast-southwest), with a funnel-shaped landward fluvial component. The combined result may be a sheet-like geometry.
Sands 3, 4, 5

Sands 3, 4, and 5 are grouped together because of their similarities in thickness, pay, and depositional setting.

The sands are fine-grained, subangular, and well- to moderately sorted, and they have varying amounts of shaly matrix and tight shelly horizons. All sands show random coarsening- or fining-upward profiles across the field. No porous section is thicker than 2 m, with most less than 1 m thick. However, Sand 3 exhibits a significant thickening of the permeable section in a southwesterly direction across the field.

The tide-dominated, shallow shelf model described for Sand 2 applies for these sands. However, these sands are located more distally on the estuarine delta distributary mouth bar and, therefore, they are thinner and more shaly and the zones are less easily correlated. Some of the sands are channels while others are bars, and although they occur in similar stratigraphic horizons, many zones are hydraulically separated both vertically from adjacent sands and laterally from other porous zones in the same sand. This results in a number of different condensate-water contacts.

SOURCE, GENERATION, AND MIGRATION OF HYDROCARBONS

The Cohasset and Panuke condensate is believed to have been generated within Jurassic deep-basin sediments, seaward of the Abenaki carbonate bank (Figure 2.2-5). Subsequent hinge-line normal faulting along and seaward of this carbonate bank may have produced conduits for the migration of hydrocarbons toward the stratigraphic and structural closures draped over the Abenaki carbonate bank.
CONCEPTUAL CROSS SECTION: SCOTIAN SHELF

FIGURE 2.2-5
Cohasset structural cross-section - correlation of major sand units

FIGURE 2.2-6
PANUKE STRUCTURAL CROSS-SECTION
CORRELATION OF MAJOR SAND UNITS
Fig. 2.2-7

NOVA SCOTIA LIMITED
Sand body geometries of barrier island depositional components illustrating where Cohasset reservoir sandstones are interpreted to occur (modified from Galloway, 1986). The Cohasset field outline is shown to scale.

After Olynyk 1989

FIGURE 2.2-8
2.3 **NET PAY**

This section discusses the methods and assumptions used to estimate the volumes of hydrocarbons-in-place and describes the net pay.

2.3.1 **ANALYSIS OF RESERVOIR UNITS**

2.3.1.1 **Computation Parameters**

The following parameters were calculated for each of the productive sand intervals:

- Shaliness correction factor
- Water resistivities
- Porosity
- Cementation exponent
- Saturation exponent and intercept
- Cutoffs

This data is available in a separate report.

2.3.1.2 **Core Results**

Cores were obtained from Cohasset A-52, Panuke B-90 and Panuke F-99. Core analysis reports are not included in this Development Application but are available if required.

2.3.1.3 **Log Analysis**

The detailed log analysis parameters and evaluations are not included in this Development Application but are available for review if required.
2.3.2 STRUCTURE MAPS AND CROSS SECTIONS

2.3.2.1 Geophysical Surveys

Several seismic surveys have been completed over the general Cohasset and Panuke area. The most comprehensive of these, the 1985 Western Geophysical Survey, was used as the primary basis for regional interpretive purposes. Shell 2-D seismic data over Panuke, and the 3-D survey over Cohasset run by Geophysical Services Inc. in 1986, provided the fundamental technical basis for the structural interpretation of the main pay intervals in Cohasset and Panuke.

The quality of the data is good. Reflectors are well-defined on several of the major acoustic interfaces in the Tertiary and Cretaceous sections, while those in the Jurassic and older periods are less continuous and more regional in nature.

These data, along with the accompanying interpretation reports, have been filed by the respective operators with COGLA. Additional seismic program is planned to further refine the mapping of these very subtle structural closures. This includes a proposed 1990 3-D seismic survey over Panuke and a reinterpretation and probable reprocessing of the 3-D survey data over Cohasset. Any such data and interpretations shall be forwarded to CNSOPB in due course.

2.3.2.2 Identification of Seismic Reflectors

The regional seismic data were tied to velocity surveys and logs in thirteen wells in the general area and specifically to the three Cohasset and two Panuke wells. Synthetic seismograms were prepared, and good correlations to actual events provided reliable identification. The main reflectors correlated included the following:

- Nashwauk/Eocene - Tertiary
- Wyandot/Maestrichtian - Late Cretaceous
- Base Petrel/Cenomanian - Logan Canyon
- Sand 5b/Albian - Lower Logan Canyon
- O Limestone - Missisauga
- Abenaki - Late Jurassic
- Scatarie - Middle Jurassic

In the area of the pay sections at Cohasset and Panuke, detailed identification made on both the 2-D and 3-D data showed that due to the small contrast between sand and shale velocities and the large ratio of seismic wave length to sand thickness, many of the sands could not be mapped directly. However, the interbedded calcareous beds were conformable to adjacent sands, and the seismic response from these was helpful in determining structure.

Representative strike and dip lines from the 1985 Western survey are shown for each of the two fields. Lines 29 and 3B (Figures 2.3-1 and 2.3-2) are representative dip and strike lines across the Cohasset Field. Note the fairly reliable horizon markers near Sands 3, 7 and 10. The 3-D data set offered similar horizon continuity (Figure 2.3-3).

Lines 25 and 6B (Figures 2.3-4 and 2.3-5) are the dip and strike lines across the Panuke Field. Note the poor reflector continuity at the Panuke reservoir zone and the much higher reflector continuity at the 5B sand horizon. The Panuke zone is defined as near top 2 sand as seen in the two wells (2252 m ss in F-99 and 2247.2 m ss in B-90). The 5B sand horizon is near equivalent to the No. 5 productive sands in Cohasset and is defined as 1949.1 m ss in B-90 and 1952.5 m ss in F-99.

2.3.2.3 Mapping

Figures 2.3-6 and 2.3-7 are two-way travel time structure maps of the 5B sand and "O" marker over the Panuke Field. Confidence in this mapping is high, though it is recognized the 1 x 2 km seismic
3D SEISMIC LINE 219: COHASSET

TIME (SEC.)

EOCENE MARKER

TOP

WYANDOT BASE

PETREL

MID LOGAN CANYON

SAND 3

SAND 4

SAND 7

SAND 9

SAND 10

"O" MARKER

FIGURE 2.3-3
Figure 2.3-4

SEISMIC LINE: PANUKA DIP

LINE 25
SOUTHEAST 136 DEG

SCALE
0 1 Kilometre

Abenaki
Scatari

Eocene
1.0 Wyandot
Petrel
5b SS
Panuke Zone
2.0 0 Marker
5.0
Legend — 2 wax ft. l.t. in msec.

SCALE 1:25,000

O Marker Structure (time) Panuke

Figure 2.3-7
line grid is not sufficiently dense to pick up the subtler structural elements. Hence, the justification for the proposed 1990 3-D seismic program.

In the Panuke area, no direct seismic response was associated with the Panuke reservoir zone. A depth map for the Panuke reservoir zone was derived as follows:

1. A "5B" sand to "0" marker isopach map was created from the well control and seismic isochron values.

2. An "0" marker depth map was constructed using a constant interval velocity of 3168 m/ks from the base of Petrel depth map as derived from the well control. This method is believed to be valid within a small area such as the Panuke structure and yields calculated mistakes of ± 0.9 metres. The Petrel depth itself was similarly derived by stripping off "layer cake" intervals of water, water bottom to Wyandot and Wyandot to Petrel (see Table 2.3-1).

3. A Panuke reservoir to "0" marker isopach was then contoured using well information and the tracking of contours to the previously derived "5B" sand to "0" marker isopach.

4. Finally, a Panuke sand depth map was produced (Figure 2.3-8) by subtracting the isopach derived in (3) from the "0" marker depth calculated in (2). This map ties the wells and illustrates the structural feature in both depth and aerial extent.
<table>
<thead>
<tr>
<th>Interval</th>
<th>Isopach (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface - Water Bottom</td>
<td>( z = 4900 \times \frac{T}{2} )</td>
</tr>
<tr>
<td>Water Bottom - Wyandot</td>
<td>( z = 1950 + 7524 \left( \frac{T - .628}{2} \right) )</td>
</tr>
<tr>
<td>Wyandot - Base of Petrel</td>
<td>( z = 400 + 9500 \left( \frac{T - .106}{2} \right) )</td>
</tr>
<tr>
<td>Where ( T = ) two-way tt</td>
<td></td>
</tr>
</tbody>
</table>


The Cohasset Field has been mapped using the 26 km² 3-D survey. Figure 2.3-9 is a two-way travel time structure map of the No. 7 sand. Confidence in this mapping is very high because of the stable horizon continuity and the 25 x 50 m subsurface sampling. A depth map (Figure 2.3-10) of the No. 7 sand was derived by stripping off the overlying layers of water depth, water bottom to Eocene, Eocene to Wyandot, Wyandot top to base, Wyandot base to Petrel, Petrel to mid Logan Canyon and mid Logan Canyon to each Logan Canyon mappable horizon in turn. These interval velocities were derived from the wells (Table 2.3-2) and provided well ties ± 0.4 metres. This method is believed the most accurate in mapping small areas with gentle structure such as the Cohasset Field. Similarly, the other productive sands with seismic markers such as No. 3 and No. 10 were mapped as for No. 7. The sands without seismic markers were mapped by using the well information and constraining the contouring to conform to the mappable sands. The excellent well-to-well continuity of the individual sands and the stability in their interval isopachs yields a high confidence in this mapping even though they are not directly detectable on seismic.
-LEGEND-

/- NORMAL FAULT

—1700— 2 WAY T.T. IN MS CC

— SEISMIC PROFILES

FIGURE 2.3-9

LASMO NOVA SCOTIA LIMITED
COHASSET FIELD DEVELOPMENT PROJECT

STRUCTURE #7 SAND (TIME): COHASSET
STRUCTURE #7 SAND (DEPTH): COHASSET

LEGEND:
- P8  PROPOSED PRODUCTION LOCATION
- I2  PROPOSED INJECTION LOCATION
-  PRODUCTION UNIT

LASMO NOVA SCOTIA LIMITED
COHASSET FIELD DEVELOPMENT PROJECT

STRUCTURE #7 SAND (DEPTH): COHASSET

FIGURE 2.3-10
TABLE 2.3-2
DEPTH CONVERSION: COHASSET

<table>
<thead>
<tr>
<th>Interval</th>
<th>Velocity (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level - Water Bottom</td>
<td>1525</td>
</tr>
<tr>
<td>Water Bottom - Eocene</td>
<td>1778</td>
</tr>
<tr>
<td>Eocene - Top Wyandot</td>
<td>2220</td>
</tr>
<tr>
<td>Top Wyandot - Base Wyandot</td>
<td>2662</td>
</tr>
<tr>
<td>Base Wyandot - Petrel</td>
<td>2510</td>
</tr>
<tr>
<td>Petrel - Mid Logan Canyon</td>
<td>2824</td>
</tr>
<tr>
<td>Mid Logan Canyon - Sand 7</td>
<td>3204</td>
</tr>
</tbody>
</table>


2.3.3

NET PAY MAPS

The Cohasset and Panuke structures have been mapped separately, Cohasset with a 3-D survey and Panuke with conventional 2-D seismic lines. The "all zones" net pay isopach maps for Cohasset and Panuke are shown in Figures 2.3-11 and 2.3-12. The pay intervals and the feasibility of water injection for each sand are described in the sections that follow.

2.3.3.1 Cohasset Field

Sand 0

Condensate pay is confined to Cohasset A-52 where there is 2.9 m of pay, with an condensate-water contact at 1758.2 m ss. At Cohasset D-42, the zone above the condensate-water contact is tight, while at Cohasset P-42 the entire sand is below the condensate-water contact. Net pay values are given in Table 2.3-3.
NET PAY ALL ZONES: COHASSET

FIGURE 2.3-11

LEGEND
- P2 PROPOSED PRODUCTION LOCATION
- P12 PROPOSED INJECTION LOCATION
- PRODUCTION UNIT
- WELL BORE DIRECTION
  SAND 0 → SAND 10
- LINE 29 = SEISMIC DIP
- LINE 3B = SEISMIC STRIKE
NET PAY ALL ZONES: PANUKE

FIGURE 2.3-12
Due to the unpredictable geometry of this sand, water injection to enhance condensate production is not expected to be successful.

**TABLE 2.3-3**

**NET PAY, SAND 0: COHASSET**

<table>
<thead>
<tr>
<th>Sand 0</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1755.7-1764.9</td>
<td>1757.5-1765.1</td>
<td>1765.5-1769.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>9.2</td>
<td>7.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>95</td>
<td>84</td>
<td>100</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>2.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>29.3</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>51.5</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>1758.2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Sands 1, 1a, 1b, 1c**

Sand 1 shows the best continuity across the field and has a condensate pay of 1.9 m at Cohasset D-42, and perhaps 0.5 m at Cohasset A-52 (Table 2.3-4). At P-42, it is water-wet. Water injection may be successful in this sand if attempted from the area with the best reservoir, that is, Cohasset P-42 in the northeastern portion of the field.

Sand 1a shows a distinct shaling-out trend toward Cohasset P-42. A maximum condensate pay of 1.9 m occurs at D-42, while it is 1.3 m at A-52. Because of the thin, lenticular, and sometimes shaly nature of this sand, water injection may not be successful in boosting recoveries from this interval.
Sand 1b is tight at Cohasset D-42. The best porosity development occurs at Cohasset P-42, where there may be a very thin zone of condensate pay as the lower limit of an updip condensate-leg. At Cohasset A-52, about 1 m of porosity is filled with condensate. The down-dip condensate-water contact is speculatively taken to be the same as at Cohasset P-42 although it may be deeper because of the lack of reservoir communication between the wells. Water injection is not expected to be effective in assisting the recovery of condensate from this interval.

Sand 1c thins and shales out toward Cohasset A-52 in the southwest, while in the northeast direction Cohasset P-42 is water-wet. There are 3.3 m of net condensate pay at Cohasset D-42 and 1.5 m at A-52. Water injection in the northeastern portion of the field, where the reservoir is best developed, may be effective in enhancing condensate recovery from this zone.

### TABLE 2.3-4

<table>
<thead>
<tr>
<th>Sands 1, 1a, 1b, 1c</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1768.7-1803.0</td>
<td>1766.9-1801.4</td>
<td>1770.5-1811.0</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>34.3</td>
<td>34.5</td>
<td>40.5</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>32</td>
<td>42</td>
<td>47</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>3.2</td>
<td>6.5</td>
<td>0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>24.0</td>
<td>21.5</td>
<td>26.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>52.0</td>
<td>47.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Contact (m ss)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

MAY 2, 1990  2.50
Sand 2

Condensate pay in Sand 2 is 3.9 m at Cohasset A-52, and 3.4 m at D-42, with a condensate-water contact at about 1834.0 m ss (Table 2.3-5). Because of the increase in shaliness and calcite cementation in the northeast, water injection is expected to be most effective in the mid to southwestern portion of the field.

### TABLE 2.3-5

**NET PAY, SAND 2: COHASSET**

<table>
<thead>
<tr>
<th>Sand 2</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1827.7-1836.3</td>
<td>1828.5-1837.3</td>
<td>1835.0-1841.8</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>8.6</td>
<td>8.8</td>
<td>6.8</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>83</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>3.9</td>
<td>3.4</td>
<td>0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>26.3</td>
<td>25.3</td>
<td>17.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>46.4</td>
<td>37.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>1834.0</td>
<td>1834.0</td>
<td>-</td>
</tr>
</tbody>
</table>

Sand 3

Condensate pay in Sand 3 is 3.0 m at Cohasset A-52 and D-42, with a condensate-water contact at 1853.4 m ss (Table 2.3-6). The zone at Cohasset P-42 is down dip and water-wet. Water injection for enhanced recovery purposes is expected to be the most effective in the mid to southwestern area of the field and into the reservoir.
interval above the highest tight horizon, because these tight zones may act as vertical permeability barriers.

**TABLE 2.3-6**  
NET PAY, SAND 3: COHASSET

<table>
<thead>
<tr>
<th>Sand 3</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1848.7-1867.7</td>
<td>1850.1-1869.3</td>
<td>1857.5-1874.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>19</td>
<td>19.2</td>
<td>17</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>74</td>
<td>75</td>
<td>65</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>4.4</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>25.6</td>
<td>25.4</td>
<td>16.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>51.8</td>
<td>44.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>1853.4</td>
<td>1853.4</td>
<td>-</td>
</tr>
</tbody>
</table>

**Sand 3a**

The condensate pay in Sand 3a at Cohasset A-52 is 3.0 m (full), while at Cohasset D-42 it is 0.6 m (full) (Table 2.3-7). Cohasset P-42 is down dip and water-wet. Because the condensate-water contact is unknown, the condensate leg is probably greater than is shown in Figure 2.2-1. Water injection for this sand will be attempted only in the most southwesterly portion of the field where the sand is best developed.
### TABIE 2.3-7
NET PAY, SAND 3a: COHASSET

<table>
<thead>
<tr>
<th></th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1872.7-1877.7</td>
<td>1873.3-1879.4</td>
<td>1880.5-1885.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>5.0</td>
<td>6.1</td>
<td>5.0</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>80</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>3.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>25.4</td>
<td>15.4</td>
<td>19.5</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>39.9</td>
<td>64.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Sand 4**

Condensate pay in Sand 4 at Cohasset A-52 is 5.9 m, while at D-42, it is 4 m. Cohasset P-42 is water-wet just below the condensate-water contact at 1910.5 m ss (Table 2.3-8). Electric log responses indicating correlatable tight zones suggest vertical permeability barriers; however, facies analysis reveals that most vertically adjacent reservoirs probably have fluid communication. Water injection, therefore, could be attempted in any location in the field.
TABLE 2.3-8
NET PAY, SAND 4: COHASSET

<table>
<thead>
<tr>
<th>Sand 4</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1902.4-1918.2</td>
<td>1903.5-1921.1</td>
<td>1909.5-1925.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>15.8</td>
<td>17.6</td>
<td>16.0</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>82.0</td>
<td>61.0</td>
<td>75.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>5.2</td>
<td>4.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>23.7</td>
<td>20.5</td>
<td>24.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>44.5</td>
<td>51.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>1910.5</td>
<td>1910.5</td>
<td>-</td>
</tr>
</tbody>
</table>

Sand 5

There are 5.0 m (full) of condensate pay in Sand 5 at Cohasset A-52 and 3.4 m (full) at D-42. Cohasset P-42 is down dip and water-wet, placing the condensate-water contact somewhere between 1940.0 and 1945.5 m ss (Table 2.3-9).

For enhanced condensate production, water injection would likely be most effective in the water leg at both ends of the elongated reservoir.

MAY 2, 1990

2.54
TABLE 2.3-9

NET PAY, SAND 5: COHASSET

<table>
<thead>
<tr>
<th>Sand 5</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1934.7-1940.4</td>
<td>1936.4-1941.0</td>
<td>1944.0-1948.0</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>5.7</td>
<td>4.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>5.0</td>
<td>3.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>20.5</td>
<td>22.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>43.3</td>
<td>21.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Sand 6

Sand 6 has 3.3 m (full) of condensate pay at Cohasset A-52, and 3.0 m (full) at Cohasset D-42. The P-42 location is down dip and water-wet. The condensate-water contact is somewhere between 1950 and 1953 m ss (Table 2.3-10).

Field-wide lateral communication of reservoir zones within this sand is probably good, and no significant vertical permeability barriers exist. There should also be no hydraulic communication between this sand and the overlying Sand 5, based on the differing condensate-water contacts. Water injection, if attempted, would be most effective in the ends of the field.
### Table 2.3-10

**NET PAY, SAND 6: COHASSET**

<table>
<thead>
<tr>
<th>Sand 6</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1943.7-1949.7</td>
<td>1944.9-1950.7</td>
<td>1952.0-1958.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>6.0</td>
<td>5.8</td>
<td>6.5</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>83.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>2.6</td>
<td>3.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>22.0</td>
<td>19.7</td>
<td>22.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>33.8</td>
<td>39.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Sands 6a, 6b, 6c**

The combined net condensate pay of these three thin sands at Cohasset A-52 is 1.1 m (all full), while at Cohasset D-42 it is 2.9 m (all full). Cohasset P-42 is water-wet (Table 2.3-11).

Water injection is not recommended because of the possible lack of well-to-well communication in the very thin pay zones.
### TABLE 2.3-11
NET PAY, SAND 6a, 6b, 6c: COHASSET

<table>
<thead>
<tr>
<th>Sand 6a, 6b, 6c</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>1959.2-1996.2</td>
<td>1960.8-1998.3</td>
<td>1970.5-2010.0</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>37.0</td>
<td>37.5</td>
<td>39.5</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>13.5</td>
<td>17.9</td>
<td>17.7</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>1.1</td>
<td>2.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>23.1</td>
<td>18.3</td>
<td>22.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>39.4</td>
<td>43.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Sand 7**

There are 4.8 m of condensate pay in Sand 7 at Cohasset A-52, 5.8 m at D-42, and none at P-42. The condensate-water contact is at 2011 m ss (Table 2.3-12); however, this boundary is at the top of a widespread tight zone, as previously discussed. If there is hydraulic separation between this upper condensate zone and water-wet porosity below the tight zones, the condensate-water contact could be much lower, somewhere between 2011 m ss and 2018.5 m ss. The latter is the top of porosity at the water-wet Cohasset P-42 well.

Water injection for this sand would be most effective above the widespread tight horizon, and preferably near the known water-wet area at Cohasset P-42, in case the condensate leg extends below 2011 m ss.

MAY 2, 1990
### TABLE 2.3-12
NET PAY, SAND 7: COHASSET

<table>
<thead>
<tr>
<th>Sand 7</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2002.2-2024.7</td>
<td>2005.5-2027.2</td>
<td>2018.2-2036.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>22.5</td>
<td>22.2</td>
<td>18.0</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>78</td>
<td>81.0</td>
<td>77.8</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>4.8</td>
<td>5.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>24.8</td>
<td>22.3</td>
<td>20.0</td>
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<tr>
<td>Water Saturation (%)</td>
<td>46.0</td>
<td>50.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>2011.0</td>
<td>2011.0</td>
<td>-</td>
</tr>
</tbody>
</table>

**Sand 8**

Condensate pay in Sand 8 at Cohasset A-52 is 5.0 m, and at Cohasset D-42, 3.7 m, with a condensate-water contact at 2047 m ss (Table 2.3-13).

Water injection would be advisable only in the mid to southwestern portions of the field. The excellent reservoir characteristics in the southwestern part of the reservoir deteriorate quickly toward the northeast where Sand 8 at P-42 is thin and tight.

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2.58
TABLE 2.3-13

NET PAY, SAND 8: COHASSET

<table>
<thead>
<tr>
<th>Sand 8</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2041.7-2059.2</td>
<td>2042.8-2053.4</td>
<td>2053.5-2056.2</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>17.5</td>
<td>10.6</td>
<td>2.7</td>
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<tr>
<td>Amount of Sand (%)</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>5.0</td>
<td>3.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>19.8</td>
<td>19.8</td>
<td>17.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>22.1</td>
<td>19.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>2047.0</td>
<td>2047.0</td>
<td>-</td>
</tr>
</tbody>
</table>

Sand 9

Condensate pay is about 0.5 m in Sand 9 at Cohasset A-52 and 3.9 m at D-42, with a condensate-water contact at 2072.0 m ss (Table 2.3-14). Cohasset P-42 intercepts the reservoir in a downdip position and has no pay.

The geometry of this type of sand indicates that it will act like a sheet sand with a good aquifer effect in terms of production. Water injection would probably be effective in any location.

MAY 2, 1990

2.59
TABLE 2.3-14
NET PAY, SAND 9: COHASSET

<table>
<thead>
<tr>
<th>Sand 9</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2071.5-2093.7</td>
<td>2068.7-2094.0</td>
<td>2077.9-2101.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>22.2</td>
<td>25.3</td>
<td>23.6</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>84.0</td>
<td>84.0</td>
<td>83.0</td>
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<tr>
<td>Net Pay (m)</td>
<td>0.7</td>
<td>3.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>21.2</td>
<td>19.7</td>
<td>21.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>51.3</td>
<td>23.9</td>
<td>100.0</td>
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<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>2072.0</td>
<td>2072.0</td>
<td>-</td>
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</table>

Sands 9a, 9b

Cohasset D-42 has 1.0 m of net condensate pay in Sand 9a with a condensate-water contact at 2107.1 m ss and 3.0 m (full) in Sand 9b. Porosity and permeability are low in Sand 9b, however, and significant production is unlikely from this interval. Cohasset A-52 is water-wet in Sand 9a and effectively tight in Sand 9b. Cohasset P-42 is water-wet in both zones (Table 2.3-15).

Because of shaliness, water injection to enhance production in these sands may not be beneficial. The northeastern portion of the field near Cohasset P-42 would be the best location for water injection if attempted.
TABLE 2.3-15
NET PAY, SANDS 9a, 9b: COHASSET

<table>
<thead>
<tr>
<th>Sands 9a, 9b</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2106.2-2159.7</td>
<td>2104.6-2156.8</td>
<td>2112.5-2168.0</td>
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<tr>
<td>Gross Thickness (m)</td>
<td>53.5</td>
<td>52.2</td>
<td>55.5</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>20.6</td>
<td>28.0</td>
<td>32.4</td>
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<tr>
<td>Net Pay (m)</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>15.0</td>
<td>20.5</td>
<td>19.5</td>
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<tr>
<td>Water Saturation (%)</td>
<td>80.0</td>
<td>40.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>-</td>
<td>2107.1 in 9a</td>
<td>-</td>
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</table>

Sand 10

Condensate pay in Sand 10 Upper (Table 2.3-16) is 4 m (full) at Cohasset D-42, and 3.6 m (full) at Cohasset A-52. The lowest known condensate occurs in the latter well at a depth of 2225 m ss. This is probably very close to the actual condensate-water contact, as the sand is probably in hydraulic communication with Sand 10 Lower in the P-42 and D-42 area. There is a known condensate-water boundary (at D-42) between 2223.5 m ss and 2225.0 m ss in Sand 10 Lower (Figure 2.2-3).

Condensate pay in Sand 10 Lower (Table 2.3-17) is 1.5 m at Cohasset D-42 where the sand appears to have lateral and vertical hydraulic communication with Sand 10 Upper. At Cohasset A-52, the condensate pay is 1.1 m in hydraulically isolated sand bodies. The lowest known condensate occurs in the latter well at 2231 m ss. Cohasset P-42 is down dip and water-wet in both sands.

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Water injection to enhance production will probably be successful only for Sand 10 Upper at Cohasset A-52 and D-42 and the condensate-bearing portion of Sand 10 Lower at D-42. Because of the decreased reservoir quality southwestward, injection should take place in the northeastern part of the field. Water injection should not be attempted for Sand 10 Lower at Cohasset A-52 because of its unpredictable geometry and hydraulic isolation.

### TABLE 2.3-16
**NET PAY, SAND 10 UPPER: COHASSET**

<table>
<thead>
<tr>
<th>Sand 10 Upper</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2221.7-2225.4</td>
<td>2216.2-2220.5</td>
<td>2228.5-2235.0</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>3.7</td>
<td>4.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>100.0</td>
<td>100.0</td>
<td>77.7</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>3.6</td>
<td>4.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>22.2</td>
<td>19.5</td>
<td>19.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>48.0</td>
<td>32.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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</table>

MAY 2, 1990 2.62
**TABLE 2.3-17**

**NET PAY, SAND 10 LOWER: COHASSET**

<table>
<thead>
<tr>
<th>Sand 10 Lower</th>
<th>Cohasset A-52</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
</tr>
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<tr>
<td>Interval (m ss)</td>
<td>2226.7-2240.2</td>
<td>2221.7-2235.5</td>
<td>2235.5-2250.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>13.5</td>
<td>14.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>52.0</td>
<td>52.3</td>
<td>60.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>1.1</td>
<td>1.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>23.8</td>
<td>17.6</td>
<td>24.0</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>50.0</td>
<td>49.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>2231.0</td>
<td>2225.0</td>
<td>-</td>
</tr>
</tbody>
</table>

2.3.3.2 Panuke Field

**Sand 2**

The condensate pay in Sand 2 (the main productive zone) at Panuke B-90 is 4.3 m (full), while at Panuke F-99 it is 3.5 m (full) (Table 2.3-18). Reservoir pressure data suggest an condensate-water contact at 2265 m ss, producing a fairly large condensate leg on the domal structure.

Water injection will materially enhance recovery of condensate from this sand. However, because of the deteriorating reservoir quality in the F-99 area of the field, it would be prudent to locate the water injection well below the condensate-water contact on the southeast flank of the structure and roughly equidistant between the B-90 and F-99 wells. This shall be reviewed following the 1990 3-D seismic survey.

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2.63
TABLE 2.3-18
NET PAY, SAND 2: PANUKE

<table>
<thead>
<tr>
<th>Sand 2</th>
<th>Panuke F-99</th>
<th>Panuke B-90</th>
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</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2252.1-2260.8</td>
<td>2247.0-2254.5</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>8.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>86.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>3.5</td>
<td>4.3</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>19.0</td>
<td>21.6</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>47.5</td>
<td>27.5</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>2265.0*</td>
<td>2265.0*</td>
</tr>
</tbody>
</table>

* Determined from reservoir pressure data.

Sands 3, 4, 5

Sand 3 has 2 m (full) of condensate pay at Panuke F-99 and 1 m (full) at Panuke B-90 (Table 2.3-19). Reservoir pressure data suggest an condensate-water contact at 2283 m ss, giving it a large condensate leg.

Sand 4 has 2.1 m (full) of condensate pay at Panuke F-99, while Panuke B-90 has about 0.5 m (Table 2.3-20). The condensate-water contact at F-99 is unknown, but it is at or below the lowest known condensate at 2270.3 m ss. At B-90, the condensate-water contact occurs somewhere between 2263.5 and 2267.6 m ss, much higher than the known condensate at Panuke F-99. This suggests hydraulic isolation of porous zones within this sand across the field.
Sand 5 contains no condensate at either the F-99 or B-90 locations. However, based on the structural setting of the sand, there is probably a condensate leg between the two wells at the apex of the domal structure. The condensate-water contact is unknown.

Water injection to enhance condensate production from Sands 3, 4, and 5 may not be effective. If attempted, injection for Sand 3 should take place in the western part of the field where porosity is best developed (Panuke F-99). The same is true for Sand 4. Development drilling will determine whether injection into Sand 5 is feasible.

### TABLE 2.3-19

NET PAY, SAND 3: PANUKE

<table>
<thead>
<tr>
<th>Sand 3</th>
<th>Panuke F-99</th>
<th>Panuke B-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2262.5-2266.1</td>
<td>2259.6-2262.4</td>
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<tr>
<td>Gross Thickness (m)</td>
<td>3.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>16.9</td>
<td>21.4</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>46.0</td>
<td>33.6</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>2283.0*</td>
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</table>

* Determined from reservoir pressure data.
<table>
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<tr>
<th>Sand 4</th>
<th>Panuke F-99</th>
<th>Panuke B-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (m ss)</td>
<td>2267.6-2271.1</td>
<td>2263.7-2268.7</td>
</tr>
<tr>
<td>Gross Thickness (m)</td>
<td>3.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Amount of Sand (%)</td>
<td>86.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Net Pay (m)</td>
<td>2.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Condensate-Water Contact (m ss)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
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<td>Completion Schedule: Cohasset Reservoir</td>
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SECTION 3. RESERVOIR ENGINEERING AND RESERVE ESTIMATES

3.1 INTRODUCTION

Based on simulation studies, the predicted recoverable reserves during 6 years of production are $2.87 \times 10^8 \text{m}^3$ for Cohasset and $2.68 \times 10^8 \text{m}^3$ for Panuke. Reserves are based on producing for 7 months per year with a system capacity of 11,130 m$^3$/d. (70,000 BBLS/day)

This section discusses the Cohasset and Panuke reservoirs, the well test data, the proposed method of reservoir development, the reservoir simulation model, and the recoverable reserves estimates.

3.2 RESERVOIR ENGINEERING DATA

This section describes the drillstem and production tests for the Cohasset and Panuke wells.

3.2.1 DRILLSTEM AND PRODUCTION TESTS

Two of the three Cohasset wells have been tested: D-42 and A-52. The third well, P-42, encountered water and was not tested. Both of the Panuke wells, B-90 and F-99, were tested. The F-99 well was tested for an extended period, and the condensate was produced into a tanker.

3.2.1.1 Cohasset D-42

Sands 2, 5, and 10 were tested in the Cohasset D-42 well. Formation fluid samples were obtained, but the tests did not provide sufficient information to evaluate reservoir performance. The test results are given in Table 3.2-1.

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### TABLE 3.2-1

**TEST RESULTS: COHASSET D-42**

<table>
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<th>Parameter</th>
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<th>Sand 5 DST 4/5</th>
<th>Sand 10 DST 3</th>
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<tbody>
<tr>
<td><strong>Interval</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Top (m-RT)</td>
<td>1,861</td>
<td>1,969</td>
<td>2,248</td>
</tr>
<tr>
<td>Bottom (m-RT)</td>
<td>1,866</td>
<td>1,973</td>
<td>2,255</td>
</tr>
<tr>
<td><strong>Production Rates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensate (m³/d)</td>
<td>36</td>
<td>167</td>
<td>43</td>
</tr>
<tr>
<td>Gas (m³/d)</td>
<td>710</td>
<td>2,060</td>
<td>1,000</td>
</tr>
<tr>
<td>Water (m³/d)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GCR (m³/m³)</td>
<td>20</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td><strong>Pressures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom - initial (MPa)</td>
<td>18.47</td>
<td>19.69</td>
<td>22.00</td>
</tr>
<tr>
<td>Bottom - flowing (MPa)</td>
<td>18.35</td>
<td>19.37</td>
<td>21.59</td>
</tr>
<tr>
<td>Drawdown (%)</td>
<td>0.7</td>
<td>1.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Wellhead - flowing (MPa)</td>
<td>3.59</td>
<td>4.79</td>
<td>3.22</td>
</tr>
<tr>
<td><strong>Choke size (mm)</strong></td>
<td>7.9</td>
<td>12.7</td>
<td>9.5</td>
</tr>
<tr>
<td>Gravity (°API)</td>
<td>49</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>Permeability (kₚ) (mD)</td>
<td>1,215</td>
<td>1,370</td>
<td>220</td>
</tr>
<tr>
<td>kₕh (mD.m)</td>
<td>7,046</td>
<td>5,481</td>
<td>1,322</td>
</tr>
<tr>
<td>Skin effect</td>
<td>0</td>
<td>0</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

**MARCH 7, 1990**
3.2.1.2 **Cohasset A-52**

Seven zones, Sands 2, 3, 4, 5, 6, 7 and 8, were tested in the Cohasset A-52 well. The test in Sand 2 showed evidence of communication with a water-bearing zone through a casing cement channel. In Sand 3, there was no depletion, and strong aquifer support was evident. Sand 4 showed no depletion and had the characteristics of a multi-layered zone. The data from the commingled Sands 5 and 6 did not define reservoir boundaries nor whether aquifer support was present. Sand 7 showed good aquifer support with no indication of pressure depletion. Sand 8 showed a good water drive and no depletion.

The test results for Cohasset A-52 are given in Table 3.2-2.

3.2.1.3 **Panuke B-90**

The main Panuke sand, Sand 2, was tested in the Panuke B-90 well. Analysis of the test indicated a fault about 500 m from the wellbore. There was evidence of aquifer support and no evidence of depletion during the test. The test results for Panuke B-90 are given in Table 3.2-3.

3.2.1.4 **Panuke F-99**

Four zones were tested in the Panuke F-99 well: the Naskapi Sand, Sand 2, Sand 3, and Sand 4. The test of the Naskapi Sand showed it to be non-productive.

Sand 2 was flow-tested for 6 days during which 3815 m³ of condensate were produced. There was communication with Sand 3 through a vertical fracture during the test, but no evidence of pressure depletion.
TABLE 3.2-2
TEST RESULTS: COHASSET A-52

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sand 2 DST 6</th>
<th>Sand 3 DST 5</th>
<th>Sand 4 DST 4</th>
<th>Sands 5/6 DST 3</th>
<th>Sand 7 DST 2</th>
<th>Sand 8 DST 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top (m-RT)</td>
<td>2,123</td>
<td>2,149</td>
<td>2,215</td>
<td>2,254</td>
<td>2,337</td>
<td>2,385</td>
</tr>
<tr>
<td>Bottom (m-RT)</td>
<td>2,127</td>
<td>2,153</td>
<td>2,226</td>
<td>2,269.6</td>
<td>2,343</td>
<td>2,388.5</td>
</tr>
<tr>
<td>Production Rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensate (m³/d)</td>
<td>811</td>
<td>209</td>
<td>699</td>
<td>799</td>
<td>889</td>
<td>1,230</td>
</tr>
<tr>
<td>Gas (m³/d)</td>
<td>7,198</td>
<td>1,757</td>
<td>7,198</td>
<td>7,566</td>
<td>5,781</td>
<td>2,352</td>
</tr>
<tr>
<td>Water (m³/d)</td>
<td>71</td>
<td>59</td>
<td>145</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GCR (m³/m³)</td>
<td>8.9</td>
<td>8.4</td>
<td>10.7</td>
<td>9.5</td>
<td>6.5</td>
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</tr>
<tr>
<td>Pressures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom - initial (MPa)</td>
<td>18.56</td>
<td>18.73</td>
<td>19.37</td>
<td>19.65</td>
<td>20.32</td>
<td>20.70</td>
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<tr>
<td>Bottom - flowing (MPa)</td>
<td>17.32</td>
<td>17.42</td>
<td>17.62</td>
<td>17.06</td>
<td>17.89</td>
<td>20.20</td>
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<td>Drawdown (%)</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Wellhead - flowing (MPa)</td>
<td>1.79</td>
<td>1.45</td>
<td>1.41</td>
<td>2.10</td>
<td>2.17</td>
<td>3.24</td>
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<tr>
<td>Choke size (mm)</td>
<td>20.6</td>
<td>11.9</td>
<td>22.2</td>
<td>19.1</td>
<td>20.6</td>
<td>17.5</td>
</tr>
<tr>
<td>Gravity (°API)</td>
<td>48</td>
<td>50</td>
<td>51</td>
<td>52</td>
<td>54</td>
<td>52</td>
</tr>
<tr>
<td>Permeability (kₛ) (mD)</td>
<td>1,163</td>
<td>302</td>
<td>505</td>
<td>272</td>
<td>1,588</td>
<td>3,928</td>
</tr>
<tr>
<td>kₘ (mD.m)</td>
<td>4,536</td>
<td>1,240</td>
<td>2,630</td>
<td>2,181</td>
<td>7,624</td>
<td>68,356</td>
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<td>0</td>
<td>0</td>
<td>-1</td>
<td>+11</td>
<td>+3</td>
</tr>
<tr>
<td>Parameter</td>
<td>Sand 2</td>
<td>DST 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>-------</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Interval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top (m-RT)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bottom (m-RT)</td>
<td>2,299.5</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Production Rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensate (m³/d)</td>
<td></td>
<td>953</td>
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</tr>
<tr>
<td>Gas (m³/d)</td>
<td></td>
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<td></td>
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<tr>
<td>Water (m³/d)</td>
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<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCR (m³/m³)</td>
<td></td>
<td>11.6</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pressures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom - initial (MPa)</td>
<td></td>
<td>22.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom - flowing (MPa)</td>
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<td>19.75</td>
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<td></td>
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<tr>
<td>Drawdown (%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wellhead - flowing (MPa)</td>
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<td>2.28</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choke size (mm)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravity (°API)</td>
<td></td>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeability (kᵢ)(mD)</td>
<td></td>
<td>844</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kᵢh (mD.m)</td>
<td></td>
<td>3,885</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin effect</td>
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<td>+4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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3.2.2 Sand 4 is considered non-productive because of low permeability.

The test results for Panuke F-99 are given in Table 3.2-4.

3.2.2 FLUID PROPERTIES

The fluids recovered during well tests were analyzed to determine PVT properties. These properties were then compared with those of fluids from other reservoirs and sands to identify similarities.

The wellhead samples from Cohasset D-42 and A-52 tests indicate that all sands in the Cohasset reservoir, except perhaps Sand 10, contain essentially the same condensate. Some doubt exists about the validity of the sample from Sand 10.

The mole fractions of hydrocarbon components C₅ through C₂₀ are given in Figure 3.2-1 A and B for the various sands in the Cohasset reservoir.

The wellhead samples from Panuke B-90 and F-99 indicate that the condensate in the individual sands of the Panuke reservoir are similar. The hydrocarbon components of the Panuke samples are given in Figure 3.2-2.

The properties of the fluids from the Cohasset and Panuke reservoirs were also compared. The pressure-volume relationship, viscosity, and compressibility are given in Figures 3.2-3, 3.2-4 and 3.2-5 respectively. The viscosity and compressibility differ between reservoirs, but are similar for the sands within the reservoirs.

The properties of Cohasset and Panuke fluids at reservoir and separator conditions are given in Tables 3.2-5 and 3.2-6 respectively. From analysis and comparison of the fluid samples, it is apparent that the condensates are different between the reservoirs but are similar between the sands of the same reservoir.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Naskapi Sand DST 4</th>
<th>Sand 2,3 DST 3</th>
<th>Sand 3 DST 2</th>
<th>Sand 4 DST 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interval</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top (m-RT)</td>
<td>2,227.5</td>
<td>2,292</td>
<td>2,303</td>
<td>2,307.5</td>
</tr>
<tr>
<td>Bottom (m-RT)</td>
<td>2,229.5</td>
<td>2,298</td>
<td>2,305</td>
<td>2,311</td>
</tr>
<tr>
<td><strong>Production Rates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensate (m³/d)</td>
<td>12</td>
<td>659</td>
<td>181</td>
<td>6</td>
</tr>
<tr>
<td>Gas (m³/d)</td>
<td>-</td>
<td>10,938</td>
<td>1,643</td>
<td>-</td>
</tr>
<tr>
<td>Water (m³/d)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>GCR (m³/m³)</td>
<td>-</td>
<td>16.6</td>
<td>9.1</td>
<td>-</td>
</tr>
<tr>
<td><strong>Pressures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom - initial (MPa)</td>
<td>22.18</td>
<td>22.79</td>
<td>22.86</td>
<td>22.90</td>
</tr>
<tr>
<td>Bottom - flowing (MPa)</td>
<td>18.75</td>
<td>17.27</td>
<td>17.28</td>
<td>19.99</td>
</tr>
<tr>
<td>Drawdown (%)</td>
<td>15</td>
<td>24</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>Wellhead - flowing (MPa)</td>
<td>0.05</td>
<td>1.34</td>
<td>0.96</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Choke size (mm)</strong></td>
<td>11.90</td>
<td>22.22</td>
<td>11.90</td>
<td>8.73</td>
</tr>
<tr>
<td><strong>Gravity (°API)</strong></td>
<td>55</td>
<td>55</td>
<td>54</td>
<td>43</td>
</tr>
<tr>
<td><strong>Permeability (kₚ) (mD)</strong></td>
<td>9</td>
<td>372</td>
<td>98</td>
<td>6</td>
</tr>
<tr>
<td>kₚh (mD.m)</td>
<td>13</td>
<td>669</td>
<td>215</td>
<td>13</td>
</tr>
<tr>
<td><strong>Skin effect</strong></td>
<td>-1</td>
<td>0</td>
<td>+1</td>
<td>+1</td>
</tr>
</tbody>
</table>

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FLUID COMPOSITION: COHASSET
WELLHEAD SAMPLES

FIGURE 3.2-1A
FLUID COMPOSITION: COHASSET
WELLHEAD SAMPLES

FIGURE 3.2-1B
FLUID COMPOSITION: PANUKE
WELLHEAD SAMPLES

FIGURE 3.2-2

MOLE FRACTION

COMPONENT

SANDS 2/3: F-99
SAND 2: B-90
PRESSURE-VOLUME RELATIONSHIPS - COHASSET & PANUKE

![Diagram showing pressure-volume relationships for different sands in COHASSET and PANUKE.](image)

- **Relative Volume** axis ranges from 0.9 to 1.9.
- **Pressure (MPa)** axis ranges from 1 to 21.
- Graph includes markers for different sands:
  - SAND 1: COH A-52
  - SAND 3: COH A-52
  - SAND 2: PAN B-90
  - SAND 2/3: PAN F-99

**Figure 3.2-3**
CONDENSATE VISCOSITY - COHASSET & PANUKE

![Graph of condensate viscosity vs pressure for different sand and COH samples.](image)

**Legend:**
- ▼ SAND 6: COH A-52
- ★ SAND 5: COH D-42
- ◀ SAND 3: COH A-52
- ✠ SAND 2: PAN B-90
- △ SAND 10: COH D-42
- ◇ SAND 2/3: PAN F-99
COMPRESSIBILITY OF SATURATED CONDENSATE - COHASSET & PANUKE

FIGURE 3.2-5

- SAND 8: COH A-52
- SAND 3: COH A-52
- SAND 2: PAN B-90
- SAND 2/3: PAN F-99
TABLE 3.2-5
FLUID PROPERTIES AT RESERVOIR CONDITIONS

<table>
<thead>
<tr>
<th>Property</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cohasset</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bubble point pressure (MPa)</td>
<td>2.69</td>
<td>2.73</td>
<td>2.71</td>
</tr>
<tr>
<td>Condensate compressibility (10^4/MPa)</td>
<td>10.15</td>
<td>9.72</td>
<td>10.00</td>
</tr>
<tr>
<td>Condensate viscosity (mPa's)</td>
<td>0.76</td>
<td>0.66</td>
<td>0.71</td>
</tr>
<tr>
<td>Condensate density (kg/m^3)</td>
<td>736</td>
<td>746</td>
<td>741</td>
</tr>
<tr>
<td><strong>Panuke</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bubble point pressure (MPa)</td>
<td>2.65</td>
<td>2.83</td>
<td>2.74</td>
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<tr>
<td>Condensate compressibility (10^4/MPa)</td>
<td>14.36</td>
<td>13.92</td>
<td>14.07</td>
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<tr>
<td>Condensate viscosity (mPa's)</td>
<td>0.37</td>
<td>0.43</td>
<td>0.40</td>
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<tr>
<td>Condensate density (kg/m^3)</td>
<td>-</td>
<td>703</td>
<td>703</td>
</tr>
</tbody>
</table>

1 Sample 1 - Cohasset A-52 (Sand 8)
   - Panuke B-90 (Sand 2)

2 Sample 2 - Cohasset A-52 (Sand 3)
   - Panuke P-99 (Sand 2,3)
<table>
<thead>
<tr>
<th>Property</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cohasset</strong></td>
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<td></td>
</tr>
<tr>
<td>Separator pressure (kPa) (abs)</td>
<td>515</td>
<td>101</td>
<td>-</td>
</tr>
<tr>
<td>Temperature (°C)</td>
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<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Gravity (°API)</td>
<td>-</td>
<td>50.6</td>
<td>50.6</td>
</tr>
<tr>
<td>Gas gravity</td>
<td>0.68</td>
<td>0.65</td>
<td>0.67</td>
</tr>
<tr>
<td>GCR (m³/m³)</td>
<td>11.1</td>
<td>2.5</td>
<td>13.6</td>
</tr>
<tr>
<td>Condensate formation volume factor</td>
<td>-</td>
<td>-</td>
<td>1.054</td>
</tr>
<tr>
<td><strong>Panuke</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separator pressure (MPa) (abs)</td>
<td>515</td>
<td>101</td>
<td>-</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>64</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Gravity (°API)</td>
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<td>56</td>
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<tr>
<td>Gas gravity</td>
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<td>1.027</td>
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<td>GCR (m³/m³)</td>
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<tr>
<td>Condensate formation volume factor</td>
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<td>-</td>
<td>1.140</td>
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</table>

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3.2.3 INJECTION FLUIDS

Initial compatibility studies have shown no calcite or gypsum scaling tendencies at 45 percent formation water and 55 percent seawater. Based on this finding, injection of treated seawater is not expected to cause problems. Refer to Appendix III for more information.

3.2.4 FORMATION TEMPERATURES

The sand temperatures range from 69°C to 84°C in the Cohasset reservoir and from 83°C to 88°C in the Panuke reservoir. The average temperature gradient is 3.73°C/100 m in Cohasset and 3.95°C/100 m in Panuke. The average formation temperatures for Cohasset are given in Table 3.2-7 and for Panuke in Table 3.2-8.

3.2.5 FORMATION PRESSURES

The Cohasset and Panuke reservoirs are both normally pressured. The hydrostatic pressure gradient for both reservoirs is 10.1 kPa/m. Formation pressures for Cohasset are given in Table 3.2-9 and for Panuke in Table 3.2-10. These tables present the values at the condensate/water contact.

3.3 RESERVES ESTIMATE

This section presents the recoverable reserves estimates for the Cohasset and Panuke reservoirs and discusses the assumptions and uncertainties.

3.3.1 VOLUMETRIC CALCULATIONS

The condensate-in-place for the Cohasset and Panuke reservoirs was determined by the volumetric method. Rock volumes were determined from the available net pay isopach maps. Porosities, water
### TABLE 3.2-7
**AVERAGE FORMATION TEMPERATURE: COHASSET**

<table>
<thead>
<tr>
<th>Sand</th>
<th>Formation Depth (m ss)</th>
<th>Formation Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1c</td>
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<td>66</td>
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<td>3</td>
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<tr>
<td>4</td>
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<td>72</td>
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<tr>
<td>5</td>
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<td>73</td>
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<td>6</td>
<td>1,944</td>
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<td>7</td>
<td>2,002</td>
<td>76</td>
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<tr>
<td>8</td>
<td>2,042</td>
<td>77</td>
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<td>9</td>
<td>2,072</td>
<td>78</td>
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<tr>
<td>10</td>
<td>2,222</td>
<td>84</td>
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</table>

### TABLE 3.2-8
**AVERAGE FORMATION TEMPERATURE: PANUKE**

<table>
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<th>Sand</th>
<th>Formation Depth (m ss)</th>
<th>Formation Temperature (°C)</th>
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</thead>
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<tr>
<td>Naskapi</td>
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<td>83</td>
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<td>86</td>
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<tr>
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<td>2,262</td>
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<td>4</td>
<td>2,303</td>
<td>88</td>
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### TABLE 3.2-9
**AVERAGE FORMATION PRESSURE: COHASSET**

<table>
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<th>Formation Depth (m ss)</th>
<th>Formation Pressure (MPa)</th>
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</thead>
<tbody>
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<td>18.56</td>
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<tr>
<td>3</td>
<td>1,853</td>
<td>18.73</td>
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<tr>
<td>4</td>
<td>1,910</td>
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<td>19.65</td>
</tr>
<tr>
<td>6</td>
<td>1,951</td>
<td>19.72</td>
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<tr>
<td>7</td>
<td>2,011</td>
<td>20.36</td>
</tr>
<tr>
<td>8</td>
<td>2,047</td>
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<tr>
<td>10</td>
<td>2,225</td>
<td>21.93</td>
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### TABLE 3.2-10
**AVERAGE FORMATION PRESSURE: PANUKE**

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<th>Formation Depth (m ss)</th>
<th>Formation Pressure (MPa)</th>
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</thead>
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<td>Naskapi</td>
<td>2,190</td>
<td>22.18</td>
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<td>2</td>
<td>2,262</td>
<td>22.99</td>
</tr>
<tr>
<td>3</td>
<td>2,270</td>
<td>23.09</td>
</tr>
<tr>
<td>4</td>
<td>&gt;2,270</td>
<td>23.13</td>
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</table>

MAY 2, 1990
saturations, temperatures, and pressures were obtained from well logs, tests and cores.

3.3.1.1 Cohasset Reservoir

The Cohasset reservoir trends northeast-southwest. It is 3.5 km long and 1.5 km wide. The original condensate-in-place for all sands is given in Table 3.3-1. This table also gives the recoverable reserves for the six year productive life.

The reserves estimates obtained from reservoir simulation have some uncertainties. First, all sands were assumed to be continuous and were modelled to respect the log-derived net pays at each well location. Linear interpolations were applied between wells. Second, the simulations did not account for faulting in the Cohasset reservoir although tests did indicate the existence of boundaries. Third, the simulations were based on limited data and no production history.

3.3.1.2 Panuke Reservoir

The Panuke reservoir trends northeast-southwest. It is 5 km long and 2 km wide. The reservoir contains numerous sands, with the majority of the reserves contained in two of them. The original condensate-in-place and recoverable reserves for these two sands is given in Table 3.3-2.

There are three uncertainties in the reservoir simulation of the Panuke reservoir. The first and most important is the degree to which natural fractures exist in the reservoir sands. Test and cores confirmed the existence of fractures. If the fractures extend into the water zone, water could be produced early in the field life.
### TABLE 3.3-1
ORIGINAL AND RECOVERABLE CONDENSATE-IN-PLACE
COHASSET RESERVOIR

<table>
<thead>
<tr>
<th>Sand</th>
<th>Original Condensate In-Place ($10^3 m^3$)</th>
<th>Recovery Factor (%)</th>
<th>Recoverable Condensate In-Place ($10^3 m^3$)</th>
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</thead>
<tbody>
<tr>
<td>0-1c</td>
<td>755</td>
<td>34</td>
<td>256</td>
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<tr>
<td>2</td>
<td>980</td>
<td>24</td>
<td>232</td>
</tr>
<tr>
<td>3</td>
<td>545</td>
<td>20</td>
<td>109</td>
</tr>
<tr>
<td>4</td>
<td>1,093</td>
<td>44</td>
<td>480</td>
</tr>
<tr>
<td>5</td>
<td>848</td>
<td>46</td>
<td>391</td>
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<td>511</td>
<td>37</td>
<td>190</td>
</tr>
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<td>1,160</td>
<td>41</td>
<td>470</td>
</tr>
<tr>
<td>8</td>
<td>661</td>
<td>41</td>
<td>271</td>
</tr>
<tr>
<td>9</td>
<td>585</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>10</td>
<td>1,008</td>
<td>43</td>
<td>431</td>
</tr>
<tr>
<td>Total</td>
<td>8,146</td>
<td>35</td>
<td>2,869</td>
</tr>
</tbody>
</table>

### TABLE 3.3-2
ORIGINAL AND RECOVERABLE CONDENSATE-IN-PLACE
PANUKE RESERVOIR

<table>
<thead>
<tr>
<th>Sand</th>
<th>Original Condensate In-Place ($10^3 m^3$)</th>
<th>Recoverable Condensate In-Place ($10^3 m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4,492</td>
<td>1,970 73.5%</td>
</tr>
<tr>
<td>3</td>
<td>2,742</td>
<td>712   26.5%</td>
</tr>
<tr>
<td>Total</td>
<td>7,234</td>
<td>2,682</td>
</tr>
</tbody>
</table>

---

MARCH 7, 1990 3.20
The second uncertainty is the depth of the condensate-water contact. This information is required to locate water injection wells. The third is the validity of the simulations, which were based on limited data and no production history.

### 3.3.2 RECOVERY FACTORS

Production forecasts were developed for operating 7 months per year at a peak condensate rate of 4,770 m$^3$/d with 5 percent downtime. The recovery factors for this seasonal production scheme for Cohasset and Panuke are included in Tables 3.3-1 and 3.3-2 respectively. Average recovery is 36 percent of original condensate-in-place. Simulation results indicate that these reservoirs have a productive life of six years.

### 3.3.3 CURRENT STUDIES

Subsequent to the studies reported in this development application, additional studies have been initiated to further evaluate recoveries and deliverabilities of these reservoirs:

- Commingle studies to determine the optimum completion strategy
- A continuing study of ultimate recovery forecasts for the reservoirs
- Studies of producer and injector location sensitivities

### 3.4 RESERVOIR DEVELOPMENT STRATEGY

This section describes the reservoir development strategy, including gas conservation and enhanced recovery.
3.4.1 RESERVOIR SIMULATION MODEL

Reservoir simulation studies were carried out using two simulators: IMEX 300, an adaptive implicit simulator and BOAST II an implicit pressure, explicit saturation simulator. Coning studies were performed using the IMEX 300 simulator.

Only primary recovery, with pressure maintenance of the two reservoirs, was simulated. Extrapolation or prediction of recovery from tertiary recovery techniques was considered too speculative to be examined at this time.

Simulation structures were generated for all sands using a coarse grid areal model (Figures 3.4-1 and 3.4-2). Figures 3.4-3 through 3.4-11 show the computer-generated structure maps for the sands in the Cohasset reservoir. Figures 3.4-12 and 3.4-13 show the structure maps for the Panuke reservoir.

Pseudo relative permeability curves based on cross-sectional and radial simulation studies were not generated because of time constraints. Instead, available data were used to generate average relative permeability curves, which were then modified to allow for a slight piston-like flow response (Figure 3.4-14). The end points of these general curves were adjusted to account for the saturation conditions in each sand and the resulting values were used in the simulator model.

Production forecasts were generated assuming a peak condensate rate of 4,770 m$^3$/d with a 5 percent downtime over a seven month season. A total fluid production constraint of 11,130 m$^3$/d was also used.

Reservoir pressure was supported with one water injection well at Panuke and two at Cohasset injecting water at a rate to replace 100 percent of the voidage caused by production. Pumps were run in all producing wells in both reservoirs from the start of production.
COHASSET SIMULATION STUDY - GRID SYSTEM

FIGURE 3.4-1

- PRODUCER WELL - CP1
- PRODUCER WELL - CP2
- PRODUCER WELL - CP3
- PRODUCER WELL - CP4
- PRODUCER WELL - CP5

X - INJECTOR WELL - CI1
X1 - INJECTOR WELL - CI2
O - D-42 WELL
O1 - A-52 WELL
FIGURE 3.4-2

PANUKE SIMULATION STUDY - GRID SYSTEM

- PRODUCER WELL - PP1
- PRODUCER WELL - PP2
- PRODUCER WELL - PP3
X - INJECTOR WELL - PI1
O - B-90 WELL
O1 - F-99 WELL

750 m
COHASSET SIMULATION STUDY - TOP SAND 2

CONTOURS
1 = 1832.3 m
2 = 1833.4 m
3 = 1834.5 m
4 = 1835.6 m
5 = 1836.7 m
6 = 1837.8 m
7 = 1838.9 m
8 = 1840.0 m

- O1 - PRODUCER WELL - CP2
- O2 - PRODUCER WELL - CP3
- O3 - PRODUCER WELL - CP4
- X - INJECTOR WELL - CI1
- X1 - INJECTOR WELL - CI2
- O - D-42 WELL
- O1 - A-52 WELL

FIGURE 3.4-3
COHASSET SIMULATION STUDY - TOP SAND 3

CONTOURS
1 = 1853.4 m
2 = 1854.6 m
3 = 1855.8 m
4 = 1857.0 m
5 = 1858.2 m
6 = 1859.4 m
7 = 1860.6 m
8 = 1861.8 m

- PRODUCER WELL - CP2
- PRODUCER WELL - CP3
- PRODUCER WELL - CP4
X - INJECTOR WELL - CI1
X1 - INJECTOR WELL - CI2
O - D-42 WELL
O1 - A-52 WELL

FIGURE 3.4-4
COHASSET SIMULATION STUDY - TOP SAND 4

CONTOURS
1 = 1998.9 m
2 = 1901.9 m
3 = 1904.9 m
4 = 1907.9 m
5 = 1910.9 m
6 = 1913.9 m

FIGURE 3.4-5
COHASSET SIMULATION STUDY - TOP SAND 6

CONTOURS
1 = 1945.2 m
2 = 1947.6 m
3 = 1950.0 m
4 = 1952.4 m
5 = 1954.8 m

- PRODUCER WELL - CP1
- PRODUCER WELL - CP3
- PRODUCER WELL - CP4
- PRODUCER WELL - CP5

X - INJECTOR WELL - CI1
X1 - INJECTOR WELL - CI2
O - D-42 WELL
O1 - A-52 WELL

FIGURE 3.4-7
COHASSET SIMULATION STUDY - TOP SAND 7

CONTOURS
1 = 2006.5 m
2 = 2008.9 m
3 = 2011.3 m
4 = 2013.7 m
5 = 2016.1 m

- PRODUCER WELL - CP1
- PRODUCER WELL - CP3
- PRODUCER WELL - CP4
- PRODUCER WELL - CP5

X - INJECTOR WELL - CI1
X1 - INJECTOR WELL - CI2
O - D-42 WELL
O1 - A-52 WELL
COHASSET SIMULATION STUDY - TOP SAND 8

CONTOURS
1 = 2042.0 m
2 = 2044.5 m
3 = 2047.0 m
4 = 2049.5 m
5 = 2052.0 m

FIGURE 3.4-9

- PRODUCER WELL - CP1
- PRODUCER WELL - CP4
O - D-42 WELL
O - A-52 WELL

300 m
FIGURE 3.4-10

COHASSET SIMULATION STUDY - TOP SAND 9

CONTOURS
1 = 2063.0 m
2 = 2066.0 m
3 = 2069.0 m
4 = 2072.0 m
5 = 2078.0 m

● - PRODUCER WELL - CP1
●2 - PRODUCER WELL - CP3
○ - D-42 WELL
○1 - A-52 WELL

300 m
COHASSET SIMULATION STUDY - TOP SAND 10

FIGURE 3.4-11

CONTOURS
1 = 2219.0 m
2 = 2222.0 m
3 = 2225.0 m
4 = 2228.0 m
5 = 2231.0 m

- PRODUCER WELL - CP1
- PRODUCER WELL - CP2
- PRODUCER WELL - CP5

X - INJECTOR WELL - CI1
X1 - INJECTOR WELL - CI2
O - B-90 WELL
O1 - F-99 WELL

600 m
FIGURE 3.4-12

PANUKE SIMULATION STUDY - TOP SAND 2

- PRODUCER WELL - PP1
- PRODUCER WELL - PP2
- PRODUCER WELL - PP3

X - INJECTOR WELL - PI1
O - B-90 WELL
O1 - F-99 WELL
PANUKE SIMULATION STUDY - TOP SAND 3

CONTOURS
1 = 2252.5 m
2 = 2258.6 m
3 = 2264.7 m
4 = 2270.8 m
5 = 2276.9 m

- PRODUCER WELL - PP1
- PRODUCER WELL - PP2
- PRODUCER WELL - PP3
X - INJECTOR WELL - PI1
O - B-90 WELL
O1 - F-99 WELL

FIGURE 3.4-13
RELATIVE PERMEABILITIES

![Graph showing relative permeabilities]

- Average relative permeability - condensate
- Piston relative permeability - condensate
- Average relative permeability - water

FIGURE 3.4-14
to ensure deliverability was maintained as water production increased.

Simulation runs were set up to maintain a plateau production rate for as long as possible by increasing the production from Panuke to make up for declining Cohasset production.

3.4.2 RESERVOIR DEVELOPMENT

This section summarizes the plan for reservoir development. For a more in-depth presentation, refer to Appendix III.

3.4.2.1 Cohasset Reservoir

The Cohasset reservoir will be developed with five producing wells and two water injection wells. The well locations for each sand are shown in Figures 3.4-3 through 3.4-11. The completion schedule resulting from this study is given in Table 3.4-1.

**TABLE 3.4-1**

<table>
<thead>
<tr>
<th>Production Season</th>
<th>Production Well</th>
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<tr>
<td></td>
<td>CP1</td>
</tr>
<tr>
<td>1</td>
<td>8,9</td>
</tr>
<tr>
<td>2</td>
<td>5,6,7</td>
</tr>
<tr>
<td>3</td>
<td>5,6,7</td>
</tr>
<tr>
<td>4</td>
<td>5,6,7</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>

MARCH 7, 1990
For the first production season, water injection was not implemented at Cohasset. In order to ensure overall recovery, it was found necessary to have make-up injection in Sands 5, 6 and 7. This was implemented prior to the start of the second season.

3.4.2.2 Panuke Reservoir

The Panuke reservoir will be developed with three producing wells and one water injection well. The well locations are shown in Figures 3.4-12 and 3.4-13. All four wells will be completed in both Sand 2 and Sand 3.

3.4.2.3 Reservoir Studies

Specific plans for testing, coring, logging, sampling, production monitoring, and reservoir studies are provided in Appendix III.

3.4.2.4 Gas Conservation

Some of the produced gas will be used as fuel and for facilities. The small amount of excess produced gas will be flared. Because of the undersaturated nature of the condensate, gas production will be very low. At full condensate production, total gas rates should be less than 85,000 m³/d.

3.4.2.5 Pressure Maintenance

Except for the first season, water injection will be initiated at both Cohasset and Panuke. During the first season, water will be injected into the Panuke reservoir only. The required water injection rates to maintain 100 percent voidage replacement over the field life are shown in Figure 3.4-15. Figures 3.4-16 and 3.4-17 show the initial and final water saturation maps for the currently simulated producing life of Cohasset Sand 5. These maps are indicative of the recovery efficiency for the entire reservoir.
WATER INJECTION

FIGURE 3.4-15

WATER INJECTION
(1000 m³/d)

PRODUCTION YEAR

□ COHASSET
□ PANUKE
△ TOTAL
INITIAL WATER SATURATION - COHASSET SAND 5

WATER SATURATION
1 = 40%
2 = 50%
3 = 60%
4 = 70%
5 = 80%

- PRODUCER WELL - CP1
- PRODUCER WELL - CP3
- PRODUCER WELL - CP4
- PRODUCER WELL - CP5
- INJECTOR WELL - CI1
- INJECTOR WELL - CI2

O - D-42 WELL
O - A-52 WELL

FIGURE 3.4-16
FINAL WATER SATURATION - COHASSET SAND 5

WATER SATURATION
1 = 40%
2 = 50%
3 = 60%
4 = 70%
5 = 80%

* - PRODUCER WELL - CP1
*2 - PRODUCER WELL - CP3
*3 - PRODUCER WELL - CP4
*4 - PRODUCER WELL - CP5
X - INJECTOR WELL - CI1
X1 - INJECTOR WELL - CI2
O - D-42 WELL
O1 - A-52 WELL

FIGURE 3.4-17
3.4.3 PRODUCTION FORECASTS

The estimates of recoverable reserves for Cohasset and Panuke reservoirs are given in Table 3.4-2.

The production forecast is based on a 7-month (210-day) producing season with 5 percent downtime.

Figure 3.4-18 shows the cumulative condensate production from Cohasset and Panuke. Figures 3.4-19 and 3.4-20 show the seasonal condensate and water production respectively.

<table>
<thead>
<tr>
<th>Season</th>
<th>Cohasset Condensate ($10^3$ m$^3$)</th>
<th>Water ($10^3$ m$^3$)</th>
<th>Panuke Condensate ($10^3$ m$^3$)</th>
<th>Water ($10^3$ m$^3$)</th>
<th>Combined Condensate ($10^3$ m$^3$)</th>
<th>Water ($10^3$ m$^3$)</th>
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<tr>
<td>1</td>
<td>430</td>
<td>374</td>
<td>525</td>
<td>0</td>
<td>955</td>
<td>374</td>
</tr>
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<td>2</td>
<td>584</td>
<td>15</td>
<td>371</td>
<td>0</td>
<td>955</td>
<td>15</td>
</tr>
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<td>3</td>
<td>574</td>
<td>346</td>
<td>381</td>
<td>0</td>
<td>955</td>
<td>346</td>
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<tr>
<td>4</td>
<td>512</td>
<td>800</td>
<td>443</td>
<td>33</td>
<td>955</td>
<td>833</td>
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<td>5</td>
<td>450</td>
<td>869</td>
<td>472</td>
<td>216</td>
<td>922</td>
<td>1,085</td>
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<tr>
<td>6</td>
<td>320</td>
<td>794</td>
<td>490</td>
<td>441</td>
<td>810</td>
<td>1,235</td>
</tr>
</tbody>
</table>

MARCH 7, 1990
CUMULATIVE CONDENSATE

CONDENSATE VOLUME
\(10^6\) m\(^3\)

PRODUCTION YEAR

FIGURE 3.4-18
CONDENSATE PRODUCTION

CONDENSATE PRODUCTION
(1000 m³/d)

PRODUCTION YEAR

[Diagram showing condensate production for various years]

FIGURE 3.4-19
## Section 4
### Table of Contents

<table>
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<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
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SECTION 4. DRILLING AND COMPLETIONS

4.1 SUMMARY

This section summarizes the drilling activities conducted to date in the Cohasset and Panuke fields and the drilling and completion plans for the production and injection wells.

4.2 EXISTING WELLS

The history and details of the wells drilled to date are presented in this section.

4.2.1 WELL PARTICULARS

Five wells have been drilled to date in the Cohasset and Panuke fields. The locations of the wells are shown in Figure 4.2-1. Particulars of the wells are given in Table 4.2-1.

4.2.2 WELL HISTORY

The Cohasset D-42 well was drilled by Mobil Oil Canada Ltd. in 1973, and was intended to be a deep test of the underlying Abenaki carbonate reef. The well was dry in the target formations, but encountered a series of thin condensate-bearing sands in the overlying lower Logan Canyon sands and in the uppermost Missisauga sand. Drillstem tests were run on three of these pay zones. The maximum flow rate recorded was 169 m³/d, and the test flow periods were very short. The recovered fluids confirmed that the condensate had a gravity of 49° to 53° API and had a very low gas content, less than 12 m³/m³. Consequently, the D-42 discovery well was abandoned, and no follow-up exploration was undertaken by Mobil and its partners at that time.
### TABLE 4.2-1
PARTICULARS OF WELLS DRILLED TO DATE
COHASSET AND PANUKE FIELDS

<table>
<thead>
<tr>
<th>Location</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
<th>Cohasset A-52</th>
<th>Panuke B-90</th>
<th>Panuke F-99</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>43°51'6.52&quot;</td>
<td>43°51'50.32&quot;</td>
<td>43°51'8.17&quot;</td>
<td>43°49'11.9&quot;</td>
<td>43°48'24.9&quot;</td>
</tr>
<tr>
<td>West</td>
<td>60°37'13.89&quot;</td>
<td>60°36'18.23&quot;</td>
<td>60°37'43.52&quot;</td>
<td>60°42'34.6&quot;</td>
<td>60°44'34.01&quot;</td>
</tr>
</tbody>
</table>

| Water Depth (m) | - | - | 36 | 47 | 45.1 |
| Drilling Unit   | Sedco J | Gulftide | Rowan Gorilla I | SDS Vinland | Rowan Gorilla I |
| Total Depth (m RT)$^1$ | 4428 | 2591 | 2496 | 3425 | 2507 |
| Total Days on Location | 81 | 31 | 99 | 49 | 55 |
| Time Drilling (d) | 57 | 25 | 59 | 36 | 25 |
| Formation Evaluation Time (d) | 24 | 6 | 40 | 13 | 30 |
| Number of Drillstem Tests | 7 | 0 | 6 | 1 | 4 |
| Maximum Bottomhole Pressure (MPa) | 39.2 | N.A.$^2$ | 26.4 | 36.2 | 24.6 |
| Maximum Bottomhole Temperature (°C) | 115 | N.A.$^2$ | 79 | 117 | 90 |

$^1$True vertical depth below rotary table.

$^2$Not available.
In 1978, Mobil drilled the P-42 delineation well. The Cohasset reservoirs were encountered in a slightly down-dip position relative to the D-42 well, and all of the sands that contained condensate at D-42 were water-bearing at the P-42 well. Exploration ceased, and no further interest was shown in exploration in the Cohasset area for several years.

In 1982, Nova Scotia Resources Limited (NSRL) purchased the interests of British Columbia Resource Investment Corporation (BCRIC) in the Sable Island block, and with it a 10 percent interest in Cohasset. NSRL became interested in the Cohasset potential as part of an independent exploration thrust to determine the prospects for condensate discoveries along the Abenaki carbonate edge rimming the western side of the Sable sub-basin. NSRL reviewed the technical data for the Cohasset D-42 discovery well and developed a justification for drilling a step-out well to the southwest of the D-42 discovery well.

Additional seismic data were obtained on the structure, and each of the four partners (Mobil, Petro-Canada, Canterra, and NSRL) undertook independent interpretations of the data.

Petro-Canada, Canterra, and NSRL concluded that the Cohasset field had economic development potential, and that a step-out well to the southwest of the D-42 well was warranted.

Mobil had no interest in drilling an additional well at Cohasset, so NSRL and Petro-Canada together as operator planned the drilling of the Cohasset A-52 well to delineate the Cohasset reservoirs in the southwest lobe of the field.

The Cohasset A-52 well encountered a pay section of about 43 m, roughly equivalent to the D-42 discovery well. Six drillstem tests run in six separate sands resulted in an aggregate tested condensate production rate of approximately 4600 m³/d.
The first well drilled in the Panuke field was Panuke B-90. This well was drilled and evaluated in 1986 by Shell Canada Ltd. A second well, Panuke F-99, was drilled by Petro-Canada in 1987. Drill stem tests resulted in condensate flows of up to 659 m$^3$/d from a single zone. An extended production test was undertaken using a floating storage vessel.

4.2.3 DRILLING OPERATIONS

The discovery wells in both fields were drilled with semisubmersible drilling units, and the three subsequent delineation wells, with jack-up drilling units.

In general, no unusual drilling situations were encountered during the drilling of the Cohasset and Panuke wells. The drilling times for each of the wells for which data was available are summarized in Figure 4.2-2. Panuke F-99 was a vertical well; Panuke B-90 was deviated to 12.5 degrees. Each well was drilled to 2350 m depth below rotary table in approximately 18 to 20 days.

Cohasset A-52 was a deviated well drilled to a maximum angle of 36.5°. The well was drilled and cored to 2350 m below rotary table in approximately 44 days, exclusive of production testing.

Typical pore pressures in the Cohasset and Panuke fields are shown in Figure 4.2-3. Formations are normally pressured to total depth at a maximum gradient equivalent to a density mud weight of 1.2. Fracture pressures are predicted as being in excess of a density mud weight of 1.7.

Temperature measurements in both fields also indicate a gradient of 3 to 4°C per 100 m as shown in Figure 4.2-4.
DRILLING TIMES
EXPLORATION AND APPRAISAL WELLS

FIGURE 4.2-2

DEPTH RT (m)

DAYS FROM SPUD

- COHASSET A-52 (1986)
- PANUKE F-99 (1987)
- PANUKE B-90 (1986)
- COHASSET D-42 (1973)
PORE PRESSURE AND FRACTURE PRESSURE vs DEPTH

FIGURE 4.2-3
TEMPERATURE vs DEPTH

EXTRAPOLATED FROM LOGS
PANUKE B-90
○ DST PANUKE B-90
□ DST COHASSET D-42
□ MAX. TEMP. COHASSET A-52

FIGURE 4.2-4
DRILLING FLUIDS

Table 4.2-2 summarizes the drilling fluid properties for the wells drilled on the Cohasset and Panuke structures. In general, the conductor and surface holes were drilled with seawater and gel/polymer pills. The production section of most wells was drilled with a potassium chloride (KCl) polymer system. An condensate-based mud was used in Panuke B-90.

CASTING PROGRAMS

The casing programs used on the previously drilled wells are summarized in Table 4.2-3. The Cohasset wells were drilled with a conductor casing string ranging in size from 340 mm to 508 mm. The Panuke wells did not use a conductor casing below the drive pipe. Surface casing of size 340 mm was run to a depth of approximately 1000 m in most wells. A 244 mm production string was run on all wells, and a 178 mm liner on the Cohasset D-42 well.

CEMENTING PROGRAMS

The cement used in the most recent exploration and appraisal wells consisted of a class G cement. Maritime and Class B cements were used in the earlier Cohasset D-42 and P-42 wells. Cement additives such as retarders, turbulence inducers, fluid loss additives, and extenders were used as required.

DIRECTIONAL CONTROL

The Cohasset A-52 well was drilled as a directionally controlled well. The 432 mm hole section was directionally drilled to a maximum angle of 36.52° S, 15.89° W at a build rate of 2° per 30 m. Some tight hole and angle building problems were encountered and resolved. The Panuke B-90 well was directionally drilled from 953 m
<table>
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<th>Hole Section</th>
<th>Cohasset D-42</th>
<th>Cohasset P-42</th>
<th>Cohasset A-52</th>
<th>Panuke B-90</th>
<th>Panuke F-99</th>
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</thead>
<tbody>
<tr>
<td>Conductor</td>
<td>Dispersed lignosulphonate</td>
<td>Seawater w/ gel</td>
<td>Seawater w/ prehydrate gel/polymer pills</td>
<td>Seawater w/ viscous slugs</td>
<td>Seawater w/ prehydrated gel/polymer pills</td>
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<tr>
<td>Surface</td>
<td>Dispersed lignosulphonate</td>
<td>Seawater w/ gel</td>
<td>Seawater w/ KCL/polymer</td>
<td>Seawater w/ viscous slugs</td>
<td>Seawater w/ prehydrated gel/polymer pills</td>
</tr>
<tr>
<td>Main</td>
<td>Dispersed lignosulphonate</td>
<td>Fresh water w/ gel</td>
<td>Seawater w/ KCL/polymer</td>
<td>Oil-based mud</td>
<td>Seawater w/ KCL/polymer</td>
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<td>Detail</td>
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<td>Cohasset P-42</td>
<td>Cohasset A-52</td>
<td>Panuke B-90</td>
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<td>---------------</td>
<td>---------------</td>
<td>---------------</td>
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<tr>
<td>Drive pipe</td>
<td>Size (mm)</td>
<td>762</td>
<td>762</td>
<td>914</td>
<td>762</td>
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<tr>
<td></td>
<td>Depth (m)</td>
<td>124</td>
<td>188</td>
<td>177</td>
<td>120</td>
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<tr>
<td>Conductor</td>
<td>Size (mm)</td>
<td>508</td>
<td>340</td>
<td>473</td>
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<td></td>
<td>Depth (m)</td>
<td>230</td>
<td>302</td>
<td>336</td>
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<tr>
<td>Surface</td>
<td>Size (mm)</td>
<td>340</td>
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<td>340</td>
<td>340</td>
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<td></td>
<td>Depth (m)</td>
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<td>1098</td>
<td>902</td>
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<td>Size (mm)</td>
<td>244</td>
<td>244</td>
<td>244</td>
<td>244</td>
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<td></td>
<td>Depth (m)</td>
<td>3094</td>
<td>1041</td>
<td>2714</td>
<td>2410</td>
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<tr>
<td></td>
<td>Size (mm)</td>
<td>178 (liner)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Depth (m)</td>
<td>3665</td>
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with a maximum hole angle of 12.5°. All other wells were drilled as vertical wells with conventional directional control techniques.

PROBLEM AREAS

The Cohasset D-42 well was drilled to total depth and tested with no evidence of significant problems although detailed operational logs were not available. A total of seven production tests were run and 141 sidewall cores were recovered. No conventional cores were taken.

Cohasset D-42 was drilled to depth, with the only significant delay attributed to weather. No production tests or conventional cores were run, but 43 sidewall cores were taken. Some equipment problems were encountered while Cohasset A-52 was being drilled. There were some tight hole problems in the 432 mm hole, but hole conditions in the 311 mm hole were described as excellent. Six drillstem tests were carried out and 22 cores were cut and recovered.

During the drilling of Panuke B-90, only minor weather delays were experienced. One drillstem test was undertaken, 163 sidewall cores were recovered, and 13 conventional cores were cut and recovered.

Panuke F-99 encountered some tight hole in the 311 mm hole, and a mechanical wellhead problem required remedial action. Three conventional cores were taken and 46 sidewall cores were recovered. Four drill-stem tests were run.

UTILIZATION OF EXISTING WELLS

There are currently no plans to re-use the exploration and delineation wells drilled to date on the Cohasset and Panuke structures.
4.3 DEVELOPMENT DRILLING

This section summarizes the well programs for the vertical and horizontally deviated wells at Panuke and Cohasset.

4.3.1 WELL PARTICULARS

A total of eleven wells are proposed for the Cohasset and Panuke development. Details of the wells are shown in Table 4.3-1. Five producing wells and two injectors will be required for Cohasset; three producers and one injector for Panuke.

<table>
<thead>
<tr>
<th>Field</th>
<th>Well Producer</th>
<th>Horizontal Deviation (m)</th>
<th>Number of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panuke</td>
<td>Producer</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>700</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Producer</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Injector</td>
<td>2450</td>
<td>1</td>
</tr>
<tr>
<td>Cohasset</td>
<td>Producer</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>700</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1200</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Producer</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Injector</td>
<td>2450</td>
<td>2</td>
</tr>
</tbody>
</table>

One vertical well will be drilled in each field. Two wells will be deviated 700 m in each reservoir and all injectors will be deviated approximately 2450 m. Two wells will also be deviated 1200 m in the Cohasset Field.
4.3.2 DRILLING METHOD

4.3.2.1 Panuke

The Panuke wells will be drilled with a severe weather jack-up drilling unit located over a well jacket. The well jacket will be installed with a derrick barge or the jack-up unit prior to spudding of the wells. The jacket will be lifted from a cargo barge, lowered to the seafloor, and secured with piles. The jack-up unit will be mobilized to the jacket location and positioned. The three production wells and one injection well will be drilled with the legs of the jack-up drilling unit remaining in the same position. The drilling substructure will be skidded to align directly over each well slot in the template. All wells will be drilled conventionally with conductor pipe and casing running back to surface, where the blowout preventer will be installed.

After the wells have been drilled and completed, they will be perforated and flowed to clean up any debris in the well. The wells will then be ready for production or injection via the flowlines to Cohasset. These flowlines connect to the jacket. The jack-up will be removed from the site after the wells have been completed.

4.3.2.2 Cohasset

After the jack-up drilling unit has completed the Panuke wells, it will be towed to the Cohasset location where it will be positioned beside the Cohasset wellhead jacket. The wellhead jacket will have been previously installed using the jack-up drilling unit or a derrick barge.

After the jack-up is in place, the drilling substructure will be cantilevered over the wellhead jacket and positioned to drill the first four wells. Production from Cohasset will commence, and the
final three wells will be drilled during the winter months after
the first production season.

4.3.3

DRILLING PROGRAM AND SCHEDULE

4.3.3.1

Drilling Program

The proposed drilling program includes two types of wells:
producing wells and water injection wells. All wells will be
deviated with the exception of one vertical well in each reservoir.
All wells will be drilled in a similar fashion, but completion
techniques will vary.

4.3.3.2

Schedule

The estimated drilling and completion times required for the
vertical wells and a highly deviated injection well are shown in
Figure 4.3-1. This figure shows the hole intervals, hole sizes,
casing sizes, and average predicted drilling times for typical
Panuke and Cohasset wells. Approximately 14 days will be required
to drill and case a typical vertical Panuke or Cohasset well to
2350 m, excluding moving time. An estimated 21 days will be
required to drill and case the injector wells to a horizontal
deviation of 2450 m. Other lesser offset wells will require fewer
days. Completion operations are estimated at 5 to 7 days (refer to
Production Engineering section of Appendix I).

The producing horizons in each reservoir are intersected by
drilling to a total vertical depth of 2350 m. Additional details
of the producing zones are provided in Section 3 of this
development plan. Additional information on well completion is
provided later in this section.

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AVERAGE PREDICTED DRILLING CURVE

FIGURE 4.3-1

DEPTH RT (m) TVD

R.T.

1 RIG UP, SPUD

450

DRILL 444 mm HOLE

LOG, RUN & CEMENT 330 mm CASING

VERTICAL WELL

DRILL 311 mm HOLE

DEVIATED WELL (2460 m OFFSET)

CORE - LOG, RET

LOG, RET

RUN CSG, CEMENT

COMPLETE

TIME (d)

0 5 10 15 20 25 30

1400 m TVD

762 mm CASING (DRIVEN)

2360 m TVD

244 mm CASING

2500

2000

1600

1200

800

400
The cumulative time required to move, drill, and complete all wells is 93 days for the Panuke reservoir and 172.5 days for the Cohasset reservoir, for a total of 265.5 days. This schedule assumes that both jackets and both sets of conductors will be set at Panuke and Cohasset prior to the arrival of the drilling unit.

Drilling schedules for Panuke and Cohasset have been prepared as follows:

- Figure 4.3-2, Panuke Drilling Schedule
- Figure 4.3-3, Cohasset Drilling Schedule
  (First Year)
- Figure 4.3-4, Cohasset Drilling Schedule
  (Second Year)

All drilling times are estimates based on actual drilling times experienced in the area.

4.3.4 CASTING DESIGN

The casing and hole sizes selected for the Panuke and Cohasset wells are based on the experience gained during exploration drilling. Each string is designed for the worst-case well and uses a single size, weight, and grade of casing. This will reduce inventories and prevent the installation of incorrect equipment in the string.

The casing design is based on the requirements of the Canada Oil and Gas Drilling Regulations. The hole sizes and preliminary estimate of tubular specifications are shown in Table 4.3-2.
FIGURE 4.3-2
PANUKE DRILLING SCHEDULE

TOW TO PANUKE, JACK-UP OVER PLATFORM

DRILL AND CASE PANUKE INJECTOR

DRILL AND CASE PANUKE PRODUCER #1

DRILL AND CASE PANUKE PRODUCER #2

DRILL AND CASE PANUKE PRODUCER #3

COMPLETE PANUKE WELLS

INSTALL AND COMMISSION PRODUCTION HEADER

JACK-DOWN

DAYS
FIGURE 4.3-3
COHASSET DRILLING SCHEDULE (FIRST YEAR)

TOW TO COHASSET; JACK-UP OVER PLATFORM

DRILL AND CASE COHASSET PRODUCER #1

DRILL AND CASE COHASSET PRODUCER #2

DRILL AND CASE COHASSET PRODUCER #3

DRILL AND CASE COHASSET PRODUCER #4

COMPLETE COHASSET WELLS 1-4

INSTALL PRODUCTION HEADER
COMMISSION PRODUCTION SYSTEM

PRODUCTION SEASON #1

DAYS
FIGURE 4.3-4
COHASSET DRILLING SCHEDULE (SECOND YEAR)

DRILL AND CASE COHASSET INJECTOR #1

DRILL AND CASE COHASSET INJECTOR #2

DRILL AND CASE COHASSET PRODUCER #5

COMPLETE INJECTORS 1 AND 2 AND PRODUCER #5

WORKOVERS AS REQ'D FOR PRODUCERS 1 TO 4

PRODUCTION SEASON #2

DAYS

10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
TABLE 4.3-2
SUMMARY OF WELL TUBULARS
COHASSET AND PANUKE DEVELOPMENT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Panuke</th>
<th>Cohassett</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Producer</td>
<td>Injector</td>
</tr>
<tr>
<td>Horizontal Deviation (m)</td>
<td>0</td>
<td>700</td>
</tr>
<tr>
<td>Conductor Pipe (driven)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (mm)</td>
<td>762</td>
<td>762</td>
</tr>
<tr>
<td>Hole size (mm)</td>
<td>762</td>
<td>762</td>
</tr>
<tr>
<td>True vertical depth -k.b.(m)</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Measured depth (m)</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Grade</td>
<td>X46</td>
<td>X46</td>
</tr>
<tr>
<td>Weight (kg/m)</td>
<td>793</td>
<td>793</td>
</tr>
<tr>
<td>Surface Casing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (mm)</td>
<td>340</td>
<td>340</td>
</tr>
<tr>
<td>Hole size (mm)</td>
<td>445</td>
<td>445</td>
</tr>
<tr>
<td>True vertical depth -k.b.(m)</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Measured depth (m)</td>
<td>1000</td>
<td>1054</td>
</tr>
<tr>
<td>Weight (kg/m)</td>
<td>91</td>
<td>91</td>
</tr>
<tr>
<td>Production Casing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (mm)</td>
<td>245</td>
<td>245</td>
</tr>
<tr>
<td>Hole size (mm)</td>
<td>311</td>
<td>311</td>
</tr>
<tr>
<td>True vertical depth -k.b.(m)</td>
<td>2350</td>
<td>2350</td>
</tr>
<tr>
<td>Measured depth (m)</td>
<td>2350</td>
<td>2540</td>
</tr>
<tr>
<td>Grade</td>
<td>L-80</td>
<td>L-80</td>
</tr>
<tr>
<td>Weight (kg/m)</td>
<td>65</td>
<td>65</td>
</tr>
</tbody>
</table>
The 762 mm conductor pipe will be installed using the derrick barge, or jack-up unit, and driven to depth to provide structural support for the axial load of the wellhead and other casing strings. The 340 mm casing will be set in normally pressured formations. The 245 mm production casing will be set at 2350 m, the total vertical depth on each well.

4.3.5 DRILLING FLUIDS

The drilling fluids program proposed for the Cohasset and Panuke wells will be similar for all wells. The 914 mm conductor pipe will be driven to depth. The 444 mm hole will be drilled to 1000 m vertical depth using prehydrated gel sweeps. After the 340 mm casing has been cemented in place, the 311 mm hole will be drilled to total depth with a KCl/polymer drilling fluid. This fluid will provide the desired rheological characteristics and shale inhibition to eliminate hole and drilling problems. The application of low toxicity oil-based muds is being evaluated. Additional information will be provided at a later date.

During the drilling program, certain hole conditions and drilling problems may require the use of oil-based mud or spotting fluids. Should this become necessary, only low toxicity mineral-based oil will be used. The guidelines and regulations concerning their use and disposal will be followed.

4.3.6 CEMENTING PROGRAM

The cementing programs for each casing string will be based on laboratory test data for the cement, additives, circulation times, temperatures, and mix water to be used for the job. Cement volumes will be based on a borehole geometry tool that will be run for each interval. The 340 mm surface casing will be cemented with class G cement over the entire length from the setting depth to the deck of the well jacket. Class G cement, with an extender additive, will

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be used to provide a less dense lead slurry followed by a more dense tail slurry of normal density. The lighter density lead slurry will be used in order to reduce the hydrostatic pressure on open hole formations during cementing. The 245 mm production casing will be cemented approximately 100 m inside the 340 mm casing with a lead slurry consisting of class G with extenders and retarders as required. The tail slurry will also be class G with the appropriate retarders.

Uniform cement distribution around the casings of directional wells will be achieved by mechanically centralizing and reciprocating and/or rotating the casing during cement displacement. Electrical logs will be run to locate the top of the cement column as required.

4.3.7

DEVIA TION CONTROL

4.3.7.1

Directional Well Program

Nine of the total of eleven wells in the Panuke and Cohasset fields will be directionally drilled. Table 4.3-3 summarizes the parameters for the deviated wells in both reservoirs.

The producing wells requiring a 700 m bottomhole deviation will be drilled vertically to 1030 m, at which point the well will be directionally drilled. Angle will be built at a rate of 2.5° per 30 metres to a hole angle of approximately 32°. From this point, the well will be directionally drilled at this angle to total depth.

A 1200 m horizontal deviation will be required for two wells in the Cohasset field. These wells will kick off at 550 m and will build angle at the same rate until an angle of approximately 38° is reached. The injector wells for each field have a horizontal
### TABLE 4.3-3
SUMMARY OF DIRECTIONAL WELL PROGRAMS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Panuke</th>
<th></th>
<th>Cohasset</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Producer</td>
<td>Injector</td>
<td>Producer</td>
<td>Injector</td>
</tr>
<tr>
<td>Horizontal deviation (m)</td>
<td>0</td>
<td>700</td>
<td>2450</td>
<td>0</td>
</tr>
<tr>
<td>True vertical depth (m)</td>
<td>2350</td>
<td>2350</td>
<td>2350</td>
<td>2350</td>
</tr>
<tr>
<td>Kick-off point (m)</td>
<td>0</td>
<td>1030</td>
<td>170</td>
<td>0</td>
</tr>
<tr>
<td>Build rate (°/30m)</td>
<td>0.0</td>
<td>2.5</td>
<td>2.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Hold angle (°)</td>
<td>0.0</td>
<td>31.9</td>
<td>53.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hold angle established</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measured depth (m)</td>
<td>0</td>
<td>1413</td>
<td>807</td>
<td>0</td>
</tr>
<tr>
<td>T.V. depth (m)</td>
<td>0</td>
<td>1393</td>
<td>720</td>
<td>0</td>
</tr>
<tr>
<td>Build section measured length (m)</td>
<td>0</td>
<td>383</td>
<td>637</td>
<td>0</td>
</tr>
<tr>
<td>Total measured depth (m)</td>
<td>2350</td>
<td>2540</td>
<td>3525</td>
<td>2350</td>
</tr>
<tr>
<td>Hold section measured length (m)</td>
<td>2350</td>
<td>1127</td>
<td>2718</td>
<td>2350</td>
</tr>
</tbody>
</table>
deviation of 2450 m. They require a kick-off point at 170 m and a maximum angle of 53°.

4.3.7.2 Drilling Directional Wells

A computer-generated program will be used to determine the well path for directional drilling service personnel, who will also provide measurement-while-drilling (MWD) services. Downhole motors will be used to build hole angle in the 444 mm and 311 mm hole sections. Stabilizers and monel collars will be used for continued directional control and for survey purposes respectively.

During development drilling, all wellbores will be accurately surveyed to prevent wellbore intersection. In the upper portion of the hole before wellbore separation is established, the following steps will be taken:

- Drilling returns will be monitored for steel and cement.
- Unusual torque or penetration rates will be monitored.

The risk of intersection will decrease with depth as the wells diverge. The possibility of wellbore intersection below the kick-off point is minimal because the target areas will not be closely spaced. Guidelines will be established to shut in producing wells downhole when the well being drilled is within a specified distance of a producing well.

4.3.8 WELL CONTROL AND SAFETY SYSTEMS

Well control will be maintained through the use of proper wellhead and blowout prevention equipment, and proper operating procedures.
4.3.8.1 Maximum Anticipated Surface Pressures

Production Wells

The maximum anticipated shut-in surface pressures have been derived from the initial reservoir pressures and the anticipated fluid gradients within the wellbores. Table 4.3-4 summarizes the deepest sands to be completed at Cohasset and Panuke, and a calculation of the maximum shut-in pressures.

Injection Wells

The maximum anticipated surface pressure for water injection wells has been determined from formation injectivity analysis and tubing performance curves (refer to the "Production Engineering" Section of Appendix J). The maximum anticipated surface injection pressure is 13.8 MPa.

Well Kill Operations

The maximum anticipated surface pressure required for well kill operations is 16.9 MPa. This is determined from the pressure required to initiate formation leak-off in the deepest sand, and is calculated as follows:

- Maximum observed formation leak-off gradient 17.6 kPa
- Depth at deepest zone 2280 m
  (Cohasset Sand 10)
- Maximum formation leak-off pressure 40.1 MPa
- Hydrostatic pressure at full seawater column 23.2 MPa
- Surface pressure to initiate leak-off 16.9 MPa

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<table>
<thead>
<tr>
<th></th>
<th>Cohasset</th>
<th>Panuke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deepest sand</td>
<td>Sand 10</td>
<td>Sand 2</td>
</tr>
<tr>
<td>SS depth (TVD)</td>
<td>2280 m</td>
<td>2245 m</td>
</tr>
<tr>
<td>Reservoir pressure</td>
<td>22650 kPa*</td>
<td>22865 kPa</td>
</tr>
<tr>
<td>Reservoir fluid</td>
<td>Condensate</td>
<td>Condensate</td>
</tr>
<tr>
<td>GOR</td>
<td>13 m³/m³</td>
<td>20 m³/m³</td>
</tr>
<tr>
<td>Fluid density (stabilized)</td>
<td>777 kg/m³</td>
<td>755 kg/m³</td>
</tr>
<tr>
<td>Density of &quot;live&quot; condensate</td>
<td>745 kg/m³</td>
<td>663 kg/m³</td>
</tr>
<tr>
<td>Minimum fluid gradient</td>
<td>7.3 kPa/m</td>
<td>6.5 kPa/m</td>
</tr>
<tr>
<td>Hydrostatic pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of full tubing string</td>
<td>16650 kPa</td>
<td>14565 kPa</td>
</tr>
<tr>
<td>Maximum surface pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with full tubing string</td>
<td>6000 kPa</td>
<td>8300 kPa</td>
</tr>
<tr>
<td>Bubble point pressure</td>
<td>2810 kPa</td>
<td>2744 kPa</td>
</tr>
</tbody>
</table>

* Extrapolated from Sand 7.

Note: Since surface shut-in pressure is well above bubble point pressure, fluid in tubing will be single phase condensate.
This pressure is also sufficient to overcome the maximum shut-in surface pressure (8.3 MPa).

4.3.8.2 Wellheads

The Cohasset and Panuke wells will be completed above sea level on the wellhead jacket deck. The casing loads will be supported by the conductor pipe.

After the wellhead jacket has been positioned, the 762 mm conductor pipe will be driven through a conductor sleeve in the jacket. The 340 mm surface casing will be installed and cemented in a drilled 444 mm hole. The 340 mm casing will have a 346 mm, 20.7 MPa wellhead installed at the lower deck of the wellhead jacket. A 340 mm tie-back string will be connected to the wellhead with a tie-back adapter, and will support the blowout preventer.

4.3.8.3 Blowout Preventers

A single stack blowout preventer (BOP) system rated at 34.5 MPa maximum working pressure will be adequate for the drilling of development wells in both the Panuke and Cohasset fields. Most drilling units will carry a BOP rated to at least 69 MPa maximum working pressure, so additional pressure integrity may be available. The BOP stack will be installed at surface after cementing the 340 mm casing. The BOP stack will remain in place until the well has reached total depth and has been logged. At that time, the BOP stack will be removed before the production tree is installed.

4.3.8.4 Safety Procedures

The reservoirs to be drilled are normally pressured, so the risks associated with overpressured formations will be reduced. Detailed
operating procedures will be provided as follows to ensure the early detection and control of hazardous well conditions:

- Definition of responsibilities for personnel
- Procedures for using well control equipment
- Mud system requirements to ensure the availability of kill-weight mud
- Flow check requirements
- Specified tripping speeds to avoid swabbing the well
- Routine checks and equipment tests to ensure well control capability
- Testing of casing and well control equipment

Drilling Parameters

Drilling parameters will be continuously monitored to give early indications of entry into hydrocarbon-bearing zones. These parameters include the following:

- Shale cutting appearance and density
- Flowline temperature
- Gas quantity in mud
- Chlorides in mud
- Mud volume in active systems
- Rate of penetration
- The dc exponent

The data logging units include alarm systems that warn against mud gain, or hole-fill volume discrepancies encountered while tripping. Mud logging will be employed from 1000 m TVD to TD.

Formation Leak-Off Tests

Formation leak-off tests (FLOT) will be conducted as necessary to determine formation integrity. The test information will be used
to determine the maximum mud weight that can be safely used without exceeding the strength of shallower formations. Kick tolerance calculations will be made to ensure that a kick can be safely circulated out without exceeding fracture pressures. Good estimates of pressure profiles and fracture gradients in the Panuke and Cohasset fields have been made using the data gathered from the exploratory wells.

Wellhead Equipment

Wellhead equipment was selected according to the following criteria:

- Hole and casing sizes
- Maximum anticipated surface pressures
- Size of BOP's to be used
- Optimization and interchangeability of equipment
- Wellhead and tubing loads supported by conductor pipe

The selected wellhead system is shown in Figure 4.3-5 and includes the following:

- A 762 mm, 21 MPa housing for use until the 340 mm casing is set

- A 762 mm, 21 MPa spool x 340 mm, 21 MPa spool for use after the 340 mm casing is set

- A 340 mm, 21 MPa spool for use after the 244 mm casing is set

4.4 COMPLETION

This section discusses the completion strategy, downhole equipment, tubulars, surface production trees, safety equipment, and artificial lift for the Panuke and Cohasset reservoirs.
TYPICAL PRODUCTION WELLHEAD SYSTEM

340 mm, 21 Mpa x
254 mm, 21 Mpa SPOOL

762 mm, 21 Mpa x
340 mm, 21 Mpa SPOOL

762 mm, 21 Mpa
WELLHEAD HOUSING

762 mm CONDUCTOR
340 mm CASING
244 mm CASING
TUBING
CONTROL LINE

FIGURE 4.3-5
4.4.1 COMPLETION STRATEGY

This section discusses the approach used in completing the Panuke and Cohasset wells.

4.4.1.1 Panuke

The Panuke producing wells will be completed to allow production from Sands No. 2 and 3 to be commingled. A balance between the zonal deliverability will be created by selectively controlling the perforations in each zone. In the event the lower of the two zones waters out, it would be abandoned by selectively setting a bridge plug across the water-producing zone. If the top zone waters out first, the perforations will be squeezed with cement or epoxy grout, and the zones with a high condensate saturation reperforated.

From the initial results of model simulation runs, it is expected that Panuke production will be essentially water-free during the first four production seasons. Recompletions are not expected during the first four seasons.

4.4.1.2 Cohasset

Large variation in reservoir permeabilities would lead to less than perfect sweep efficiency if all the Cohasset sands were commingled simultaneously. An optimum completion strategy will be developed to commingle certain sand combinations.

The wells will be recompleted as required to allow optimum recovery of undrained sands. Recompletions will be scheduled in the winter season to reduce production downtime and to implement pump maintenance. Zones producing at high water cut at the end of the summer production season will be temporarily suspended and the wells recompleted in another zone. The isolation methods are
designed so that all zones with a relatively low water saturation can be commingled for final depletion towards the end of the field life.

4.4.2 COMPLETION METHODS

Table 4.4-1 summarizes the conditions for which the completions for Panuke and Cohasset production and injection wells will be designed. The following sections provide details of the completion.

4.4.2.1 Panuke Production Well

Panuke producers will be capable of natural flow for 4 years. Artificial lift in the form of electric submersible pumps will be used as required. Some equipment required for pumping may be installed during the initial completions to avoid the necessity for a rig re-entry and to allow the pumps to be installed and commissioned with a wireline operation.

All three Panuke production wells may eventually be equipped with artificial lift. A schematic of a typical production well with an electric submersible pump completion is shown in Figure 4.4-1.

Production in both the flowing and pumping modes will be through 114 mm tubing run inside the 244 mm casing. The pump will be bypassed when not in use by removing the plug from the 68 mm tailpipe.

Wellheads and tubing hanger spools will be rated to 20.7 MPa. Downhole safety equipment will consist of a wireline-retrievable surface-controlled subsurface safety valve (WRSCSSV) and a hydraulic set retrievable packer to isolate the annulus.
### TABLE 4.4-1
**OPERATING CONDITIONS FOR WELL COMPLETIONS**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Panuke</th>
<th>Cohasset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reservoir</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Datum depth, subsea (m)</td>
<td>2245</td>
<td>2045</td>
</tr>
<tr>
<td>Reservoir pressure (MPa)</td>
<td>22.9</td>
<td>20.3</td>
</tr>
<tr>
<td>Reservoir pressure gradient (MPa m)</td>
<td>10.2</td>
<td>9.9</td>
</tr>
<tr>
<td>Bubble point pressure (MPa)</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Reservoir temperature (°C)</td>
<td>87</td>
<td>75</td>
</tr>
<tr>
<td><strong>Fluids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensate gravity (kg/m³)</td>
<td>755</td>
<td>777</td>
</tr>
<tr>
<td>Gas condensate ratio (m³/m³)</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Gas gravity</td>
<td>0.94</td>
<td>0.68</td>
</tr>
<tr>
<td>H₂S content in gas (ppm)</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>H₂ partial pressure at bubble point (kPa)</td>
<td>-</td>
<td>0.006</td>
</tr>
<tr>
<td>CO₂ content in gas (%)</td>
<td>2.9</td>
<td>2.0</td>
</tr>
<tr>
<td>CO₂ partial pressure at bubble point (kPa)</td>
<td>79</td>
<td>56</td>
</tr>
<tr>
<td><strong>Production Wells</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wellhead pressure rating (MPa)</td>
<td>20.7</td>
<td>20.7</td>
</tr>
<tr>
<td>Shut-in tubing head pressure (MPa)</td>
<td>8.3</td>
<td>4.8-6.0</td>
</tr>
<tr>
<td>Flowing tubing head pressure (MPa)</td>
<td>1.0-9.3</td>
<td>0.7-4.8</td>
</tr>
<tr>
<td>Flowing tubing head temperature (°C)</td>
<td>38-60</td>
<td>35-57</td>
</tr>
<tr>
<td><strong>Injection Wells</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wellhead pressure rating (MPa)</td>
<td>20.7</td>
<td>20.7</td>
</tr>
<tr>
<td>Shut-in tubing head pressure (kPa)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Injecting tubing head pressure (kPa)</td>
<td>6.9-13.8</td>
<td>5.5-13.8</td>
</tr>
</tbody>
</table>

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TYPICAL PRODUCING WELL COMPLETION

102 mm, 20.7 Mpa XMAS TREE
DUAL BORE TUBING HANGER
WITH ELECTRICAL CONNECTOR
SSV CONTROL LINE
WR SC SSV AND NIPPLE
PACKER FLUID
244 mm CASING
POWER CABLE
114 mm TUBING

89 mm NIPPLE
HYDRAULIC SET DUAL RETRIEVABLE
PACKER LANDED IN COMPRESSION
WITH ELECTRIC CABLE PENETRATOR
Y TOOL FOR WL BYPASS
MULTISTAGE PUMP
PUMP INTAKE SCREEN
ELECTRIC MOTOR
BACK-UP NIPPLE
NIPPLE AND PLUG

SPENT TCP GUN

FIGURE 4.4-1
4.4.2.2  Panuke Injection Well

A schematic of the proposed Panuke injection well completion is shown in Figure 4.4-2. A 140 mm injection string will be run in 244 mm casing and will permit injection rates of approximately 2,000 m$^3$/d.

The wellhead and tubing hanger spool will be rated at 20.7 MPa. A WRSCSSV will be incorporated to accommodate back flow due to local supercharging. A hydraulic set permanent packer will isolate the annulus. To maximize injectivity, the completion intervals will be perforated with tubing conveyed guns.

4.4.2.3  Cohasset Production Well

All five Cohasset production wells will be equipped with electrical submersible pumps (ESP's) at the time of completion. A schematic of the proposed Cohasset production well completion is similar to that shown in Figure 4.4-1.

The description of the equipment is similar to that for the Panuke production wells.

Tubing conveyed perforating guns will be used to maximize the productivity of the poorer zones.

4.4.2.4  Cohasset Injection Well

A schematic of the Cohasset water injection well completion is shown in Figure 4.4-3. A 178 mm injection conduit will be run inside the casing and latched on to the top of the 178 mm liner using a polished bore receptacle hanger in place of a packer.
PANUKE INJECTION WELL COMPLETION

- 102 mm, 20.7 Mpa XMAS TREE
- 279 mm x 140 mm THS
- 279 mm x 244 mm THS
- SSV CONTROL LINE
- 140 mm WR SSV & NIPPLE
- INHIBITED BRINE PACKER FLUID
- 244 mm PRODUCTION CASING
- 140 mm 15.5 φ J55 PLASTIC COATED TUBING (2.866 m)
- 114 mm NIPPLE (ID 95 mm)
- EXPANSION JOINT (ID 95 mm)
- ANCHOR SEAL ASSEMBLY (ID 124 mm)
- HYDRAULIC SET PERMANENT PACKER
- MILL-OUT EXTENSION
- 114 mm BACK-UP NIPPLE (ID 95 mm)
- 114 mm NO-GO NIPPLE (ID 93 mm)
- TCP SHEAR RELEASE SUB
- SAND #2
- SAND #3
- SUMP
- SPENT 152 mm TCP GUN
- PBTD
- 244 mm CASING SHOE AT TD

FIGURE 4.4-2
COHASSET INJECTION WELL COMPLETION

ALTERNATIVE

FIGURE 4.4-3
An additional 89 mm concentric tubing string will be run as required inside the 178 mm conduit to permit selective injection into various sands.

A WRSCSSV will be used on the inner 89 mm conduit and single 178 mm completion.

An annular surface-controlled safety valve (ASCSV) mounted on the 89 mm inner string will be required for the 178 mm x 89 mm annulus.

Hydraulic set permanent packers with anchor seal assemblies will be used to isolated the 89 mm x 178 mm annulus. A liner hanger packer and polished bore receptacle (PBR) seal assembly will be used to isolate the 244 mm x 178 mm annulus. The PBR will also incorporate a wireline nipple to isolate the completion interval during workover. A 20.7 MPa working pressure wellhead will be used for surface pressure control.

The upper zones will be selectively perforated with wireline guns, with the number of shots selected to obtain a balanced injection profile. The poorer intervals will be heavily perforated, while the better zones will have a limited number of holes to prevent them from acting as thief zones.

WELL PERFORMANCE AND TUBING SELECTION

A productivity and deliverability analysis was undertaken to select tubing and flowline sizes that would provide acceptable pressure drops. Injection well designs were also analyzed to ensure that condensate production could be offset with injection fluid on an annual basis. The following sections discuss the well deliverability, well injectivity, and tubing selection details for each field.
4.4.3.1 Well Deliverability

Panuke

Production from Panuke wells was assumed to flow through the tubing into a common flowline running 8 km to a separator operating at 0.7 MPa inlet pressure. Flowing bottomhole pressure was plotted against liquid production rates for various tubing sizes and flowline sizes. The plots showed that 114 mm tubing and 219 mm flowline sizes were optimum.

The plots also showed that artificial lift should be available in the event of premature water breakthrough or imperfect flood response.

Cohasset

Using the same procedures as for Panuke, the Cohasset tubing size was selected as 114 mm.

Efficient pressure maintenance will be required early in the life of the wells to accommodate imperfect maintenance of the reservoir pressure by the injection wells.

4.4.3.2 Well Injectivity

Panuke

Injectivity curves were developed assuming constant surface injection pressure and varying injection rates. Sensitivities to flowline and tubing sizes were studied, and 165 mm flowline and 140 mm tubing sizes were selected.
In injectivities were investigated through various tubing configurations for individual sands and for the total well.

In both injector wells, Sands 2 through 7 will be selectively perforated to control the relative injection rates. Injection into these sands will be through a common string. The wells will also be set up so that some sands can be selectively completed with a concentric dual completion. Appendix I provides more detail with regard to the injection well design.

4.4.3.3 Tubing Selection

Typical tubing specifications are shown in Table 4.4-2. Detailed design will be undertaken during the more advanced stages of the project, and specifications will be finalized.

<table>
<thead>
<tr>
<th>Field</th>
<th>Item</th>
<th>Diameter (mm)</th>
<th>Grade</th>
<th>Weight (kg/m)</th>
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<tr>
<td>Panuke</td>
<td>Producer - inner</td>
<td>114</td>
<td>J55</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Injector</td>
<td>140</td>
<td>J55</td>
<td>23</td>
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<td>Cohasset</td>
<td>Producer</td>
<td>114</td>
<td>J55</td>
<td>19</td>
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<tr>
<td></td>
<td>Injector - outer</td>
<td>178</td>
<td>L80</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Injector - inner</td>
<td>89</td>
<td>J55</td>
<td>14</td>
</tr>
</tbody>
</table>

In most producers and injectors, long-thread and coupling or modified buttress couplings would be sufficient, but a low-cost premium coupling may be preferred to simplify handling and make-up operations.

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4.4.4 DOWNHOLE EQUIPMENT

All downhole equipment consists of standard items with field-proven capabilities. The following sections provide a brief description of the major components.

4.4.4.1 Subsurface Safety Valves

WRSCSSV's are proposed for the producing wells. Although tubing-retrievable sub-surface safety valves are more reliable and have longer lives, the relatively short life of these completions would not justify the incremental cost and complexity. Moreover, the average mean time to failure for a wireline-retrievable flapper valve is much greater than the expected re-entry frequency. These wells will also be accessible from a wellhead jacket, permitting wireline workovers.

4.4.4.2 Packers and PER Assemblies

The casing annulus in all wells will be isolated with a packer or PER.

Dual-retrievable hydraulically-set packers will be required for the Panuke and Cohasset producers to accommodate the electrical cable penetration.

Cohasset injectors will have a PER mounted on the tubing hanger packer. The production tubing will be sealed into this PER with a conventional seal assembly similar to that used on permanent packers.

In the concentric dual completions, the lower two zones will be isolated with hydraulically set permanent packers.

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4.4.4.3 Tailpipes and Nipples

Each well will contain a tailpipe and nipples that will permit various functions to be performed using wireline servicing.

Production wells will be equipped with a wireline bypass around the downhole ESP's to permit logging or surveys while the pump is operating. Other nipples will facilitate tubing tests, packer settings, and installation of the WRSCSSV. Cohasset injectors will contain nipples that will permit isolation of the perforations for removal of the 178 mm tubing.

4.4.4.4 Perforating

Tubing-conveyed perforating (TCP) is proposed to maximize the in-flow performance for all the poorer zones.

Through-tubing perforating with bar guns will be used as an alternative method in some of the better intervals and for all workovers.

Wireline-run casing guns may be used to selectively perforate sands in the water injection wells.

4.4.5 FLUIDS AND PRODUCTION PROBLEMS

This section describes the produced fluids; corrosion potential; completion, packer, workover, and kill fluids; and scaling tendencies.

4.4.5.1 Produced Fluids

The Cohasset and Panuke fields both contain sweet, light condensate with a low gas-condensate ratio and some CO₂ in the produced gas. The wells will initially produce clean condensate, but formation
water and injection water will break through relatively quickly, especially at Cohasset. The condensate has a very low pour point, and no wax problems are expected. If hydrates exist or are expected, methanol injection will be available at the well jackets. Because of the low gas-condensate ratio and low bubble point, wellhead velocities will be quite low and no serious erosion problems are anticipated.

4.4.5.2 Corrosion Potential

Initial analyses have shown moderate amounts of CO₂ in both fields and only 2 parts per million (ppm) of H₂S for Cohasset. Since the bubble point pressures are very low, the risk of sulphide stress cracking and sour corrosion are low. The use of large tubulars will keep velocities low and will also minimize the corrosion and erosion potential. Normal alloy steels will be used for the tubing and wellheads.

De-aeration of the injection seawater together with the addition of an oxygen scavenger like ammonium bi-sulphate will reduce the oxygen concentration below 0.05 ppm and reduce corrosion. Plastic-coated tubing will be used in the wells in the event of process upsets. The use of stainless steel trim for the trees of injection wells will be investigated in the detailed design phase.

The life of the field will be relatively short, and the potential for bacterial corrosion or souring of the fields will not be a major problem.

4.4.5.3 Scaling Tendencies and Compatibility

Computer studies on compatibility of Cohasset formation water and seawater under simulated pumping and injection conditions have shown no calcite or gypsum scaling tendencies (Menniger 1989). Injectivity loss is not expected from magnesite scale formation.
Barite scaling problems are not anticipated. Treated seawater will be used for water injection.

4.4.5.4 Completion Fluids

Seawater will be used as a completion fluid until the wells are perforated.

Most wells will be perforated using the tubing-conveyed perforating technique, so that the packer will be set and the wellhead installed before the well is made live. Where wells will be perforated before the tubing is installed, a 12 percent NaCl brine will provide the necessary overbalance.

4.4.5.5 Packer Fluids

The packer fluid will occupy the annular space between the tubing and casing. The resulting pressure acting on the seal assembly and packers will be designed to be slightly higher than the static reservoir pressure to prolong the seal life by minimizing the pressure reversals. Inhibited 5 percent NaCl brine will be used to provide an overbalance of 0.5 MPa on seals and packers. An oxygen scavenger and caustic will be used to provide inhibition against corrosion of the casing by this brine.

4.4.5.6 Workover Fluids

Seawater-based NaCl brine will be used to avoid both excessive fluid loss to the formation and swabbing in during trips. The salt concentration will be based on the latest pressure data from the zone.

The brine will be filtered to less than 200 ppm suspended solids to prevent impairment in the event of losses into the perforations.
4.4.5.7 Kill Fluids

Kill fluids will be similar to workover fluids and will be available on the drilling and production jack-up unit all times. Two tubing volumes will be available as pre-mixed brine. Additional rock salt will be kept on-site to permit mixing of a second batch.

4.4.6 WELLHEADS AND CHRISTMAS TREES

This section describes the design features of the wellheads and Christmas trees.

4.4.6.1 Standards and Specifications

The wellhead safety equipment will be designed and manufactured in accordance with the requirements of API, COGLA, and certifying authorities.

4.4.6.2 Design Features

A typical wellhead arrangement for a Cohasset producing well is shown in Figure 4.4-4. Two master valves will be used, with the upper valve remotely operated and connected to the emergency shutdown (ESD) system. This arrangement will also provide a wireline-cutting capability. The swab valve will provide full-bore wireline access to the tubing for blanking plug installation and WRSCSSV servicing.

The water injection wells at Panuke and Cohasset will be equipped with wellheads rated to 20.7 MPa. This pressure exceeds the reservoir pressure at datum and the maximum pressures to which the tree is likely to be subjected during a well kill.

For Panuke wells, a check of annulus pressure will be part of a routine weekly maintenance visit to the jacket structure. The
TYPICAL PRODUCTION TREE

PRODUCTION WELLS
20.7 Mpa, ESP OPTION
114 mm TUBING

SWAB VALVE

WING VALVE

MASTER VALVES
103 mm, 20.7 Mpa

279 mm, 20.7 Mpa

279 mm, 20.7 Mpa

CHoke

FIGURE 4.4-4
frequency of checking annulii can be increased if well conditions warrant such action.

The wing valve on all trees will be remotely operated and connected to the ESD system.

Remotely operated, full-opening wellhead chokes will be provided to bring the wells on-line and to avoid wear on the gate valves.

4.4.6.3 Annulus Pressure Monitoring

The annulii between production/injection tubing and 244 mm production casing will be equipped to permit annulus pressures to be monitored. The annulii will be equipped with a valve and pressure gauge fitting so that the pressure can be checked periodically.

For Panuke wells, a check of annulus pressure will be part of a routine weekly maintenance visit to the jacket structure. The frequency of checking annulii can be increased in well conditions warrant such action.

4.4.7 SAFETY EQUIPMENT

This section describes the basic safety philosophy, subsurface safety valves, shutdown procedures, well kill procedures, and well control during servicing.

4.4.7.1 Basic Philosophy

In the completion designs and the associated operating procedures, defences are designed to prevent the uncontrolled emission of hydrocarbons:
- The tubing and production casing
- The tree and SCSSV
- The packer and wellhead
- The completion fluid and BOP

The wells will automatically shut in should a potentially unsafe situation occur such as a fire, leaks, high or low pressure, or loss of well control. These shutdown systems will be tied into smoke, heat, flame, gas, and pressure sensors.

Four levels of alarm may cause the wells to shut down:

Level 1: Abandon Platform Shutdown
Level 2: Emergency Shutdown
Level 3: Process Shutdown
Level 4: Wellhead Unit Shutdown

4.4.7.2 Subsurface Safety Valves

All wells will be equipped with a surface-controlled subsurface safety valve (SCSSV) set more than 30 m below the seabed. These valves will be tied into the ESD and platform control systems and will automatically close on Level 1 and Level 2 alarms or with loss of control line pressure due to wellhead or tubing damage.

4.4.7.3 Shutdown Procedures

The wells will normally be opened or closed with the automated wellhead chokes and isolated with the wing valves. Both of these functions will be operated from the production control room located on the drilling and production jack-up at Cohasset.

If the wells are closed in response to a Level 2, 3 or 4 alarm, the wing valve will close immediately, followed by the upper master valve, which will close after a 15-second delay to ensure that it
closes in a static flow condition. The SCSSV will also close to isolate the master valve after a further 15-second delay. Level 1 shutdowns will trigger the closure of all valves immediately.

4.4.7.4 Well Kill Procedures

The preferred well control procedure will be the placement of downhole isolation plugs by wireline. If necessary, this procedure will be backed up with an overbalancing fluid column.

If wireline access is not feasible, kill fluid will be pumped into the well at sufficient rate and pressure to squeeze fluids into the formation. The wellhead and tubing will be designed to withstand the resulting burst and tension loads.

4.4.7.5 Well Control During Well Servicing

During wireline well servicing, a wireline BOP and lubricator will be installed on the tree and pressure-tested before being exposed to well pressure. The swab valve of the tree will be used to provide access into the wellbore. In an emergency, the remotely operated upper master valve will be capable of cutting the wireline or logging cable.

4.4.7.6 Well Control During Workovers

A normal drilling BOP will be installed in place of the production tree during all workover operations. At least two pressure barriers will be in place in the production conduit before removal of the tree or BOP's. The primary safety barrier during operations is the overbalanced hydrostatic head of the workover fluid.
ARTIFICIAL LIFT

An extensive evaluation of the artificial lift methods applicable to low GCR, high rate offshore wells was undertaken; case histories were reviewed and equipment manufacturers were consulted. Electrical submersible pumps (ESP's) are proposed for Cohasset production wells, and either ESP's or hydraulic jet pumps may be used for the Panuke wells.

Artificial Lift Requirements at Panuke

Artificial lift at Panuke may be necessary to enhance overall recovery. Well performance simulator predictions indicate the Panuke wells will cease flowing if the reservoir pressure depletes by 3.5 MPa and the water cut reaches 40 percent. Even if the reservoir performs better than predicted and pressure is maintained at the initial level, wells will rapidly decline after water breakthrough commences and will cease flowing when the water cut reaches 70 percent. Provision will be made in the Panuke wells to add artificial lift equipment when required.

Artificial Lift Requirements at Cohasset

Artificial lift will be provided at Cohasset. Some Cohasset sands have relatively low deliverabilities, and wells completed in these sands will not be able to flow at the desired rates from the time of initial completion. The combined effect of pressure decline and water cut increases will rapidly reduce well productivities, and the wells will cease flowing at an average water cut of 40 percent if the reservoir pressure depletes by 3.5 MPa.

Wells producing from the more prolific sands, where early water breakthrough is more likely, are sensitive to reservoir pressure support at water cuts of 40 percent.
4.4.8.3 Lift System Selection

Without sufficient volumes of excess associated gas to use for gas lift, ESP's are the preferred choice for artificial lift.

4.4.8.4 Electrical Submersible Pumps

The ESP's at Cohasset will be installed during the initial completion and will include the following:

- An electrical penetrator through the tubing hanger and adaptor flange
- A power cable, which is clamped to the production string
- An electrical penetrator through the packer
- A multistage pump, pump intake, protector, and motor
- A pressure transducer
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SECTION 5. PRODUCTION AND EXPORT SYSTEMS

5.1
SELECTED PRODUCTION AND EXPORT SYSTEMS

The proposed development of the Cohasset and Panuke condensate fields will utilize production facilities on a jack-up drilling unit located at Cohasset. Both Cohasset and Panuke wells will be completed on well jackets, and the Panuke wells will be interconnected to the Cohasset facilities by subsea flowlines. Condensate from the production facilities at Cohasset will be exported via a subsea flowline to a moored storage tanker and then to a shuttle tanker for export. Figure 5.1-1 illustrates the production and export systems.

5.1.1
COHASSET FACILITIES

The Cohasset facilities consist of a well jacket supporting wellhead and manifold facilities, and a jack-up drilling unit supporting the production process and ancillary facilities. The jack-up drilling unit will cantilever over the well jacket to provide drilling and workover capability. The Cohasset well jacket structure and production facilities are discussed in the sections that follow.

5.1.1.1
Well Jacket

The well jacket structure will be a piled structural steel platform designed to provide lateral support to the drilling conductors and vertical support to deck facilities. The structure will be composed of welded tubular frame members, pinned to the seafloor with skirt piles driven to about 100 m below the seabed.

The jacket structure will support the Cohasset wellheads, a production manifold, flowline isolation valves, and a small heat exchanger to warm incoming Panuke fluids.
SELECTED PRODUCTION AND EXPORT SYSTEM

FIGURE 5.1-1
5.1.1.2 Jack-up Facilities

The production facilities and ancillary support systems and equipment will be located on the jack-up drilling unit. A pipe and conduit rack will interconnect the wellhead facilities on the jacket structure with the production facilities on the jack-up.

The facilities that will be added to the jack-up unit to process the Cohasset and Panuke production streams are discussed in the sections that follow.

Production Facilities

Primary process facilities will consist of three-phase, two-stage separation. A test separator will test one well at a time and operate at the same process conditions as the Stage 1 separator. A small heater will be provided on the Panuke inlet stream to warm the incoming fluids.

Gas from the three separators will be used for fuel or purging. The excess will be flared through overboard flare booms. Produced water from the three separators will be transferred through a flash drum for gas and condensate removal, treated in a corrugated plate interceptor (CPI) separator and a flotation cell, and then directed overboard or combined with seawater for water injection.

Downhole electric submersible pumps (ESP's) will be required in the Cohasset wells to assist production. Panuke wells may require downhole pumps later during the life of the field.

A relief system consisting of relief headers, high- and low-pressure relief drums, and liquid return pumps will provide over-pressure protection of the process facilities, and liquid removal from the relieving fluid prior to disposal.
Ancillary Facilities

A number of ancillary facilities will be required on the jack-up to support the operation of the production facilities. These include water injection; electrical; well control; drain; heating, ventilating and air conditioning; and topsides safety systems. These systems are discussed in the following paragraphs.

Water Injection System: Injection water will be supplied from an existing seawater supply system. The water will pass through cartridge filters for filtering, and a deaerator for oxygen removal. Charge pumps will take suction from the deaerator and boost the pressure for the injection pumps thus increasing the pressure to the required level. Injection water will be used to kill a well should the need arise.

Electrical System: The electrical system will consist of motor control centres, switchgear transformers, and hardware required to support the production facility additions. Normal and emergency power will be provided from existing jack-up unit facilities.

Well Control System: The well control system will be supplied with power fluid by a hydraulic power unit. Cohasset wells will interface directly with the hydraulic well control system. Panuke wells will be controlled using a subsea pilot control umbilical, a subsea electrical cable, and/or line-of-sight telemetry systems. A final selection of control methods will be completed during the detailed design phase.

Drain System: A drain separator will collect drain liquid from sump pumps located in the production and wellhead areas. Collected condensate will be skimmed from the drain separator and returned to the production train. Water collected in the drain separator will be routed through the produced water system prior to being discharged.
Heating, Ventilating, and Air Conditioning System: Process equipment will be located on the deck of the jack-up to eliminate the need for a ventilating system.

Electrical switchgear and motor control rooms, the batter room, the control room, and the safety equipment room will be heated by make-up air heaters or unit heaters. The heat source will be the existing utility steam system.

Topsides Safety Systems: Topsides safety systems required for protection of the process and ancillary systems will include a fire detection system, a firewater distribution and sprinkler system, an aqueous film-forming foam system, halon protection of the electrical and controls systems, emergency shutdown systems, and an emergency power system. Studies and field results using AFFF systems will be reviewed to provide the best overall system.

5.1.2

PANUKE FACILITIES

All wells at the Panuke site will be drilled and completed through a steel piled well jacket similar to the one at Cohasset. Subsea flowlines will interconnect the Panuke jacket with the Cohasset jacket.

5.1.2.1

Well Jacket

The well jacket at Panuke will have the same structural configuration as at Cohasset. The jacket structure will support the wellheads, a helideck, a boat landing for access to the structure, and a deck crane.

5.1.2.2

Subsea Flowlines

The Panuke production and water injection wells will be interconnected to the Cohasset production facilities by an
electrical power cable, a production flowline, and a water injection line. A pilot-operated hydraulic control umbilical will be installed with the flowlines for remote control of the Panuke wellheads and manifold. A subsea power cable is being evaluated for power and data transmission for future artificial lift pumps at Panuke.

5.1.3

OFFSHORE EXPORTING

A catenary anchor leg mooring (CAIM) system combined with a floating loading line and flexible steel riser was selected for the offloading system on the basis of simplicity, reliability and capital cost. The CAIM buoy is not required to moor tankers during winter storms.

The system will consist of a cylindrical buoy with a diameter two to three times its depth. The buoy will be secured with a six or eight chain mooring system depending on final tanker selections and system redundancy aspects. Each line will be approximately 500 to 700 m long, 89 mm chain, with either anchors or steel piles. A flexible riser will connect the pipeline end manifold (PLEM) to the buoy. The buoy will be equipped with a turntable arrangement containing the connection point for the mooring hawser and the floating cargo hoses. This will permit the vessel to weathervane around the buoy.

One 153 mm ID flowline will be installed from the Cohasset jacket to the CAIM buoy using the same equipment used to install the interfield flowlines.

Production from the CAIM will flow to a storage tanker for later transfer to a shuttle tanker.
5.2 ALTERNATIVES

During the preliminary engineering phase for the Cohasset/Panuke Development Project, several alternatives were evaluated. This section discusses some of these alternatives grouped into conceptual and component alternatives.

5.2.1 CONCEPTUAL ALTERNATIVES

Conceptual alternatives that were evaluated included the following:

- seasonal vs year-round operations
- combined Cohasset and Panuke development versus stand-alone Cohasset development and stand-alone Panuke development
- fixed versus floating structures for supporting the production facilities
- export pipeline to mainland Nova Scotia

5.2.1.1 Seasonal Versus Year-Round Production

Due to the shallow water at the location, catenary type mooring systems are less effective in storm weather conditions. It would be operationally inefficient to moor a combined storage tanker and a shuttle tanker on a year round continuous basis. Disconnect downtimes in excess of 50% would be expected during the more severe winter months of November through March. Subsea type loading systems utilizing two dynamically positioned shuttle tankers are currently being evaluated as this approach may improve winter period operating efficiency. However, at this stage, it has been concluded that primary production would be confined to a seven month period, April through October, and winter offloading would
only be undertaken based on operating experience and reliably forecasted periods of acceptable winter weather conditions. Each winter season has its own specific characteristics, some winters having extended calm periods.

5.2.1.2 Combined Cohasset-Panuke Development versus Stand-alone Development

Either of the two fields developed in isolation is a marginally economic venture. With combined production of the two fields, substantial capital facilities and operating costs can be shared; therefore, the stand-alone concept was discarded in favour of a combined approach. By managing production rates from each reservoir, a fairly constant condensate production profile can be achieved over the 6 year production life. Higher recovery from the reservoirs is expected in the combined production plan being proposed.

5.2.1.3 Floating Production and Storage Systems

A concept was evaluated that involved using the floating storage tanker to support the production facilities and hence eliminate the need for a jack-up drilling unit throughout the production phase of the project. The cost of the jack-up drilling unit would be more than offset by the following additional costs:

- Production facilities costs for the storage vessel including all utilities, power, and accommodations provided on the jack-up unit

- A multipass, swivel-type riser required for floating production facilities would have to accept produced fluid from Cohasset and Panuke, and transmit injection water to Cohasset and Panuke

- The floating storage vessel could not be used to re-enter and work over the Cohasset wells during the winter season; a jack-up
5.2.1.4 Export Pipeline to Mainland Nova Scotia

With the estimated reserves base of approximately $5.6 \times 10^6 \text{m}^3$ and the production life of six years, the capital cost of a marine pipeline to Nova Scotia would make the combined development of these fields uneconomic. On-shore receiving and storage facilities would also be required. Capital cost estimates are in excess of $150 \text{ million CDN}$, approximately equal to the entire capital cost being contemplated for the project.

A marine pipeline would provide the ability to produce the reservoirs with less downtime than the tankering approach. However, the production management of the reservoirs, particularly Cohasset, will require extended downtime periods for workovers, recompletions and ESP maintenance.

5.2.2 COMPONENT ALTERNATIVES

Each of the major components was reviewed and compared with an alternative as follows:

- Jack-up drilling unit versus fixed platform
- Jack-up drilling unit versus gravity-based production and storage system
- Well jackets versus subsea templates
- Electric submersible pumps versus hydraulic jet pumps

5.2.2.1 Jack-Up Drilling Unit Versus Fixed Platform

A jack-up drilling unit has the following advantages when compared to a fixed platform:
- There are suitable jack-up units available world-wide. A platform would have to be custom-designed and built.

- The jack-up unit would be easily removed and re-usable when the project is completed. A platform would have very little residual value.

- The production facilities on a platform would be self-contained resulting in higher capital costs. The jack-up provides accommodation, power and utilities as part of the drilling system.

The jack-up unit has therefore been selected for the Cohasset/Panuke Development Project.

5.2.2.2 Jack-Up Drilling Unit Versus Gravity-Based Production and Storage System

A concept was proposed that included a gravity-based (GBS) storage tank supporting two jack-up platforms: one for drilling facilities, and one for production facilities. The cost of the gravity-based structure was high relative to other concepts for the following reasons:

- Production facilities costs increased because of the need for utilities previously supplied with a jack-up unit including power generation, personnel accommodations, and utilities previously provided by the storage tanker including offloading pumps and condensate handling pumps in the storage tank.

- A jack-up drilling unit would be needed initially for drilling operations, each subsequent year for workover operations, and the drilling of extra wells if required.
- The residual value and re-use of the GBS is uncertain and therefore, for comparison purposes, must be estimated at a low value.

5.2.2.3 Well Jackets Versus Subsea Templates

Well jackets have been selected over subsea templates for the following reasons:

- The cost of drilling and maintaining subsea wells is higher than the cost of drilling and maintaining platform wells.

- Electric submersible pumps or hydraulic jet pumps could be used with a well jacket whereas a subsea template requires hydraulic pumps.

- Higher workover costs would be associated with subsea completions.

- Direct wellhead access at the surface is preferable to subsea diving operations.

5.2.2.4 Electric Submersible Pumps Versus Hydraulic Jet Pumps

The types of submersible pumps for artificial lift were reviewed to determine the best type for the development of the Cohasset and Panuke fields. Electric submersible pumps (ESP's) were selected for Cohasset and Panuke for the following reasons:

- The initial cost of installing ESP's is less than the cost of hydraulic pumps.

- The additional cost of installing supplemental production facilities to process the additional produced fluid and to supply power fluid at much higher pressures than injection water
requirements exceeds the additional maintenance costs associated with ESP's.

- Power can be transmitted to the remote Panuke location more efficiently with an electric power cable than with a hydraulic fluid flowline.

- Due to the nature of the reservoir, major well recompletions will be scheduled, and ESP replacements could take place at the same time (primarily the winter months).

5.3 PRODUCTION FACILITIES

A jack-up drilling unit is proposed as the permanent production platform at the Cohasset location. A suitable jack-up unit to support production facilities has been used at other offshore locations, and initial concerns with regard to leg joint fatigue, foundation scour and settlement, and periodic inspections have lessened based on actual experience. Certification will be obtained to operate the selected jack-up at the Cohasset location for a continuous period of 6-7 years.

5.3.1 GENERAL DESCRIPTION AND LAYOUT

The following sections describe the general arrangement of the hazardous process equipment and nonhazardous support facilities that will be required. The preliminary layout that has been developed for a typical large jack-up drilling unit is shown in Figure 5.3-1.

The existing pipe rack area located in the center of the jack-up will be converted to the production area. All topside systems will be located in this area except the flare system, which will be located next to the flare boom(s). In this central deck area, the hazardous process systems will be located on the drill rig side of
the structure and the nonhazardous systems on the accommodation side. With this layout, the hazardous process equipment will be located as far as possible from the accommodation area. Nonhazardous facilities such as the water injection system and electrical and control buildings will be between the process equipment and the accommodation area. The production equipment will be stacked vertically to occupy less of the pipe rack area, and to maintain a clear portion of the starboard pipe rack for simultaneous drilling and production.

5.3.1.1 Hazardous Process Equipment

The hazardous equipment consists of Stage 1 and Stage 2 production separator skids, a test separator and meter prover skid, and three large skid-mounted components that comprise the produced water treatment system. Hazardous areas and safety system drawings are being prepared as part of the production system design.

5.3.1.2 Flare Equipment

A high- and low-pressure flare relief system mounted on a single skid will be located near the flare boom(s). This location will ensure that hydrocarbon liquid carryover is removed from the relief head before gas enters the relief tips.

5.3.1.3 Nonhazardous Equipment

The nonhazardous equipment will be located between the hazardous process equipment and the accommodation. This equipment will include a filter skid; a deaerator-pump skid containing the deaerator, injection charge pumps, vacuum pumps, and vacuum pump knockout (KO) drums; a high pressure water injection pump skid; a chemical injection skid; and a hypochlorite system skid.
A coalescer was not included in the production separation system for the following reasons:

- The size, weight and cost of the unit are substantially greater than those of a three-phase separator.
- To effectively use a coalescer, a slop condensate tank with a minimum practical retention of 30 minutes is required to redirect off spec condensate if problems develop. This tank adds cost and topside weight.
- A small bottoms clean-up system on the storage vessel would result in similar performance to that of the coalescer, as for much of the condensate transferred to the tankers, the retention time in the condensate tanks would be in excess of 24 hours. The separation with this retention time would likely be as good as with a coalescer.

5.3.2.2 Condensate Transfer

Condensate from the Stage 2 separator will be transferred to storage by three 50 percent condensate transfer pumps each with a downstream flowmeter. A meter prover with capacity equivalent to the throughput of one pump will be used to monitor and maintain flowmeter accuracy. Condensate will be transferred to the floating storage tanker through a subsea transfer line and a catenary leg mooring system (CAIM).

Produced condensate samples taken from the Stage 2 separator will be monitored using laboratory analysis to determine the percentage of water carryover.

5.3.2.3 Well Test Facilities

A test separator will meter the production from one well at a time for well test purposes and will be designed for a flowrate of
795 m$^3$/d. This separator will be a three-phase unit equipped with flow-recording devices for each phase of separation. It will operate at a pressure of 554 kPa(g) and a temperature of 40°C. A Panuke inlet test heater will be provided to heat the production from Panuke wells to the required test separator temperature. Heat will be supplied by the existing utility steam system. Gas from the test separator will be metered and commingled with gas from the Stage 1 separator. Water from the test separator will be metered and transferred to the produced water system for treatment. The condensate will be metered and combined with the production from the Stage 1 separator.

For testing of wells from the Panuke field, all wells will be shut in except the testing well, and the production from this well will flow through the common subsea flowline to the test separator.

5.3.2.4 Produced Water System

The produced water system (Figure 5.3-3) will be designed to collect and treat water from the following sources:

- Test separator
- Stage 1 separator
- Stage 2 separator
- Drain separator

The collected water will pass through a produced water flash drum where flash gas will vent to atmosphere through the open vent header. The flash drum will also separate condensate slugs that enter the vessel. The water from this drum will be transferred to a corrugated plate interceptor (CPI) separator. The CPI unit will provide condensate particle coagulation by passing the liquid through corrugated plate sections. The water will be transferred from this vessel to a flotation cell for final cleanup, then to the open sea via the existing drain sump. Condensate collected in the
5.3.1.4 Control and Electrical Rooms

The control room, the electrical motor control centre (MCC) and switchgear rooms, the safety equipment room, and the transformer skid will be located between the produced water treatment equipment and the accommodation. These rooms will be positioned as far away from the process equipment as possible.

5.3.1.5 Helideck

The helideck will be an integral part of the jack-up drilling unit. Although the drilling unit has not yet been selected, all drilling units considered will be equipped with helidecks capable of landing large helicopters.

5.3.1.6 Personnel Safety and Life-Saving Appliances

The life-saving appliances existing on the selected jack-up drilling unit will be supplemented, if necessary, to accommodate the additional persons required for combined drilling and production operations. Normal production and workover operations will require fewer personnel on board than drilling operations.

5.3.1.7 Firefighting Systems

The existing firefighting system of the jack-up drilling unit will be used and supplemented as necessary to provide additional coverage for the added production facilities.

5.3.2 PROCESS FACILITIES

The process facilities that will be installed on the jack-up drilling unit for processing the Cohasset and Panuke condensate streams are discussed in the sections that follow. The process
facilities consist of the production separation, well test, condensate transfer, and produced water treatment systems.

5.3.2.1 Production Separation Facilities

The production separation facilities will be designed to produce condensate with a Reid vapour pressure of approximately 75 kPa and an outlet condensate product containing 3 to 5 percent water. The facilities will consist of two stages of separation; in both stages, free gas and water will be removed. Figure 5.3-2 is the production facility process flow diagram.

Production will flow from the Cohasset wellheads to the production manifold at 54°C. Production from the Panuke field will enter the production manifold from the subsea flowline at 4°C and commingle with the Cohasset production. The commingled production stream will have a temperature of 40°C; thus pre-heating of the Panuke inlet stream will not be required.

From the production manifold, the produced fluid will flow to the Stage 1 separator, which will operate at 554 kPa(g) and 40°C and separate solution gas and water from the production liquid. The liberated gas will go to the high-pressure flare system and the separated water to the produced water system. Approximately 75 percent of the produced water will be removed in the Stage 1 separator.

The production from the Stage 1 separator will then flow to the Stage 2 separator, which will operate at 71 kPa(g). Heating of the production between separators is not required. Liberated gas from the Stage 2 separator will go to the flare system and the water will go to the produced water system. The condensate product from the Stage 2 separator will have a water content of 3 to 5 percent and a maximum Reid vapour pressure of 75 kPa.
PRODUCED WATER SYSTEM

V-201
PRODUCED WATER
FLASH DRUM
1529 ID x 4877 P/T
700 kPa (g) @ 70°C

T-201
SKIMMED COND. TANK.
1000 m3 x 2000 m3
CAPACITY 2 m3

V-202
CPI SEPARATOR
4000 m3 x 2200 m3 x 1000 m3
FLOW: 265 m3/h

V-203
FLOTATION CELL
9800 m3 x 2500 m3 x 2800 m3
FLOW: 265 m3/h
POWER 40 25 hp

FIGURE 5.3-3
flash drum, the CPI separator and the flotation cell will be sent to a skimmed condensate tank and recycled back to the inlet of the Stage 3 separator. The produced water system will be designed for a maximum effluent quality of 40 mg/L of hydrocarbons.

Produced water samples taken from the flotation cell effluent will be monitored using laboratory analysis on a regular basis.

Although the produced water system has been designed to discharge treated water overboard, ongoing research and testing is currently underway to confirm the compatibility of produced water and seawater. If the two waters are compatible, i.e., they can be combined without precipitates forming in the reservoir, the treated produced water will be re-directed to the water injection system thereby reducing both the quantity of water discharged overboard and the quantity required from the seawater supply system.

5.3.3   ANCILLARY FACILITIES

The ancillary facilities consist of the secondary systems related to the process facilities, and the utility systems.

5.3.3.1   Fuel Gas System

Gas from the Stage 1 separator will be the normal gas supply for the fuel gas system (Figure 5.3-4). A gas supply from the test separator for start-up purposes will also be available. The fuel gas will flow through a fuel gas scrubber and be distributed to the flare pilots, produced water flotation cell, and other fuel gas users. A portion of the fuel gas will also be used as strip gas for the injection water deaerator. Liquid from the fuel gas scrubber will flow to the closed hydrocarbon drain header.
The major fuel gas users will be equipped with fuel gas filters for particulate and hydrocarbon liquid removal. The fuel gas system has been sized to handle 28,300 m³/d of gas; this size includes the capacity for a future power generator.

5.3.3.2 Water Injection System

Injection water will be required to maintain reservoir pressure. Figure 5.3-5 shows the injection water system. Injection water will be obtained from the existing seawater supply system or the produced water system as discussed in Section 5.3.2.4. The water will be injected with hypochlorite and passed through three 50 percent cartridge filters before being transferred to the deaerator. The primary purpose of these cartridge filters is to filter any solids from the water before it enters the deaerator. The deaerator will utilize a dual gas stripping vacuum deaeration arrangement and will be designed for oxygen removal to 0.05 ppm.

Water from the deaerator will be injected with hypochlorite, bactericide, and corrosion inhibitor. The pressure will then be boosted to 700 kPa(g) through three 50 percent injection water charge pumps and fed to two 50 percent high pressure water injection pumps. The water will then flow to the water injection manifold and be distributed at a pressure of 13.45 MPa(g) to the Cohasset water injection wells and via subsea flowline to the remote Panuke wellhead jacket. Water from the injection pumps will also be used as the well kill fluid.

The large electric motors for the injection water pump will require an air supply for motor cooling (Figure 5.3-6).

5.3.3.3 Well Control System

The well control system will be served by a wellhead hydraulic control unit common to all wells. The local well systems will be
FIGURE 5.3-6
controlled by electrically operated solenoid valves configured to operate in a fail-safe mode. The remote Panuke production trees will be controlled by pilot-operated hydraulic valves also configured in fail-safe mode.

5.3.3.4 Submersible Pumps System

Artificial lift (ESP's) will be installed in the Cohasset wells from the beginning of production. Variable speed electric submersible pumps (ESP's) will be installed with each production tubing string, and each will require a variable speed controller and transformer as surface equipment. Five 112 kW electric submersible pump units will be required.

Three electric submersible pumps may also be required at Panuke at the end of year four of the field's production life. These would be operated remotely from Cohasset.

5.3.3.5 Well Kill System

The well kill fluid will be seawater supplied from the water injection system. The kill fluid system will be capable of supplying 1.0 m³/min. at a pressure of 13.45 MPa(g). The jack-up drilling rig mud pumps and/or cementing unit could also be connected to the production and injection manifolds for direct access to the problem well.

5.3.3.6 Electrical System

Electrical power will be supplied from the existing normal and emergency power generation systems. The electrical power distribution equipment required for the production facilities will be contained in two separate modules. Transformers will be mounted outdoors on a skid.

MARCH 7, 1990
One enclosed module will contain two 600-V, 3-phase motor control centres to provide the power and control for the majority of the production and utilities equipment, plus the variable frequency (speed) drive controllers for the five submersible well pumps. Space may be provided at Panuke for the three variable frequency drive controllers that may be required in the future. An individual 600-V, 3-phase feeder will be routed to each motor control centre from the jack-up unit's existing electrical system. Equipment duplicates will be provided for each motor control centre for electrical supply redundancy, as required by regulatory requirements.

A second enclosed module will contain two sets of 4160 V switchgear, one for each of the 1.12 MW water injection pumps. The pumps will be three-step reduced voltage started (auto transformer, closed transition) to minimize the starting impact on the existing electrical system. A 1500 kVA, 600 V to 4160 V, 3-phase, step-up transformer will be used to increase existing system voltage to 4160 V. A separate feeder and transformer will be required for each pump. Figure 5.3-7 shows the water injection pump motor.

An open skid will contain the two 1500 kVA, 600 V to 4160 V step-up transformers for the water injection pumps, and the five variable frequency drive transformers for the Cohasset submersible well pumps. Three variable frequency drive transformers for the Panuke submersible well pumps may be installed at a later date on the Panuke well jacket.

5.3.3.7 Heating Medium System

The existing utility steam system will be used to supply the required heat to process exchangers and utility systems. Figure 5.3-8 shows the heating medium system distribution.
WATER INJECTION PUMP MOTOR
SINGLE LINE DIAGRAM

600 V 3Ø INCOMING FEEDER

2000 A

1500 KVA
600/4160 V 3Ø
TRANSFORMER

MAIN BREAKER

4160 V 3Ø BUS

3 STEP AUTOTRANSFORMER
REDUCED VOLTAGE
STARTER

1500 HP
P-803 A
WATER INJECTION
PUMP

600 V 3Ø INCOMING FEEDER

2000 A

1500 KVA
600/4160 V 3Ø
TRANSFORMER

MAIN BREAKER

4160 V 3Ø BUS

3 STEP AUTOTRANSFORMER
REDUCED VOLTAGE
STARTER

1500 HP
P-803 A
WATER INJECTION
PUMP

FIGURE 5.3-7
5.3.3.8 Seawater Supply System

The existing seawater supply system will be used to supply seawater to the injection water system.

5.3.3.9 Service Water System

The service water system will be extended from the existing system and will include one 100 percent sodium hypochlorinator unit, a sodium hypochlorite storage tank, and two supply pumps. The extended system will supply hypochlorite to the injection water system and to the existing service water system. Figure 5.3-9 shows the additions to the service water system.

5.3.3.10 Air and Purge Gas Systems

The air system for the production facilities will remain as it exists on the jack-up, with the exception of the addition of an instrument air dryer package to the existing rig air compressor system for instrument air supply to the production facilities.

A purge gas producer will generate an oxygen-deficient gas for purging of the process system prior to start-up. The unit will supply the purge gas at a pressure of 200 kPa(g). This system will also provide purge gas for maintenance operations. Figure 5.3-10 shows the purge gas and air system additions.

5.3.3.11 Chemical Storage

Chemicals will be transported to the structure and stored in 1.4 m³ tote tanks. Table 5.3-1 is a summary of the chemical storage volumes.
SERVICE WATER SYSTEM

T-901
SODIUM HYPOCHLORITE
STORAGE TANK
1800 gal. x 200 ft. x 0.04 m
CAPACITY: 2 m³

KP-901
HYPOCHLORITATION UNIT
10% NaOCl
ELECTRIC 240 V

FL

P-901 A/B
HYPOCHLORITE SUPPLY
PUMP 1.5 x 1.0 x 0.5
3 HP

EXISTING SERVICE WATER SYSTEM

EXISTING SERVICE WATER SYSTEM

WATER MAIN
WATER MAIN
WATER MAIN

FIGURE 5.3-9
AIR AND PURGE GAS PRODUCER SYSTEMS

**KP-1101**
INSTRUMENT AIR
DRYER PACKAGE
1035 kPa (g) @ 50°C
CAPACITY: 85 m³/h
DEW POINT: -40°C

**KP-1102**
PURGE GAS PRODUCER
50 m³/h @ 100 kPa (g)
3% O₂ CONCENTRATION

COOLING WATER

DIESEL FUEL

**KP-1102**

PURGE GAS TO
PROCESS VESSELS

**KP-1101**

INSTRUMENT AIR
DISTRIBUTION

EXISTING RIG AIR SUPPLY

FIGURE 6.3–10
**TABLE 5.3-1**  
**CHEMICAL STORAGE CAPACITY**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Storage Capacity (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion inhibitor</td>
<td>1.4</td>
</tr>
<tr>
<td>Scaling inhibitor</td>
<td>1.4</td>
</tr>
<tr>
<td>Foam inhibitor</td>
<td>1.4</td>
</tr>
<tr>
<td>Oxygen scavenger</td>
<td>1.4</td>
</tr>
<tr>
<td>Bactericide</td>
<td>1.4</td>
</tr>
<tr>
<td>Demulsifier</td>
<td>1.4</td>
</tr>
</tbody>
</table>

A tote tank storage rack capable of containing 10 tanks will be provided, and chemicals will be extracted directly from the tanks. Figure 5.3-11 shows the chemical injection system.

Corrosion inhibitor, bactericide, and oxygen scavenger will be used in the produced water system. Scaling inhibitor, foam inhibitor, and demulsifier will be used in the condensate dehydration processing train.

**5.3.3.12 Heating, Ventilating, and Air Conditioning System**

The primary process separation facilities, produced water treatment facilities, and injection water system will be located on the open upper deck to eliminate heating and ventilating requirements for this equipment. The heating, ventilating and air conditioning (HVAC) system for the control room and two MCC rooms will consist of 100 percent make-up air units. A steam coil in each make-up air unit, supplied with steam from the existing utility steam system, will provide the heating source. The battery room and safety equipment room will contain unit heaters with a steam coil and exhaust blowers for discharging air. Figure 5.3-12 shows the heating and ventilating systems.
### CHEMICAL INJECTION SYSTEM

**T-12 xx**  
**TYPICAL TOTE TANK**  
3/4 I.D. x 1829 IT  
700 kPa(g) @ 50°C

<table>
<thead>
<tr>
<th>TANK TAG. NO.</th>
<th>DESCRIPTION</th>
<th>CAPACITY (m³)</th>
<th>PUMP TAG NO.</th>
<th>PUMP HP.</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1201</td>
<td>CORROSION INHIBITOR</td>
<td>1.4</td>
<td>P-1201 A,B</td>
<td>0.5</td>
</tr>
<tr>
<td>T-1202</td>
<td>SCALING INHIBITOR</td>
<td>1.4</td>
<td>P-1202 A,B</td>
<td>0.5</td>
</tr>
<tr>
<td>T-1203</td>
<td>FOAM INHIBITOR</td>
<td>1.4</td>
<td>P-1203 A,B</td>
<td>0.5</td>
</tr>
<tr>
<td>T-1204</td>
<td>OXYGEN SCAVENGER</td>
<td>1.4</td>
<td>P-1204 A,B</td>
<td>0.5</td>
</tr>
<tr>
<td>T-1205</td>
<td>DEMULSIFIER</td>
<td>1.4</td>
<td>P-1205 A,B</td>
<td>0.5</td>
</tr>
<tr>
<td>T-1206</td>
<td>BACTERICIDE</td>
<td>1.4</td>
<td>P-1206 A,B</td>
<td>0.5</td>
</tr>
<tr>
<td>T-1207</td>
<td>GLYCOL</td>
<td>1.4</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>T-1208</td>
<td>SPARE</td>
<td>1.4</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>T-1209</td>
<td>SPARE</td>
<td>1.4</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>T-1210</td>
<td>SPARE</td>
<td>1.4</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**FIGURE 5.3-11**
HVAC SYSTEMS

H-1302
SAFETY ROOM
DUTY 8 kW
MOTOR 1/2 HP

H-1301
CONTROL ROOM
MAKE-UP AIR UNIT
DUTY 8 kW
MOTOR 1/4 HP

H-1304
BATTERY ROOM
UNIT HEATER
DUTY 4 kW
MOTOR 1/2 HP

H-1303
MEC ROOM
MAKE-UP AIR UNIT
DUTY 10 kW
MOTOR 1/2 HP

FIGURE 5.3-12
5.3.3.13 Drain System

Two drain sumps will be provided to collect drain liquids from directly under the Stage 1, Stage 2, and test separators, and at the wellhead and manifold area. Sump pumps will operate on level control to transfer open drain liquid to a drain separator. Each sump and the drain separator will be provided with an overflow to allow direct discharge overboard should heavy rains or operation of the sprinkler system flood the drain system beyond its rated capacity. The drain separator will also be interconnected to collect drain water from the produced water treatment equipment. Figure 5.3-13 shows the drain system.

The closed hydrocarbon drain system from the process facilities will drain into the HP or LP relief drums for temporary containment of drain liquid during maintenance. The collected hydrocarbon liquids will be recycled when the production system begins operating.

5.3.3.14 Process Control Systems

The process control panel located in the control room will use a programmable logic controller (PLC) to perform all process control. A man-machine interface will be provided by an industrial computer to allow operator interface and control. Process flow diagrams, alarms, and equipment status will be actively displayed on a high resolution colour monitor supplied with the system.

A safety system control panel located in the control room will be similar in construction and content to the process control panel. This panel will monitor all fire detection equipment in the new area and control various equipment for ventilation and fire suppression, including automatic process and wellhead shutdown with interfacing to the existing facility safety systems.
5.3.4 ACCOMMODATION

The existing crew accommodation quarters on the jack-up unit will be used to house the required drilling operating and maintenance personnel.

5.3.5 FLARE AND RELIEF SYSTEMS

High-pressure gas from the Stage 1 separator and test separator will flow through a high-pressure flare tip. Similarly, low-pressure gas from the Stage 2 separator will flow through a low-pressure flare tip. The existing well test burner will be modified to include high and low radiation flare tips. Gas from the open vent header will flow through an open vent separator to a vent partway along the flare boom. Figure 5.3-14 shows the flare system.

High-pressure relief vapours from the Stage 1 separator will flow through a high-pressure relief drum to remove liquid carryover in the relieving gas stream. Similarly, low-pressure gas will flow through a low-pressure relief separator.

5.3.6 TELECOMMUNICATIONS

Telecommunications to be provided include the following:

- marine and aircraft communications
- production data and marine-to-land communications
- remote facility operation

These are described in the sections that follow.

5.3.6.1 Marine and Aircraft

Marine and aircraft communications will be handled using existing radio systems from the jack-up unit. A complete list of existing
FLARE SYSTEM

V-301
H.P. RELIEF DRUM
3/4 ID x 1829 T/T
700 kPa (g) @ 50°C

V-303
OPEN VENT SEPARATOR
608 ID x 1828 T/T
700 kPa (g) @ 50°C

V-302
L.P. RELIEF DRUM
3/4 ID x 2438 T/T
700 kPa (g) @ 50°C

BS-301 A/B
FLARE TIP
3T x 10⁶ m³/yr

FIGURE 5.3-14
equipment will be available after the drilling unit has been selected. The following is a list of typical equipment available on a jack-up drilling unit:

- two 1000 W linear single sideband transceivers
- one 1000 W VHF-FM transceiver
- aircraft homing beacons
- eight portable handsets

5.3.6.2 Production Data

All production data and ship-to-shore communication will be sent via satellite link to the onshore operations centre.

5.3.6.3 Remote Facility Operation

Line-of-site telemetry is being considered for the remote operation of the wellheads and deck facilities at Panuke.

5.3.7 WINTERIZATION SYSTEMS

Because of the seasonal production schedule (April through October), extensive winterization modifications are not planned. Except for draining of water lines and the possible adding of antifreeze, winterization of the jack-up and facilities is not considered necessary.

5.3.8 CORROSION PROTECTION

Extensive corrosion protection is not required.
5.4 WELL JACKETS

The Cohasset and Panuke fields will be developed with seven and four wells respectively. These wells will be directionally drilled through a steel-piled well jacket using a jack-up drilling rig.

5.4.1 GENERAL DESCRIPTION

A well jacket is a tubular, steel-framed structure that supports a minimum deck load, and that is designed primarily to provide lateral support to the wells and conductors that extend from the seafloor to an elevation above the highest anticipated wave. Figure 5.4-1 shows a typical steel well jacket. At Panuke, the well jacket and wells would stand alone, with production from the wells flowing back down a riser to a flowline on the seafloor. At Cohasset, the jack-up unit would be positioned adjacent to the well jacket.

5.4.2 ALTERNATIVES

Many different configurations of well jackets are used in the offshore petroleum industry. These range from very small shallow water structures supporting only one well to more substantial structures in deep water supporting several wells. In all cases, a well jacket is drilled with a tender drilling unit, eliminating the need to support drilling facilities on the structure. The type of well jacket proposed for Cohasset and Panuke is one that has been used in several Gulf of Mexico and Southern North Sea locations. The structure was selected because it could be designed to be installed with a jack-up drilling unit.

5.4.3 ADVANTAGES

The steel piled well jacket has the following distinct advantages over a subsea completion template:
STEEL PILED WELL JACKET
- The wellheads and xmas trees would be located above the water surface providing ready access to the wellhead valves.

- The wells could be drilled and completed using conventional surface wellheads and xmas trees rather than more complex and expensive subsea wellheads and xmas trees.

- The well support system would be entirely passive and would not require risers and tensioning systems to support the wells from the seafloor to surface facilities.

- Although the initial cost of the well jacket is higher than the initial cost of a subsea template and the associated riser and tensioning system, the operating and drilling costs will be less using a well jacket.

**PLATFORM CONFIGURATION**

The platform consists of a base frame, piled to the seafloor, two vertical tubular members each containing a well conductor and extending to the deck level, and a simple deck to provide access to the surface wellheads. A number of horizontal frames will tie the two vertical tubulars together at different levels and support additional conductors as required. In addition, the two vertical tubular members will be tied to the base frame by four diagonal members that will extend from the +3.2 m elevation to the -17 m elevation.

The base frame will consist of four 1372 mm diameter pile sleeves interconnected by four cross-braced trusses on each side and two cross-braced trusses in each of the top and bottom frames. The base frame for Cohasset will be 16.5 m wide, 21.0 m long and 22.9 m high. The Panuke base frame has the same horizontal dimensions, but would be 33.2 m high due to the greater water depth.
The two vertical tubular members will be framed together with horizontal conductor guides at the seafloor, at the top of the base frame, at an elevation 3.2 m above the sea surface, at the deck level, and at two intermediate locations. The horizontal frame at the 3.2 m elevation will be braced to the base frame by four 914 mm diameter diagonals.

Figure 5.4-2 shows the general configuration of each of the proposed structures.

The deck for each structure will measure 9.1 m x 9.1 m and be located above the maximum wave crest elevation. The equipment located on this deck will be minimal, and therefore the deck will provide a lateral tie-in between the conductors and the two main tubes and provide a personnel walkway around the wells. The Panuke well jacket will require access by boat and helicopter as it is located remotely from the Cohasset facilities. A boat landing and helideck will be provided. The Cohasset well jacket will be located adjacent to the jack-up drilling unit, and access will be by walkway and stairway from the jack-up unit. A boat landing and helideck may be required if the jack-up drilling and production unit is removed from the Cohasset location.

A detailed design of the piles and conductors will be conducted after a site-specific borehole analysis has been completed. For preliminary purposes, a soil capacity curve was generated assuming that a uniform medium to dense sand extended beyond the depth required for piles. The piles would be installed through the four pile sleeves of the base frame and driven to the required penetration using a high-energy, surface pile driver, and skirt pile followers. After installation, the pile would be grouted to the base frame and the pile follower removed by cutting above the top of the base frame. Piles would be 1219 mm diameter with wall thicknesses ranging from 32 mm to 51 mm.
The conductors installed through the two vertical tubes would be 1067 mm diameter. The conductors installed through the exterior conductor guides measure 762 mm diameter and would be driven to a penetration of about 31 m.

5.4.5 CORROSION PROTECTION

The well jackets will be divided into three different zones, each protected from corrosion in a different manner. The zones are defined as follows:

- Atmospheric Zone: The portion of the structure located above the influence of attack by seawater during the annual storm. This zone will be protected with appropriate coatings.

- Submerged Zone: The portion of the structure located below the influence of the oxygen-laden atmosphere during the annual storm. This zone will be protected with cathodic protection.

- Splash Zone: The portion of the structure located between the atmospheric and submerged zones. This zone will be protected by application of the following:
  - Additional wall thickness to account for a corrosion allowance
  - Fibreglass tape wrap on critical diagonal members
  - A four-coat epoxy paint system
  - Visual inspection of organic coating or corrosion-resistant metal sheathing in the splash zone

The protective coating and sacrificial anodes will be inspected each year to determine the extent of damage and the need for repair or replacement.
5.5

**INTERFIELD FLOWLINES**

This section discusses the intended subsea flowline configurations and installation methods.

The flowlines between the Panuke and Cohasset wellhead jackets will contain the following:

- 203 mm production line
- 152 mm water injection line
- 152 mm hydraulic hose bundle
- possibly, a submarine power cable

All lines will be grouped together as they are spooled from the pipelaying vessel. The flowlines may intersect a Teleglobe Canada telecommunication cable, depending on the final position selected for the Panuke well jacket.

5.5.1

**FLOWLINE INSTALLATION METHODS**

The flowline installation methods considered include using a reel barge, flexible pipe, a lay barge, and the tow method. These are described in the sections that follow. The reel barge is the preferred method but the flexible pipe alternative is also being considered.

5.5.1.1

**Selected Method: Reel Barge**

The joints of pipe would be prewelded onshore into long sections and coiled onto large-diameter reels on a barge. The barge would spool the pipe onto the seabed as it travelled along the flowline route.
Flexible Pipe

Flexible pipe is manufactured in continuous lengths. It is made up of layers of steel reinforcing interspersed with layers of synthetic fibre. The layers of reinforcing or the carcass provide the strength to contain the internal pressure. This combination would provide a compliant pipe which can be installed similar to a cable. This method is being investigated as an alternative to the reel barge method.

Lay Barge

The lay barge would be stationed on the previously surveyed flowline route would maintain station with a conventional mooring system. Dynamic positioning may be used to assist the mooring system in some cases. The pipe joints would be welded together on the barge before the pipe was pulled to the seabed over a stinger. This operation would be best suited for large-diameter lines installed over long distances.

Tow Method

Long lengths of pipe would be fabricated on land and towed offshore while additional lengths were being added. The completed line would be towed from the staging area to the installation site. The length of the towed string would be limited by the towing force that was generated which, in turn, would be a function of the drag forces. The tow method would be most suitable in remote areas where pipeline installation infrastructure is not available.
5.6  EXPORT SYSTEM

5.6.1  SELECTED EXPORT SYSTEM

5.6.1.1  General Description

The processed condensate will be transferred from the production facilities on the jack-up via a subsea flowline and dynamic riser to a catenary anchor leg mooring system (CALM), a mooring buoy, storage vessel, and shuttle tanker. As shown in Figure 5.6-1, the export system will consist of the following components:

- a flowline from the jack-up, along the seabed approximately 2 km to a flowline end manifold (PLEM)

- a flexible riser from the PLEM to the CALM buoy

- a six- or eight-anchor CALM buoy, installed in 37-39 m of water

- a segregated ballast storage vessel with a bow mooring system, bow loading manifold, and stern offloading and mooring system

- a segregated ballast shuttle tanker with a bow mooring system and a bow loading system

The flowline, PLEM, riser, and CALM system will remain in position throughout the year. The storage vessel will remain at the field for the 7-month primary production season (April - October). The storage tanker will be available for trips to the field during the winter period subject to suitable weather periods. The shuttle tanker will operate between the storage vessel and final market destinations throughout the season and will be released during the winter period (November - March).
Preliminary flow has been calculated to size the flowline, resulting in 153 mm ID pipe with an inlet pressure of 1967 kPA (g) and an outlet pressure of 864 kPa.

The flowline and the flexible steel riser will be provided with an external steel casing to provide additional protection against the abrasive action of the seabed.

An existing tanker will be used for the storage vessel. The tanker will be modified to meet the design requirements. A general arrangement for the modified tanker is shown in Figure 5.6-2.

If a suitable unit is available, an existing CALM buoy will be modified to meet the design conditions. Figure 5.6-3 shows the general arrangement of the CALM buoy and storage tanker.

An existing tanker will also be used for the shuttle tanker. The tanker will be modified as required. Figure 5.6-4 shows the general arrangement of the modified tanker. The storage vessel offloading and shuttle tanker mooring arrangement is shown in Figure 5.6-5.

5.6.1.2 Operational Limits

The flowline will be located on the seabed at a depth of about 40 m and will be anchored to the well jacket at one end and the flexible riser base (PLEM) at the other end. Although on-bottom currents and some scouring are anticipated during the winter storms, the offloading system will not be operating; therefore, the flowline has no operational limits. After each major storm, the flowline will be inspected prior to commencement of production.

There are no operational limits for the riser with respect to 100-year storm conditions. The riser will be of the steep wave configuration rising from the PLEM to buoyancy modules and then to the CALM buoy at the surface.

MARCH 7, 1990
CALM BUOY AND STORAGE VESSEL MOORING

FIGURE 5.6-2
STORAGE VESSEL ARRANGEMENT

STER OFFLOADING LINE
SHUTTLE HAWSER
FLOATING HOSE

CARGO CONTROL ROOM

PUMP ROOM

ENGINE ROOM
CARGO TANK 7
CARGO TANK 6
CARGO TANK 5
CARGO TANK 4
CARGO TANK 3
CARGO TANK 2
CARGO TANK 1

PROFILE

PROTECTIVELY LOCATED SEGREGATED BALLAST TANKS

BOW LOADING QUICK DISCONNECT SYSTEM

HOSE RACK

MIDSHIP MANIFOLD

CHAIN STOPPER

CHAFING CHAIN

FIGURE 5.6-3
STORAGE VESSEL OFFLOADING

SHUTTLE TANKER

PROFILE

PROTECTIVELY LOCATED SEGREGATED BALAST WING TANKS

PLAN

MIDSHIP MANIFOLD

BOW MANIFOLD

PICK-UP ROPE REEL

CHAIN STOPPER

HOMERACK

PUMP ROOM

STERN MANIFOLD

FLOATING HOSE

HYDRAULIC HOSE

STOPPER

ENGINE ROOM

CARGO TANK 7

CARGO TANK 6

CARGO TANK 5

CARGO TANK 4

CARGO TANK 3

CARGO TANK 2

CARGO TANK 1

CENTER CENTER CENTER CENTER

ENGINE ROOM

CARGO TANK 7

CARGO TANK 6

CARGO TANK 5

CARGO TANK 4

CARGO TANK 3

CARGO TANK 2

CARGO TANK 1

CENTER CENTER CENTER CENTER

HAWSER

FIGURE 5.6-4
SHUTTLE TANKER ARRANGEMENT

CARGO CONTROL ROOM

PUMPROOM

PROFILE

PROTECTIVELY LOCATED SEGREGATED BALAST WING TANKS

ENGINE ROOM
CARGO TANK 7
CARGO TANK 6
CARGO TANK 5
CARGO TANK 4
CARGO TANK 3
CARGO TANK 2
CARGO TANK 1

BOW MANIFOLD

MIDSHIP MANIFOLD

FLOATING HOSE

HAWSER

PICTUP ROPE REEL

CHAIN STOPPER

CHAFING CHAIN

FIGURE 5.6-5
The only operational limit that will restrict the export system to receive and transfer condensate is related to sea state and surface equipment. From practical experience, typical operational limits can be set at the following conditions:

- Maximum significant wave for mooring and hose retrieval: 4.5 m
- Maximum hawser tension for continuation of loading: 100 t (7.6 m sig. wave height) (thruster assisted)
- Maximum significant wave for buoy maintenance: 2.5 m

These limits will vary depending on the combination of field conditions prevailing at the time and the specific tankers selected.

Operationally, the production system can continue to export condensate to the storage vessel and, in turn, to the shuttle tanker in seas that greatly exceed those expected during the 7-month operating season. Table 6.4-5 in Section 6 summarizes the wave heights on a monthly basis.

5.6.1.3 Efficiency and Downtime

The efficiency of the export system is expected to be close to 100 percent during the April through October period. The expected sea states will seldom exceed 3.5 m (significant wave height), well within the shuttle tanker's ability to retrieve the mooring line and hose from the storage vessel. Storms with waves in excess of 7.6 m would force disconnection of the storage vessel from the mooring system.

The efficiency of the flowline and riser is expected to be fairly high. Regular inspections and maintenance would be conducted during
the summer period. No downtime during the six-year production period is anticipated.

Downtime can be expected due to mechanical problems with the mooring system. These may not require a production shutdown, but, from experience, downtime of up to 5 percent can be expected. Any major repairs that may be required may be carried out during the off-season. The transit time from Halifax to the field is only 12 hours, allowing rapid deployment and retrieval of maintenance equipment.

No downtime is expected for the storage and shuttle tankers due to mechanical problems. Past experience indicates that ships of this type have an availability in excess of 350 days per year. Two weeks of downtime per year is required for normal maintenance and repairs and this can be accommodated during the off-season.

5.6.2 ALTERNATIVE EXPORT SYSTEMS

The other export systems considered include a CALM buoy and shuttle tanker, a turret-moored floating storage and offloading (FSO) system and shuttle tanker, and a disconnectable chain-moored FSO and shuttle tanker.

5.6.2.1 CALM Buoy and Shuttle Tanker

A system using a CALM buoy and shuttle tanker would be similar to that described in Section 5.6.1. The system consists of only four components, as shown in Figure 5.6-6:

- A flowline from the jack-up along the seabed approximately 1000 m to a PLEM

- A flexible riser from the PLEM to the CALM buoy
CALM BUOY AND SHUTTLE TANKER

**Profile**

- Engine Room
- Cargo Tank 1
- Cargo Tank 2
- Cargo Tank 3
- Cargo Tank 4
- Cargo Tank 5
- Cargo Tank 6
- Cargo Tank 7
- Cargo Tank 8
- Cargo Tank 9
- Cargo Tank 10
- Cargo Tank 11

- Pile Anchor
- Anchor Chain
- Flexible Riser
- Buoyancy Modules
- Calm Buoy
- Hawser
- Floating Hose

**Plan**

- Pump Room
- Bow Manifold
- Midship Manifold
- Pick-up Rope Reel
- Chain Stopper
- Hawser
- Chafing Chain

**Figure 5.6-6**
- A CAIM buoy with six anchor legs, floating in 39 m of water

- A 200,000 DWT segregated ballast shuttle tanker with a bow mooring system and midship loading manifold system (similar to the tanker described in Section 5.6.1.1)

The flowline, PLEM, riser, and CAIM system would remain in position throughout the year. The shuttle tanker would moor to the CAIM buoy and take on condensate at the maximum flowrate of the field. When the tanker was full, production would be shut down and the tanker would disconnect and proceed to market destination. After discharge of the cargo, the tanker would return to the field and repeat the cycle.

When this system is compared to the system described in Section 5.6.1, the following differences are apparent:

- A storage vessel would not be required.

- The capital and operating costs of the marine component would be lower.

- The quantity of condensate delivered would be lower by up to 20 percent as a result of the shutdowns that occur when the tanker leaves for the discharge port.

- The overall transportation cost per barrel would be lower by approximately 30 percent.

This system is similar to several which operate in the North Sea and appears to be a practical alternative for this project.
Turret-Moored FSO and Shuttle Tanker

A system using a turret-moored FSO and shuttle tanker is similar to the system described in Section 5.6.1, except for the method of mooring the storage vessel. The system consists of only four components, as shown in Figure 5.6-7:

- A flowline from the jack-up, along the seabed approximately 1000 m to a PLEM

- A flexible riser from the seabed to the turret of the storage vessel

- A 60,000 DWT segregated ballast storage vessel with six anchor legs, a bow mooring turret system, a bow loading manifold, and a stern offloading and mooring system

- A 40,000 DWT segregated ballast shuttle tanker with a bow mooring system and bow loading system

The flowline, riser, and mooring system would remain in position throughout the year. The storage vessel would remain at the field for the 7-month season, returning to a home port for winter lay-up. The shuttle tanker would operate between the storage vessel and the discharge port throughout the season and be released for the winter lay-up period.

When this system is compared to the system described in Section 5.6.1, the following differences are apparent:

- The capital cost of the marine component is higher due to the higher cost of the turret equipment.

- The overall transportation cost per barrel is higher by approximately 20 percent.
The reliability and maintainability of this system is likely to be higher because of the high maintenance of the turret and swivel components.

This system has been used in several locations and is thought to be a practical, but more expensive, alternative for this project.

5.6.2.3 Disconnectable Chain-Moored FSO and Shuttle Tanker

A system using a chain-moored FSO and shuttle tanker is similar to the system described in Section 5.6.2.2, except for the method of mooring the storage vessel. The system consists of five components, as shown in Figure 5.6-8:

- A flowline from the jack-up along the seabed approximately 1000 m to a PLEM
- A flexible riser from the seabed to a riser buoy and then to the turret of the storage vessel
- A catenary anchor mooring (CAM) and condensate transfer system which can connect to and disconnect from a turret assembly on the bow of the storage tanker
- A 60,000 DWT segregated ballast storage vessel with a bow mooring turret system, bow loading manifold, and stern offloading and mooring system
- A 40,000 DWT segregated ballast shuttle tanker with a bow mooring system and bow loading system

The flowline, riser, anchor legs, and riser buoy will remain in position throughout the year. The storage vessel will remain in the field for the 7-month season, returning to a home port for winter lay-up. The shuttle tanker will operate between the storage
DISCONNECTABLE CHAIN-MOORED FSO AND SHUTTLE TANKER

- SWIVEL
- WILDCAT
- CHAIN JACK
- COLLAR STRUCTURE
- TURRET TUBE
- MAIN BEARING
- CHAIN RISER
- FLEXIBLE JUMPER
- JUMPER DISCONNECT COUPLING
- CHAIN RISER SUPPORT BOUY
- GUIDE TUBES
- HOSE GUIDE TUBE SUPPORTS
- ARTICULATING END TERMINATION
- FSO
- CHAIN TABLE/COUNTERWEIGHT
- CHAIN STOPPERS
- MOORING CHAIN

FIGURE 5.6-8
vessel and the discharge port throughout the season and will be released for the winter lay-up period.

When this system is compared to the system described in Section 5.6.1, the following differences are apparent:

- The capital cost of the marine component would increase due to the higher cost of the mooring and turret equipment.

- The overall transportation cost would be higher by approximately 20 percent.

- The reliability and maintainability of this system would be higher.

This system has not been used before but appears to be a practical, but more expensive, alternative for this project.

5.7 CONSTRUCTION AND INSTALLATION

This section discusses the overall project schedule, fabrication, construction, assembly, and installation of all of the components of the selected production system.

5.7.1 PROJECT SCHEDULE

This section discusses the project schedule, including the design, procurement, and construction of all the major components. The project schedule is shown in Figure 5.7-1.

5.7.1.1 Well Jackets

Detailed design of the well jackets will begin in January 1990 and take approximately 3 months to complete. Procurement of materials will begin in June 1990, while fabrication will start in July 1990.
### CONSTRUCTION AND INSTALLATION SCHEDULE

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<td>COMMISSIONING</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>JACK-UP DRILLING &amp; PRODUCTION UNIT</td>
<td>ENGINEERING</td>
<td></td>
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<td></td>
<td>TRANSPORTATION</td>
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<td></td>
<td>MODIFICATIONS</td>
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<td></td>
<td>TRANSPORTATION &amp; RIG-UP</td>
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<tr>
<td></td>
<td>DRILL PANUKE WELLS</td>
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<tr>
<td></td>
<td>INSTALL PROD. EQUIP.</td>
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<tr>
<td></td>
<td>MOVE TO COHASSET</td>
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<tr>
<td></td>
<td>DRILL COHASSET WELLS</td>
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<tr>
<td></td>
<td>DRILL ADDITIONAL WELLS</td>
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<tr>
<td>MILESTONES</td>
<td>GOVERNMENT APPROVAL</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>FIRST PRODUCTION</td>
<td></td>
<td></td>
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</tbody>
</table>

**FIGURE 5.7-1**
Construction of the jackets is expected to take 6 months, being completed by March 1991. Transportation and installation of the structures will be completed by May 1991.

5.7.1.2 Production Facilities

The detailed design of the topside production facilities will begin in December 1989 and is expected to take 10 months. Procurement of items will begin in April 1990 and fabrication will begin in October 1990 and be completed by August 1991. Installation of the skids will take place inshore upon completion. Hook-up and commissioning of the production facilities will be completed by April 1992. If possible, the production facilities will be installed on the selected jack-up at an in-port location, prior to drilling the first wells at Panuke.

5.7.1.3 Flowlines Schedule

Procurement of the subsea flowline materials will begin in May 1990 with manufacturing and fabrication starting in October 1990. Transportation and installation of the flowlines will be scheduled to start in May 1991. Installation will require 1 to 3 months depending on the type of pipe selected.

5.7.1.4 Mooring and Offloading System

Design of the mooring and offloading system will begin in January 1990 and will be completed by March 1990. Procurement of materials needed for the modification of the CALM and tankers and fabrication of the condensate export line, PLEM and riser will begin in June 1990. Fabrication will begin in July 1990 and will be completed in three months. Transportation and installation of the system is expected to take three months, beginning in February 1991. Installation of the condensate export line will coincide with the installation of the interfield flowline. Connecting of the storage
vessel and commissioning of the system will begin in September 1991 and will be completed by April 1992, subject to weather conditions.

5.7.1.5 Jack-Up Drilling Unit

Design of the modification to the jack-up drilling unit and tie-ins to existing systems will begin in January 1990 and will be completed by February 1991. The jack-up will be transported to a facility where the modifications will be made in March 1991. The tie-in modifications will begin in March 1991 and are expected to take three months. The rig will then be transported to Panuke for drilling operations which will begin in June 1991. When drilling is completed in October 1991, the production facility modules will be installed and the rig moved to Cohasset. While the first of the Cohasset wells are being drilled beginning in December 1991, the production facilities will be hooked up and commissioned, with the first condensate being produced in April 1992. It may be possible to install the production equipment inshore, before the start of drilling operations at Panuke.

5.7.2 CONSTRUCTION MATERIALS

This section discusses the construction materials used for the wellhead jackets, process facilities, and subsea flowlines.

5.7.2.1 Structures Material

The wellhead jacket structures will be constructed primarily from round tubular members using either seamless structural steel pipe or rolled structural steel plate.

The structural material will generally conform to API RP 2A, API 2H, CSA CAN 3-G 40.20M, and CSA CAN 3-G 40.21 M. Structural steel plates, shapes, and pipes will conform to the group and class
categories of these standards with modified chemical and mechanical properties as required.

Most of the structural steel that will be used is classified into two main groups within the API RP 2A standard. Group I is designated as mild steel with yield strengths up to 260 MPa; Group II is designated as intermediate-strength steels with yield strengths between 260 and 360 MPa. Table 5.7-1 shows examples of typical steel specifications.

**TABLE 5.7-1**
**TYPICAL STEEL SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Group</th>
<th>Typical Specification</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>ASIM - A.36</td>
<td>Mild steel application</td>
</tr>
<tr>
<td></td>
<td>CAN3-G40.21-M81</td>
<td>Barge bumpers</td>
</tr>
<tr>
<td></td>
<td>ASIM A53 Grade B</td>
<td>Mud mats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anode supports</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grout and jet lines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Caisson support frames</td>
</tr>
<tr>
<td>II</td>
<td>CAN3-G40.21-M81 Gr 260 WT-350 WT</td>
<td>Legs</td>
</tr>
<tr>
<td></td>
<td>ASIM A516 Grade 65</td>
<td>Diagonals</td>
</tr>
<tr>
<td></td>
<td>API 5L Grade x 52</td>
<td>Noncritical joints</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Important horizontals</td>
</tr>
<tr>
<td>IIIs</td>
<td>CAN3-G40.21-M81 Gr 350 WT</td>
<td>Critical joints</td>
</tr>
<tr>
<td>(Special)</td>
<td>with guaranteed through-</td>
<td>Padeyes</td>
</tr>
<tr>
<td></td>
<td>thickness properties</td>
<td>Through-thickness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>requirements</td>
</tr>
</tbody>
</table>

The process facilities will consist primarily of skid-mounted equipment, placed and interconnected on the deck of a severe environment jack-up drilling and production unit. Materials will conform to appropriate specifications as required.

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5.7.2.3 **Subsea Flowlines Material**

The material for the steel pipe alternative will conform to API 5LX-52. The material for the flexible pipe alternative will consist of the following:

- inner interlocked steel carcass
- pressure plastic sheath
- crosswound tensile armour
- external plastique sheaths
- outer interlocked wrap

5.7.3 **CONSTRUCTION FACILITIES**

This section discusses the available construction facilities for the wellhead jackets, production and process equipment and systems, subsea flowlines, and CAIM system.

5.7.3.1 **Wellhead Jackets**

The jackets, decks, piles, and conductors can be fabricated in a facility with access to the ocean and adequate resources to weld tubular elements and load out a 500 t package onto a barge. Competitive fabrication and installation bids will be solicited from Nova Scotia fabricators and several international fabricators.

5.7.3.2 **Production and Process Equipment and Systems**

The manufactured components of the production facilities and ancillary systems will be obtained primarily in Canada. These components include pumps, switchgear, piping, controls, separators, valves, and fittings. Modular components will be fabricated in Western Canada, where the expertise is already in place, and then transported to the east coast. Modular components that are too large to transport will be fabricated in Nova Scotia.
5.7.3.3 Subsea Flowlines

The reel barge method of laying steel pipe will require a shore facility capable of making up the long sections of pipe to minimize the time it takes to load the main reel. Two such yards, one in Leith, Scotland and the other in Houma, Louisiana could be used. The potential for a suitable Nova Scotia location may be investigated. If flexible pipe is selected, then it would be manufactured in either the USA or France and brought into Nova Scotia already prepared on reels.

5.7.3.4 CAIM Buoy

An existing CAIM buoy may be modified and leased. If a suitable unit is not available, a new unit will be fabricated. Fabrication may take place in Nova Scotia subject to the competitive bids obtained.

5.7.3.5 Modifications to Selected Storage Tanker

Modifications will be made to a tanker to convert it to a storage and offloading facility. These modifications will include the following:

- The addition of equipment for retrieval and connection of the mooring hawser for connection from the bow to the loading buoy

- The addition of equipment for the mooring of a shuttle tanker to the stern

- Equipment for the retrieval and connection of the loading hose from the loading buoy

- Equipment for the offloading of condensate from the stern
5.7.3.6 Modifications to Selected Shuttle Tanker

Modifications will be made to a tanker to be used for a shuttle tanker. These modifications will include equipment for retrieval and connection of the mooring hawser and the hose string.

5.7.4 OFFSHORE INSTALLATION

This section discusses the offshore installation of the wellhead jackets, subsea flowlines, and CALM system.

5.7.4.1 Well Jacket

For cost estimating purposes, it was assumed that installation would be performed by a derrick barge, mobilized from the U.S. Gulf Coast. Alternatively, it is possible to install the jackets by using only the jack-up rig and the leg-jacking mechanism to lift, install and support the structure prior to pile installation. Details of the installation procedure will be finalized once the drilling contractor has been selected and the installation plan developed in conjunction with the drilling or installation contractors.

5.7.4.2 Subsea Flowline

The Reel Barge Pipe-Laying Method

A reel barge would be selected from several candidates world-wide subject to availability. A typical reel barge would be about 125 m long with a 21 m beam. It would have a cruising range of about 8000 km at a speed of 12.5 knots. The vessel would be dynamically positioned and have a full diving spread on board. It would be capable of making all the subsea tie-ins.
The most important feature of the pipe-handling system is the vertical reel capable of holding up to 1800 t of pipe. A typical reel could hold 32 km of 203 mm pipe and 49 km of 152 mm pipe. For this project, only 8 km of each size will be required. In addition to the main reel, typical reel barges also can carry two smaller reels for small diameter lines or control bundles.

Reel barges have recently been operating in the North Sea. If this method of line installation is selected, the pipe material will be purchased and sent to the barge home base. Similarly, the control bundle will be sent there for load-out. The reel barge will dock in its home port, load up all pipe, control hose, supplies and materials required for the complete project, steam to Nova Scotia and, after completion of the flowline laying, return to its home port.

Flexible Pipe Alternative

Flexible pipe flowlines would be installed by a purpose-built, dynamically positioned reel barge. The barge would be capable of transporting and installing up to eight reels of flexible pipe without re-supply. Pipe would be loaded onto the reels at a pipe manufacturing plant and pipe in excess of reel barge capacity would be shipped on a third-party cargo vessel.

Flowline Connections

Once the flowline has been laid, the first end connections will be at the Panuke jacket and the second end connections at the Cohasset jacket. The first end connections will be a J-tube pull-in. The flowlines and control hose will be passed in one bundle and pulled into the J-tube, located on the well jacket structure, using a winch located on the Panuke jacket.
For the second end connections, the lay vessel will pass beside the Cohasset jacket and pass a pull-in line to the jack-up, which will pull the flowline bundle into the J-tube on the well jacket.

A J-tube pull-in will then be made at the Cohasset jacket for the condensate export line. The export line will be installed to the location of the CALM and welded to the PLEM before is is lowered to the seabed. The PLEM will be fixed to the seabed with piles or by pumping cement, mud, or other ballast into buoyancy tanks built into it. Each line will be pressure-tested from the jacket as it is completed. All pressure tests will be completed prior to demobilization of the lay vessel.

5.7.4.3 CALM Buoy

The CALM buoy would be installed in a six- or eight-point mooring arrangement using two anchor-handling tug supply vessels, a team of divers, and a marine survey team located on each vessel to ensure accurate positioning of the anchors.

The vessels will be supplied with suitable chain chasing equipment and work wires. One vessel will carry the diving crew, a suitable fast rescue craft and decompression chamber for their use, and a remote operated vehicle for inspection.

5.7.5 QUALITY ASSURANCE AND QUALITY CONTROL

A comprehensive quality assurance procedure will be prepared to monitor compliance to specifications and end product quality. The Operator will contract a third-party inspection firm to review engineering calculations, construction drawings, equipment specifications, and fabrication trade inspectors' reports. Section 10 covers quality assurance and quality control in detail.
5.8 SUSPENSION OF OPERATIONS AND ABANDONMENT

This section discusses seasonal suspension of producing operations and permanent abandonment of the production facilities.

5.8.1 SEASONAL SUSPENSION OF PRODUCING OPERATIONS

During the winter months, November through March each year, producing operations may be suspended. The shuttle tanker will be released, and the storage tanker brought into port. Workover operations will be conducted during the winter months. The storage tanker, depending on prevailing weather conditions, may be used to transport several addition loads of condensate during the winter months. The following components will remain in place throughout the winter:

- wells
- jack-up drilling and production unit
- flowlines
- mooring and offloading system

5.8.2 PERMANENT ABANDONMENT

When the Cohasset and Panuke fields have been depleted, the production facilities will be removed. Wells will be abandoned in accordance with all regulations, and the well jackets removed to a level below the seabed. Residual hydrocarbons in the flowlines will be flushed out to the Cohasset facility, and the flowlines recovered for possible future use. Hydrocarbons from the condensate export line will be flushed out to the storage vessel and recovered for possible future use.
5.9 SAFETY SYSTEMS AND CONSIDERATIONS

Each component of the offshore systems will undergo risk and reliability analysis, hazard and operability analysis, and internal IASMO safety reviews and audits.

Operational safety and contingency procedures are presented separately in Section 11, Safety Plan.

5.9.1 PROCESS SAFETY SYSTEMS

Typical process safety systems will include the following:

- fire detection
- firewater, aqueous film-forming foam system
- Halon
- emergency shutdown
- emergency power
- communication and life-saving appliances.

5.9.1.1 Fire Detection

Fire detection and alarm systems will be included in the process areas, motor control centre and switchgear modules, open transformer module, and control and safety equipment room.

Process Areas

Combination ultraviolet and infrared fire detection heads will be located throughout the on-deck process areas. Gas detection equipment will also be used in these open areas.
Motor Control Centre and Switchgear Modules

Combination ultraviolet and infrared fire detection heads, plus ionization type detectors will be located in the motor control centre (MCC) and switchgear modules.

Open Transformer Module

Combination ultraviolet and infrared fire detection heads will be provided in the open transformer module.

Control and Safety Equipment Room

Ionization type detectors plus heat detectors will protect the control and safety equipment room. Manual pull stations will be located throughout all areas to manually activate the alarm systems. Audible alarm devices will be located throughout all areas. The fire detection system will be tied into the existing jack-up safety systems in the form of unit alarms.

Firewater System

The firewater system will be expanded from the existing firewater header to include the production facilities.

The firewater distribution system for the production facilities will consist of firewater headers supplying specific sprinkler zones, hose reels, and monitors. A zoned dry sprinkler system will be provided for the production area, wellhead area, and safety equipment room. Figure 5.9-1 shows the firewater distribution system.
Process vessels will be fitted with exterior spray nozzles connected to the firewater header system. The firewater system will be divided into zones, with only the actively detected zone being deluged with water. Activation of the zone deluge will be automatic (as well as manual), however a minimum of two detectors will be activated for automatic deluge to occur.

5.9.1.3 Aqueous Film-forming Foam System

The aqueous film-forming foam (AFFF) system will be capable of injecting foam into the firewater sprinkler system. Figure 5.9-1 shows the integration of the AFFF system with the firewater distribution system.

An AFFF package consisting of primary and secondary 1.3 m³ foam tanks and a foam pump will inject foam into the sprinkler system in the production and wellhead areas. Two strategically located monitor foam systems with a foam tank capacity of 1.3 m³ each will also be provided for the production area. The AFFF will be manually introduced into the firewater deluge system by remote manual operation of a foam additive valve.

5.9.1.4 Halon Systems

The existing halon system will be extended to include halon protection of the MCC module, the switchgear module, and the control room module. The system for each area will be operated by the activation of any two fire detectors. When the halon system is activated, prior to discharge, all appropriate ventilation equipment will be shut down, ventilation dampers closed, and a 20-second pre-discharge audible warning alarm sounded. Figure 5.9-2 shows the halon system.
# HALON SYSTEM

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>ITEM NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCTION CONTROL ROOM</td>
<td>V-1001</td>
</tr>
<tr>
<td>INSTRUMENT EQUIP. ROOM</td>
<td>V-1002</td>
</tr>
<tr>
<td>BATTERY ROOM</td>
<td>V-1003</td>
</tr>
<tr>
<td>MCC ROOM</td>
<td>V-1004 A, B</td>
</tr>
</tbody>
</table>

**Figure 5.9-2**
Emergency Shutdown Systems

The safety valves of the wells will be interconnected with production control and safety monitoring systems to shut in when specific abnormal conditions occur. Two methods are available for shutting in the well: activation of the upper master valve on the tree, or activation of the hydraulically operated, fail-closed subsurface safety valve. The high degree of redundancy provided for shutting in each well ensures that well control will be maintained at all times.

The flowline interconnecting the Cohasset production facility and Panuke will be equipped with flowline isolating valves, which will close upon detection of specific abnormal conditions of flowline or production facilities operation, or the activation of safety systems devices. If required, the subsea flowlines will also be depressurized through the flare system.

Emergency Power Systems

Emergency power will be obtained from systems existing on the jack-up drilling and production unit.

An uninterruptable power supply (UPS) inverter and battery system will be installed to supply power to critical safety controls.

Communication Systems

The existing communications equipment on the jack-up unit will be used during all project operations. Although the specific jack-up unit has not been selected, all jack-up units considered will have emergency radios and transceivers, homing beacons, aircraft transceivers, and portable radio equipment.
5.9.1.8 **Life-Saving Appliances**

The selected jack-up unit will have an existing survival system. The jack-up units considered will be equipped with fully certified, enclosed escape capsules capable of evacuating 200 percent of persons onboard.

5.9.2 **STORAGE TANKER AND SHUTTLE TANKER SAFETY SYSTEMS**

The storage tanker and shuttle tanker safety systems will include the following:

- fire detection system
- firewater system
- aqueous film-forming foam system
- CO₂ system
- emergency shutdown system
- emergency power system
- communication systems
- life-saving appliances
- first aid and medical facilities
- emergency locker outfits

5.9.2.1 **Fire Detection**

Equipment will be provided to detect and warn of any outbreak of fire in the machinery spaces or the accommodation. Detector heads will be provided at all levels in the machinery spaces and galley, public rooms, and accommodation alleyways.

A mimic diagram showing the location of the various groups of detectors will be located in the wheelhouse.

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5.9.2.2 Firewater System

The firefighting equipment installed in the vessels will comply with the International Maritime Organization (IMO) requirements, the rules of the appropriate certifying society, and the regulatory authority's requirements. The system is described in the following paragraphs.

A fire main with hose reels will be provided in the engine room space and on deck. Typical hydrant distribution will be as follows:

- main deck monitors and spray curtain systems
- 9 hydrants in the machinery space
- 8 hydrants along the upper deck
- 13 hydrants on other exposed decks
- 16 hydrants in accommodation spaces, aft stores and pumproom
- hoses, nozzles and fog adaptors

Two hoses and nozzles will be stowed in the pump room access, and two in the access to the forward stores. Specific numbers and locations will depend on the selected vessels.

5.9.2.3 Aqueous Film-Forming Foam System

The main foam system will consist of seawater pumps forward and aft, foam compound proportionating units, and a distribution system on deck. The system will employ 10 monitors with a capacity of 2000 l/min, arranged to ensure that at least two foam monitors can be brought to bear on any spot of the cargo deck area.

The foam pump will be fitted into the machinery space. The foam compound proportionating unit will include two tanks, each containing sufficient foam compound to allow 20 minutes operation of at least two monitors simultaneously.
The forward tank will contain sufficient foam compound for operating at least one monitor for 30 minutes. The combined output of the aft and forward systems will be capable of covering the whole deck with a 50 mm foam blanket in 15 minutes.

Four portable applicators and flexible hoses will be stored forward and in a suitable space in the accommodation.

A pressurized mechanical foam fire system of the pre-mixed type will protect the pump room and engine room space, and act as an alternative source of foam for the main system. This system will be operable from outside the pump room entrance and from the wheelhouse.

The engine room will have a minimum of four hose connections with two sets of flexible hoses and portable applicators. A fixed spreader nozzle system will be installed to protect the main and auxiliary boiler firing platforms and bilges, the oil fuel service system, and the purifier room. Control valves will be operated from the wheelhouse and from the main deck outside the engine room.

5.9.2.4 Carbon Dioxide System

A CO₂ total flooding system will protect the main machinery spaces and cargo pumproom. The controls will be in locked boxes outside the spaces protected. Two independent actions will be required to release the gas to the space concerned.

5.9.2.5 Emergency Shutdown Systems

A number of emergency shutdown devices will be arranged to allow critical systems to be shut down if they pose a danger to the personnel, the ship, or the environment.
Shutdown of the condensate loading system will be possible from the cargo control room on both vessels, from the manifold and from the bow mooring station on the storage vessel, from the bow manifold on the shuttle vessel, or from the production facility on the jack-up.

The condensate loading line can be disconnected immediately by releasing the "quick disconnect" coupling, which attaches the hose to the shipboard manifold on both vessels. Disconnection of the forward mooring hawser can be achieved by releasing the "quick disconnect" coupling that attaches the hawser to the storage vessel. The aft mooring hawser can be disconnected by releasing the "quick disconnect" coupling that attaches the hawser to the shuttle vessel.

The cargo pumps can be stopped immediately from several locations:

- cargo control room
- pump room
- aft discharge station
- shuttle tanker loading station

5.9.2.6 Emergency Power System

Emergency power will be required on each vessel to meet the power demands of those systems that must continue to function during a blackout of the main electric power generating plant. The emergency power generator and associated systems are described in the following paragraphs.

The emergency generator will comprise a diesel engine of the turbo charged type, suitable for direct coupling to a generator of the constant voltage, compounded, self-regulating type of simple and compact design. The cooling and lubricating systems will be completely self-contained with a heater fitted in the jacket.
Starting will be automatic on failure of the 440 V normal supply system. A starting air receiver will be provided, of sufficient capacity for a continuous start of 3 minutes duration. Starting and running the engine will be completely independent of any electrical supply.

The combined bedplate of the emergency generator set will be resiliently mounted and will be located outside the machinery spaces in a compartment above the main deck.

The 440 V emergency supply system will supply all users connected to the 440 V switchboards, which will have busbars directly coupled to the emergency supply switchboard.

In the event of a failure of the 440 V normal supply system switchboard, or a voltage drop to 350 V, the "Normal Supply" circuit breaker will trip out and actuate the automatic starting equipment of the emergency generator, which will then supply the emergency switchboard. A 220 V emergency supply system will supply all users connected to the 220 V emergency supply switchboard.

An emergency lighting system will be installed at the aft end of the storage tanker. It will switch on automatically if the 220 V normal supply system fails and will operate for a period of at least 30 minutes. The system will include the following:

- Tungsten lamp fittings supplied from the 48 V DC extra low power system in the emergency generator room and in the escape trunks and passageways leading from the machinery spaces to the deck

- Sixteen independent battery lamps, of the fixed and portable type, in the machinery spaces and engine control room
An emergency lighting system will be installed at the forward end. It will switch on automatically on failure of the 220 V normal supply system and will operate for a period of at least 30 minutes. The system will include the following:

- Self-contained mains and battery-operated lighting fittings in the forward spaces
- A watertight spotlight fitting on a swivel mounting near each liferaft for preparation, clearing, and embarkation purposes

5.9.2.7 Communication Systems

The storage vessel and shuttle vessel will be equipped with communication systems that comply with regulatory and operational requirements.

Equipment for the main radio station will be consist of the following:

- A very high frequency (VHF) radio telephone with a remote unit for the wheelhouse and portable handsets and socket connections for the bridge wings
- A medium and high frequency (MF and HF) transmitter and receiver including a radio telephone with remote handsets for the master's office and a telephone booth in the radio room
- A radio telephone and automatic telephone linking unit
- A reserve transmitter and receiver
- An auto keying unit
- An auto alarm

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- A direction finder

- Aerials arrays

- Portable radio equipment for use in a lifeboat and stored in the wheelhouse

An amplified "talk back" system will give channels of communication from the wheelhouse and each bridge wing to the foredeck and poop area and will consist of the following:

- Two microphone-speaker units located in the wheelhouse, one near the steering stand, the other near the engine order telegraph. These units will operate only when the wheelhouse is selected from either bridge wing.

- For the foredeck, three watertight microphone-speaker units will be provided. Each unit will have an "Emergency Speak" pushbutton giving immediate communication with the wheelhouse and bridge wings, overriding any other selected channel.

- For the poop, two permanently fixed watertight microphone-speaker units will be provided. Each unit will have an "Emergency Speak" pushbutton giving immediate communication with the wheelhouse and bridge wings, overriding any other selected channel.

An automatic dial telephone system and a system of sound-powered telephones will allow communication between all areas of the ship. The power supply for the systems will be taken from the 220 V emergency supply or the 48 V DC extra low power supply.

An amplified talk-back system will be provided to give channels of communication from the machinery control console to points in the machinery spaces.
A public address system will be provided with the following features:

- All radio receiver signals and taped recordings will be amplified and broadcast via speakers in the public room, cabins, and galley.

- Recording on tape from the receiver or microphone.

- Broadcasting to all speakers of announcements via the wheelhouse microphone will override all volume controls.

- Broadcasting by speakers in all public rooms, alleyways, and galley will override all volume controls.

5.9.2.8 Life-Saving Appliances

The life-saving appliances will include those items normally found onboard oil tankers and will comply with all IMO and regulating authority requirements. The following will be included:

- One fully enclosed lifeboat of glass-fibre construction, fitted on each side of the vessel with air-cooled diesel engines of sufficient power to give a speed of 6 knots when the boat is fully loaded. Each lifeboat will be capable of taking all personnel for whom berths are provided, plus 10 extra. The lifeboats will be supported in gravity type davits controlled by manually operated mechanical winches.

- Inflatable liferafts on each side of the ship

- Eight lifebuoys fitted in two racks, one on each side of the bridge (with water lights and smoke floats)
- Portable fire extinguishers throughout the accommodation, forward spaces, and machinery spaces

- Two lockers for safety equipment such as smoke helmets, breathing apparatus, protective clothing, and rescue gear

5.9.3

SAFETY PROGRAMS

Section 11 contains a summary of the proposed safety plan. Details of the plan will be finalized during the detailed design phase.

5.9.4

SAFETY INSPECTIONS

A regular inspection and maintenance program will cover major equipment disassembly and inspection or replacement of equipment internals. This type of program will be based on three criteria:

- The manufacturer's recommendations for expected life of equipment

- The results of monitoring in the preventive maintenance program (described in Section 5.10)

- The certification inspection requirements

Flowline surveillance, nondestructive testing, routine inspection of the producing facilities, and inspection of subsea structures and flowlines will be done by underwater inspection contractors.

5.9.5

ACCIDENT REPORTING AND INVESTIGATION

The operator's and contractors' policies will comply with Transport Canada, Canadian Coast Guard, and Department of Energy requirements. Specific procedures will be provided at a later date.

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5.9.6 PERSONNEL TRAINING

This section discusses training of personnel required for the drilling, production, and crude exporting operations.

5.9.6.1 Drilling Operations Training

The drilling contractor selected for the project will be an established contractor with extensive offshore drilling experience using a jack-up drilling unit. Canadian personnel will have had east coast offshore drilling experience. Courses and practical training for jack-up drilling operations will be implemented by the operator and drilling contractor.

5.9.6.2 Production Facility Personnel Training

Offshore production personnel assigned to the Cohasset/Panuke Development Project will be selected first on production experience, second on offshore experience, and third on jack-up experience. The operator will sponsor and promote courses and practical training in these areas in which the candidate is weak or requires re-training.

5.9.6.3 Storage Vessel and Shuttle Tanker Personnel Training

The training and qualification requirements for the crews of all Canadian registered ships are regulated by the Canada Shipping Act, which is administered by the Canadian Coast Guard, Ship Safety Branch. The current regulations make no reference to vessels that are engaged in offshore operations, and no additional training or qualification requirements have been specified.

Training will be required for personnel involved in activities that may be outside the experience of conventionally trained oil tanker personnel. Courses and practical training for offshore and at-sea
loading procedures will be implemented by the operator and the tanker contractors.

5.10

PRODUCTION OPERATIONS AND MAINTENANCE

This section describes the personnel and services required during the operational phase of the project.

5.10.1

OVERVIEW

The production facilities will be operated to optimize production and maintain maximum safety standards to prevent injury to personnel, contamination of the environment, and damage to equipment.

The production facilities and wells will be attended with 24-hour supervision. The day and night shifts will include supervisory, operating, and maintenance staff. While the Panuke jacket will be remotely operated, 24-hour continuous monitoring of all wellhead parameters will take place. Physical intervention will be possible as necessary for safe operations.

In order to ensure satisfactory and safe performance of the facilities, there will be a preventive maintenance program consisting of regular checks and equipment monitoring. The program will involve periodic visual checks of equipment, monitoring of operational parameters, and vibration monitoring.

Turnarounds will be scheduled during the months of suspended operations in the winter. Remedial maintenance of offshore facilities will be done on location except when the nature of the task precludes this. Defective offshore components will be replaced from the onshore supply base.
5.10.2 RECORDS AND REPORTING

This section discusses reporting and record-keeping procedures, and production, operation, and safety manuals.

5.10.2.1 Reporting Procedures

All hydrocarbons producing operations require a number of periodic reports to be submitted to various regulatory agencies that monitor conservation practices and ensure efficient use of the resources. The following is a partial list of these reports:

- Production
- Well Completion
- Drilling Status
- Workover Status
- Accident and Incident
- Condensate Spills
- Ship, Air, and Radio Traffic
- Inspection and Testing

5.10.2.2 Manuals

To ensure that the production operators are fully familiar with the design basis for the facilities and related equipment, a series of manuals will be prepared during the design period. The following is a partial list of these manuals:

- Operating
- Maintenance
- Safety
- Contingency Plan
- Emergency Response Plan

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5.10.3 LOGISTICS

An onshore supply and support base will be selected within mainland Nova Scotia. Specific plans will be made available later.

5.10.3.1 Drilling Operations

During drilling operations, approximately 65 persons will be offshore at any one time, and drilling consumables (mud, cement, casing, and bits) will be used at a rapid rate. Two supply boats and one standby-safety vessel will be on a full-time contract, with frequent helicopter support.

5.10.3.2 Producing Operations

During producing operations, approximately 30 persons will be offshore at any one time, and consumables will be used at a much slower rate. One supply boat will be used on an intermittent basis, and helicopter flights will be scheduled as required. One standby-safety vessel would be on location at all times.

5.10.4 MANPOWER LEVELS

This section discusses the manpower for operation of the jack-up drilling and production unit, storage tanker, and shuttle tanker.

5.10.4.1 Jack-Up Drilling and Production Unit

The personnel required for operation of the jack-up drilling and production unit can be divided into the following three categories:

- Drilling personnel
- Production personnel
- Shorebase operations personnel
Drilling Personnel Requirements

Drilling operations will require a rig crew of 32 persons plus marine, catering, and service company personnel on the jack-up unit at any one time, for a total of approximately 65 persons. Table 5.10-1 summarizes a typical list of rig crew personnel.

**TABLE 5.10-1**

**DRILLING PERSONNEL REQUIREMENTS**

<table>
<thead>
<tr>
<th>Classification</th>
<th>On Rig</th>
<th>On Shore</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resident Manager</td>
<td>As required</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rig Superintendent</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Tool Pusher</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Electrician</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mechanic</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Barge Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Welder</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Roustabout Foreman/Operator</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Driller</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Assistant Driller</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Derrickman</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Engineman</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Floorman</td>
<td>6</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Mudwatcher/Pumpman</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Roustabout</td>
<td>8</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Radio/Clerk</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

**Total**                                | 32     | 33       | 65    |

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Production Personnel Requirements

Production operations will require 21 persons plus marine, catering and service company personnel, for a total of approximately 30 persons. Table 5.10-2 summarizes the production operations personnel.

**TABLE 5.10-2**

**PRODUCTION PERSONNEL REQUIREMENTS**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number of Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On Rig</td>
</tr>
<tr>
<td>Supervisor</td>
<td>1</td>
</tr>
<tr>
<td>Superv. or Sr. Operator</td>
<td>1</td>
</tr>
<tr>
<td>Prod. or Proc. Operator</td>
<td>5</td>
</tr>
<tr>
<td>Radio Operator Clerk</td>
<td>2</td>
</tr>
<tr>
<td>with first aid training</td>
<td></td>
</tr>
<tr>
<td>Crane Operator</td>
<td>1</td>
</tr>
<tr>
<td>Deck Roustabout</td>
<td>4</td>
</tr>
<tr>
<td>Mechanic</td>
<td>2</td>
</tr>
<tr>
<td>Inst. Technician</td>
<td>2</td>
</tr>
<tr>
<td>Elec. Technician</td>
<td>2</td>
</tr>
<tr>
<td>Telecom. Tech</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21</strong></td>
</tr>
</tbody>
</table>

Shorebase Operations Personnel Requirements

For production and drilling operations, a shorebase staff of about three people will be required. Table 5.10-3 summarizes the required shorebase operations personnel.
TABLE 5.10-3
SHOREBASE OPERATIONS PERSONNEL REQUIREMENTS

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number of Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Manager</td>
<td>1</td>
</tr>
<tr>
<td>Secretary</td>
<td>1</td>
</tr>
<tr>
<td>Logistics Supervisor</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

(plus contracted services)

5.10.4.2 Storage Tanker

The storage tanker will require a crew of approximately 13 persons to operate. Table 5.10-4 summarizes typical crew requirements of a storage vessel.

TABLE 5.10-4
STORAGE TANKER PERSONNEL REQUIREMENTS

<table>
<thead>
<tr>
<th>Classification</th>
<th>On Vessel</th>
<th>On Shore</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captain</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Chief Officer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2nd Officer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Chief Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2nd Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3rd Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cook</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Messman</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Leading Seaman</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ratings</td>
<td>4</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
<td><strong>13</strong></td>
<td><strong>26</strong></td>
</tr>
</tbody>
</table>

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5.10.4.3 Shuttle Tanker

The shuttle tanker will require a crew of approximately 26 persons to operate. Table 5.10-5 summarizes typical crew requirements of a shuttle tanker.

<table>
<thead>
<tr>
<th>Classification</th>
<th>On Vessel</th>
<th>On Shore</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captain</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Chief Officer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2nd Officer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3rd Officer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Chief Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2nd Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3rd Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4th Engineer</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Electrician</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cook</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Leading Seaman</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ratings</td>
<td>15</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>26</td>
<td>52</td>
</tr>
</tbody>
</table>

5.10.4.4 Contract Personnel Requirements

The following contractor services are expected during normal operations:

- Air transportation
- Marine transportation
- Catering offshore
- Painting offshore
- Laboratory analyses
- Environmental monitoring, weather forecasting
- Communications equipment servicing
- Diving
- Specialized machinery and valve servicing
- Flowline inspection
- Well servicing

5.11 DESIGN CRITERIA

This section discusses the structural, producing, crude storage and transportation design parameters, and product specifications.

5.11.1 STRUCTURES

The structural design criteria for the well jackets and the jack-up drilling and production unit are discussed in this section.

5.11.1.1 Well Jackets

In order to conduct a preliminary design analysis to determine the configuration, weight estimate, and cost of a steel piled well jacket, a preliminary list of design criteria was prepared. These environmental criteria are summarized in Table 5.11-1. The functional criteria are summarized in Table 5.11-2.

5.11.1.2 Jack-Up Drilling and Production Unit

In order to act as a stable facilities support platform, a jack-up drilling unit must satisfy the following criteria:

- The drilling unit must be equipped with adequate leg length and strength to withstand the design storm (once per 100-year return interval) at the Cohasset location.
### TABLE 5.11-1
**WELL JACKET ENVIRONMENTAL DESIGN CRITERIA**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Cohasset</th>
<th>Panuke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water depth</td>
<td>m</td>
<td>37</td>
<td>47</td>
</tr>
<tr>
<td>Design wave height</td>
<td>m</td>
<td>24.4</td>
<td>26.8</td>
</tr>
<tr>
<td>Associated period</td>
<td>s</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Design wind speed</td>
<td>km/h</td>
<td>154</td>
<td>154</td>
</tr>
<tr>
<td>Design surface current</td>
<td>cm/s</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Water levels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Crest elevation</td>
<td>m</td>
<td>18.5</td>
<td>20.4</td>
</tr>
<tr>
<td>- Astro tide</td>
<td>m</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>- Storm tide</td>
<td>m</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>- Air gap</td>
<td>m</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Seafloor conditions</td>
<td></td>
<td>Sand</td>
<td>Sand</td>
</tr>
</tbody>
</table>

### TABLE 5.11-2
**WELL JACKET FUNCTIONAL DESIGN CRITERIA**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cohasset</th>
<th>Panuke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of wells</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Size of conductor (mm)</td>
<td>762</td>
<td>762</td>
</tr>
<tr>
<td>Boat landing</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Helideck</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Deck crane</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Deck facilities</td>
<td>Manifold</td>
<td>Manifold</td>
</tr>
<tr>
<td>Size of flowline risers (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Offloading</td>
<td>114</td>
<td>-</td>
</tr>
<tr>
<td>- Injection to Panuke</td>
<td>168</td>
<td>168</td>
</tr>
<tr>
<td>- Production from Panuke</td>
<td>219</td>
<td>219</td>
</tr>
</tbody>
</table>

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- The unit must contain adequate deck area and variable deck load capacity to support all of the proposed production facilities while, at the same time, conducting drilling activities and/or workover operations.

- The available pre-load capacity must be sufficient to ensure that the maximum spud can reaction anticipated during the design storm can be duplicated during pre-load procedures.

- The drilling unit must be available for a long-term contract during the period from 1991 through 1997.

- The drilling unit must be capable of being certified by Canadian authorities for long-term use at the Cohasset location, considering the water depth, design storm parameters, and the foundation conditions.

5.11.2 Production Facilities

The design criteria used to develop the facilities for the selected production system are summarized in Table 5.11-3.

5.11.3 Subsea Flowlines

The interfield flowline design parameters are summarized in Table 5.11-4. The condensate transfer flowline and dynamic riser design parameters are summarized in Table 5.11-5.

5.11.4 CONDENSATE STORAGE AND EXPORT SYSTEM

This section discusses the CALM system, storage tanker, and shuttle tanker design parameters.
### TABLE 5.11-3

PRODUCTION FACILITIES DESIGN CRITERIA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panuke</td>
</tr>
<tr>
<td><strong>Well Requirements</strong></td>
<td></td>
</tr>
<tr>
<td>Production wells</td>
<td>3</td>
</tr>
<tr>
<td>Water injection wells</td>
<td>1</td>
</tr>
<tr>
<td><strong>Wellhead Conditions</strong></td>
<td></td>
</tr>
<tr>
<td>Max. wellhead pressure (kPa)</td>
<td>2760</td>
</tr>
<tr>
<td>Min. flowing wellhead pressure (kPa)</td>
<td>2760</td>
</tr>
<tr>
<td>Flowing wellhead temp (°C)</td>
<td>65</td>
</tr>
<tr>
<td>Panuke fluid temp at Cohasset (°C)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Design Rates</strong></td>
<td></td>
</tr>
<tr>
<td>Condensate (m³/d)</td>
<td>1590</td>
</tr>
<tr>
<td>Produced water (m³/d)</td>
<td>1590</td>
</tr>
<tr>
<td>Produced fluid (m³/d)</td>
<td>3180</td>
</tr>
<tr>
<td>GCR (m³/m³)</td>
<td>14.2-19.6</td>
</tr>
<tr>
<td><strong>Well Stream Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Stabilized condensate specific gravity (API)</td>
<td>51</td>
</tr>
<tr>
<td>Sand production</td>
<td>Minimal</td>
</tr>
<tr>
<td>Emulsion and foaming tendency</td>
<td>Minimal</td>
</tr>
<tr>
<td>Wax content (wt %)</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>Produced Water</strong></td>
<td></td>
</tr>
<tr>
<td>Produced water condensate remnant (mg/L)</td>
<td></td>
</tr>
<tr>
<td><strong>Condensate Product Export</strong></td>
<td></td>
</tr>
<tr>
<td>BS &amp; W (%)</td>
<td></td>
</tr>
<tr>
<td>Reid vapour pressure (kPa)</td>
<td></td>
</tr>
</tbody>
</table>

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### TABLE 5.11-3
PRODUCTION FACILITIES DESIGN CRITERIA
(cont'd)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panuke</td>
</tr>
<tr>
<td>Injection Water</td>
<td></td>
</tr>
<tr>
<td>Design rate (m³/d)</td>
<td>3180</td>
</tr>
<tr>
<td>Design pressure (MPa)</td>
<td>13.8</td>
</tr>
<tr>
<td>Production Separator*</td>
<td></td>
</tr>
<tr>
<td>Design Criteria</td>
<td></td>
</tr>
<tr>
<td>Stage 1 retention time (min.)</td>
<td>-</td>
</tr>
<tr>
<td>Stage 2 retention time (min.)</td>
<td>-</td>
</tr>
<tr>
<td>Test retention time (min.)</td>
<td>-</td>
</tr>
<tr>
<td>Product Transfer Equipment</td>
<td></td>
</tr>
<tr>
<td>Design Criteria</td>
<td></td>
</tr>
<tr>
<td>Condensate transfer pumps and metering</td>
<td>-</td>
</tr>
<tr>
<td>Injection Water Equipment</td>
<td></td>
</tr>
<tr>
<td>Design Criteria</td>
<td></td>
</tr>
<tr>
<td>Deaerator O₂ content</td>
<td>-</td>
</tr>
<tr>
<td>Injection water pumps</td>
<td>-</td>
</tr>
<tr>
<td>Power Generation Equipment</td>
<td></td>
</tr>
<tr>
<td>Design Criteria</td>
<td></td>
</tr>
<tr>
<td>Emergency power generation</td>
<td>-</td>
</tr>
<tr>
<td>Primary power generation</td>
<td>-</td>
</tr>
<tr>
<td>Artificial Lift</td>
<td></td>
</tr>
<tr>
<td>Pump type</td>
<td>-</td>
</tr>
<tr>
<td>Gas Disposal</td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>-</td>
</tr>
</tbody>
</table>

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### TABLE 5.11-3
**PRODUCTION FACILITIES DESIGN CRITERIA**
*(cont'd)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panuke</td>
</tr>
<tr>
<td><strong>Seawater Life</strong></td>
<td></td>
</tr>
<tr>
<td>Seawater lift pumps</td>
<td>-</td>
</tr>
<tr>
<td><strong>Environmental Design Criteria</strong></td>
<td></td>
</tr>
<tr>
<td>Water depth (m)</td>
<td>47</td>
</tr>
<tr>
<td>Maximum wave height (m)</td>
<td>25.8</td>
</tr>
<tr>
<td>Max - Ambient air temp (°C)</td>
<td>24</td>
</tr>
<tr>
<td>Min - Ambient air temp (°C)</td>
<td>-10</td>
</tr>
</tbody>
</table>

* Separator sizing assumes 50 percent liquid level.

### TABLE 5.11-4
**INTERFIELD FLOWLINE DESIGN CRITERIA**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production Flowline</strong></td>
<td></td>
</tr>
<tr>
<td>- Maximum pressure (kPa)</td>
<td>2760</td>
</tr>
<tr>
<td>- Maximum temperature (°C)</td>
<td>65</td>
</tr>
<tr>
<td>- Fluid rate (m³/d)</td>
<td>3180</td>
</tr>
<tr>
<td><strong>Water Injection Line</strong></td>
<td></td>
</tr>
<tr>
<td>- Maximum pressure (MPa)</td>
<td>13.8</td>
</tr>
<tr>
<td>- Water rate (m³/d)</td>
<td>3180</td>
</tr>
</tbody>
</table>

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TABLE 5.11-5
CONDENSATE TRANSFER FLOWLINE AND RISER
DESIGN CRITERIA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowrate (m³/d)</td>
<td>4770</td>
</tr>
<tr>
<td>(degassed, dewatered condensate)</td>
<td></td>
</tr>
<tr>
<td>Minimum allowable outlet pressure at top of riser (kPa)</td>
<td>670</td>
</tr>
<tr>
<td>Distance from Cohasset to SPFM* (m)</td>
<td>2000 ±</td>
</tr>
<tr>
<td>Water conditions</td>
<td></td>
</tr>
<tr>
<td>- Approximate depth (m)</td>
<td>39</td>
</tr>
<tr>
<td>- Temperature (°C)</td>
<td>3 to 5</td>
</tr>
<tr>
<td>- Significant wave height (m)</td>
<td>4.5</td>
</tr>
<tr>
<td>(during operating season)</td>
<td></td>
</tr>
<tr>
<td>- 100-year wave height (m)</td>
<td>24.4</td>
</tr>
<tr>
<td>- Surface current (cm/s)</td>
<td>150</td>
</tr>
<tr>
<td>Bottom conditions</td>
<td></td>
</tr>
<tr>
<td>- Depth of glacial sand (m)</td>
<td>9.2</td>
</tr>
</tbody>
</table>

* Single point mooring
5.11.4.1 CALM System

The mooring system will be designed to meet the following criteria:

- 100 year survival storm (no vessel moored)
  - 24.4 maximum wave
  - 150 cm/s current
  - 154 km/h maximum wind speed

- Operations (vessel moored)
  - 7.6 m significant waves
  - 150 cm/s current
  - 93 km/h wind speed

5.11.4.2 Storage Tanker

The storage tanker will have the following design criteria:

- Cargo capacity to be determined

- Segregated ballast capacity to satisfy the MARPOL minimum draft (protectively located)

- Bow mooring equipment for retrieval and connection of the mooring hawser

- Mooring equipment for the mooring of a shuttle tanker to the stern

- Condensate loading equipment for the retrieval and connection of the hose string

- Cargo pumping capacity of approximately 6000 t/h

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5.11.4.3 Shuttle Tanker

The shuttle tanker will have the following design criteria:

- Cargo capacity to be determined

- Segregated ballast capacity to satisfy the MARPOL minimum draft (protectively located)

- Bow mooring equipment for retrieval and connection of the mooring hawser

- Condensate loading equipment for the retrieval and connection of the hose string

- Cargo pumping capacity of approximately 4000 t/h

- Cargo characteristics
  - Reid vapour pressure of 75-90 kPa
  - Water content of 3-5%
  - API gravity of 51°C
  - Viscosity @15°C of 0.74 cP
5.12 REGULATIONS, CODES, AND CERTIFICATION

This section will discuss the following:

- Approval process
- Certifying authority
- Regulations, codes, and standards

5.12.1 APPROVAL PROCESS

Section 10 describes, in detail, the Certification Plan.

5.12.2 CERTIFYING AUTHORITY

The Canada Oil and Gas Production Installation Regulations require that a certifying authority (CA) be employed to independently assess the compliance of the production facilities and structures with the regulations. The CA will assess design, methods of construction, transportation, and installation methods and will provide material and construction inspections. "Certificates of Fitness" will be issued by the CA when it is satisfied that the requirements as outlined in the regulations have been met. The certificates will be issued prior to the application to CNSOPB for the final production operations approval. Section 10, Certification Plan, contains additional detail.

5.12.3 REGULATIONS, CODES, AND STANDARDS

The design of the production facilities will be governed by the regulations, codes, and standards described in the sections that follow.

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5.12.3.1 Structures

The applicable regulations for the structural design and construction of offshore platforms are the Canada Oil and Gas Production Installation Regulations.

Detailed analysis of the well jackets was performed to AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, Latest Edition. Unless otherwise indicated in this design criteria or in the AISC specifications, the design principles and procedures applied for these structures comply with API RP 2A, Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms, Latest Edition. The design will be checked against the preliminary standards S471, S472 and S473, parts I, II and II of the new Canadian Code for The Design, Construction and Installation of Fixed Offshore Production Structures.

Secondary structures such as modules, decks, and walkways will also be designed in accordance to these codes and standards.

5.12.3.2 Production Facilities

The design and construction of the production-process facilities will be governed by the Canada Oil and Gas Production Installation Regulations. The following major standards will be used in the design and construction of the facilities:

- API RP 2G for Facilities Design
- API RP 14C, API 520, API 521, and API RP 14 G for Safety Systems
- CSA B-51 for Pressure Vessels
- ANSI B31.3, and API RP 14E for Piping
- API RP 14F, and API RP 500B for Electrical Systems
5.12.3.3 Subsea Flowlines

The interfield flowline from Panuke to the Cohasset facilities and the condensate export line from the facilities to the CAIM will be designed and constructed in accordance with the Canada Oil and Gas Production Installation Regulations. The following major standards will be used for design and construction:

- API RP 17B
- API RP 14H
- CSA CAN3-Z183-M86

5.12.4 Condensate Storage and Export System

The condensate storage vessel and shuttle tanker will meet Lloyd's classifications or equivalent under the designation of +100Al oil tanker, IMC, UMS, IGS and will comply with the regulations of:

- Canada Shipping Act
- SOLAS 1974/1978
- MARPOL 1973/1978
- International Load Line Conventions, 1974
- International Regulations for Prevention of Collision at Sea, 1972
- TERMPOL Code, Second Edition, 10/83

The design and construction of the CAIM system will comply with Canada Shipping Act regulations. The following major standards will be used for design and construction:

- API RP 2M
- API BULL-25-88
- API SPEC 2F
- TERMPOL Code, Second Edition, 10/83

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SECTION 6. METEOROLOGY AND OCEANOGRAPHY

6.1

INTRODUCTION

Average and extreme meteorological and oceanographic variables are required to determine appropriate design loads and establish reasonable operational constraints. Environmental data sets of continuous measurements are not available. Historical marine weather observations reported by ships travelling through the area of interest are useful in establishing basic climatological statistics, but are unsuitable for predicting extreme events. With a relatively long-time series of measurements available, extremal analyses were carried out to establish the most severe conditions likely to occur over a given design period.

The type and quality of information provided by each source is described in Section 6.1.1.

6.1.1

DATA SOURCES

This section will review the data sources categorized as follows:

- Marine Climatology Data Base
- Ocean Data Gathering Program
- U.S. Navy Spectral Ocean Wave Model
- U.S. Army Waterways Experiment Station
- Geostrophic Wind Climatology
- Marine Environment Data Service
- Bedford Institute of Oceanography
- Other Sources

6.1.1.1

Marine Climatological Database

The principal sources of meteorological data are the historical ship and rig observations archived in the Atmospheric Environment Service (AES) marine climatological database. The database consists
of marine weather observations collected by itinerant ships and exploratory drilling rigs. All information is forwarded to AES for archiving, and data sets are subjected to standardized quality control checks prior to incorporation into the database. The Marine Statistics (MAST) and Duration Statistics (DUST) software packages developed by AES were used to derive various climatological statistics within the area of interest (42°45'N-45°00'N; 59°00'W-63°00'W).

While this database is commonly used to describe the marine climate within a designated region, the data products produced by MAST and DUST are used with caution. Ship observations archived in the database tend to be concentrated along the main shipping routes or within major fishing areas. This inherent bias in the data set will result in inadequate spatial or temporal coverage in certain areas. In addition, wave and swell height, period and direction statistics are derived from visual observations rather than instrument measurements. Although rigorous quality control procedures are applied to all variables stored in the database, visual archived wave data are considered inappropriate for estimating extreme wave conditions.

6.1.1.2 Ocean Data Gathering Program Hindcasts

The Ocean Data Gathering Program (ODGP) database was created from the analysis cycle of the real-time operation of the ODGP ocean wave model over a 3-year period (1983-1986). This model was evolved from the U.S. Navy Spectral Ocean Wave Model (SOWM) and has been described in Eid and Cardone (1987) and MacLaren Plansearch (1985). The database consists of fully directional spectral wave data and gridded wind velocities at 54 grid point locations off the east coast of Canada. The database covers the period from October 1, 1983 to September 30, 1986. Winds were obtained from sea level pressure analysis fields derived in a man-machine procedure.
Recent studies have shown that ODGP wave predictions are significantly more accurate than those generated by other long-term hindcast services (Eid 1989).

Although the existing ODGP time series is relatively short, it represents a fairly energetic 3 years with a large number of severe storm events. The database is a valuable source of information because it provides directional spectral wave information. No other database presently available provides these wave products. Mean monthly wave information was based on data from the nearest grid point (#3950) located south of Sable Island. This data set was considered to be the most appropriate source for establishing the wave climatology at the Cohasset and Panuke sites.

Under a current contract with AES which is funded by the Federal Panel on Energy Research and Development (PERD), MacIaren Plansearch has compiled wind and wave data from over 300 individual storms that tracked across the Scotian Shelf. The criterion for the selection of these storms was their potential for generating large waves. The top 50 most severe storms on the east coast were selected and hindcast using the ODGP model (Swail 1989). Preliminary extremal analysis of the hindcast data was carried out for the Cohasset-Panuke site using the top 30 storms. These values were fitted to a Gumbel distribution for prediction of long-term design wave height (i.e., twenty 100-year return periods). Extreme wind speeds were determined in a similar manner using the top wind speed events. This PERD data set is considered to represent the most comprehensive source of information for extreme predictions along the east coast of Canada.

The ODGP is a deepwater model, and the data sets represent deepwater conditions that require modification for shallow water effects.
6.1.1.3 U.S. Navy Spectral Ocean Wave Model

The U.S. Navy Spectral Ocean Wave Model (SOWM) database is a 20-year hindcast data set of wind and wave information (Lazanoff and Stevenson 1977). Surface pressure fields between 1956 and 1975 were objectively analyzed by the Fleet Numerical Weather Centre of the U.S. Navy.

The length of the SOWM database together with its relatively few data gaps makes this time series suitable for extreme analysis. However, several limitations inherent in the wave model (Brown 1986) precluded the use of SOWM for wave height predictions in the study area. The deepwater wave model fails to consider the effects of bathymetry on wave growth, particularly in shallow water locations such as Sable Island. SOWM also did not take into account the effect of sea ice on the model predictions. Furthermore, because of the relatively large grid spacing (over 300 km), the Scotian Shelf, and Sable Island area in particular, are poorly represented. Extreme wave height predictions established from this data source are not likely to accurately represent the wave climate in the vicinity of Cohasset and Panuke.

6.1.1.4 U.S. Army Waterways Experiment Station

The Waterways Experiment Station (WES) database uses a discrete spectral model developed by Resio (1981) to produce a wind and wave hindcast time series for 20 years (1958-1975). Wind input consists of surface pressure fields derived by the Fleet Numerical Weather Center.

The WES data set extends continuously from 1956 to 1975, making it suitable for deriving extreme wind speeds and wave heights for various return periods. However, difficulties in defining pressure fields on the Scotian Shelf (Resio 1982) reduce the accuracy of
the model in the vicinity of Sable Island. Wave height predictions
determined by WES may not be considered representative of extreme
conditions likely to occur at the Cohasset-Panuke site.

6.1.1.5 Geostrophic Wind Climatology

The Geostrophic Wind Climatology (GWC) is a hindcast wind speed and
direction database developed by AES (Mendenhall 1978; Hall and
Mendenhall 1971). The GWC data set is based on the 6-hour surface
pressure analyses prepared by Fleet Numerical Weather Center
between 1946 and 1987. Although these data may be considered
appropriate for extreme wind analysis, the database is not commonly
used for design applications.

6.1.1.6 Marine Environmental Data Service

All historical measured wave data (e.g., waverider buoys) are
archived by the Marine Environmental Data Service (MEDS), Ottawa.
Site-specific measurements from the Scotian Shelf are available
from approximately 1970, but individual time series at any one site
are typically of short duration. Most waverider deployments are
not continuous, long-term data sets since data collection typically
coincides with periods of active offshore exploratory drilling.
These data gaps are particularly troublesome for wave duration and
persistence analyses, and extreme wave heights cannot be accurately
determined using such data sets. Moreover waverider buoys do not
measure wave direction.

MEDS is also the federal government agency responsible for
archiving historical temperature and salinity measurements. All
available information was compiled and summarized in order to
describe the monthly water column structures. Although relatively
few discrete measurements were available in the vicinity of
Cohasset and Panuke, data quality is considered excellent.
6.1.1.7 Bedford Institute of Oceanography

All current meter information acquired along the east coast of Canada is archived at the Bedford Institute of Oceanography (BIO). Gregory and Smith (1988) identified individual data sets available from the Scotian Shelf.

6.1.1.8 Other Sources

Site-specific current meter data collected by Petro-Canada Resources at the Cohasset A-52 wellsite in 1986 were acquired and analyzed in further detail. Measured current speeds were compared with the overall ranges derived from Gregory and Smith (1988). Maximum tidal current speeds and tidal heights were calculated based on these wellsite measurements.

Average and maximum current speed and direction statistics derived for Shell Canada Limited for the region south of Sable Island were also accessed. The results of this study (MacLaren Plansearch 1986) were used to establish a representative current profile in the vicinity of the site.

Other sources of information include the following:


- MacLaren Plansearch Limited data archives and environmental reports

- Canadian Climate Centre, AES, Report #84-13 (1983) "Severe Storms Canada's East Coast - A Catalogue Summary for Period 1957 to 1983"

- Canadian Climate Centre, AES, Report #84-14, (1984). "Climatology of the East Coast Marine Areas"
NORMAL CLIMATOLOGICAL SUMMARIES

The normal climatological summary statistics are calculated from the data sources given in Section 6.1.1. The results are presented in the form of tables and graphs. Similar analyses are carried out for both meteorological and sea state data. The Marine Climatological Database at AES was accessed through their MAST and DUST software packages to provide these statistics.

EXTREMAL ANALYSIS

Offshore drilling and production developments require extreme meteorological and oceanographic events to be defined to determine design loads and operational constraints. Accurate specification of historical wind and wave fields is a critical requirement for engineering design of the offshore facilities at the study site. In the absence of sea ice, waves are the dominant load for the offshore structures.

Previous experience with the historical meteorological data base for the Northwest Atlantic Ocean basin supports the selection of storms from the past 30 years. The database for earlier periods is much less extensive, and wind fields may not be specified accurately.

Two methods are commonly used to predict extreme values. The first is to use a long period of continuous record (i.e., 20 years). The measured, or observed, data coverage is limited both to space and to time to provide such a data set. Therefore, hindcasting is the only viable means to provide such a data set. The SOWM and WES 20-year hindcast databases could be ideal for this application; however, due to several limitations these databases are not suitable for the study site.

The second method is to specify extreme wave and wind climate by selecting the most severe storms (i.e., top-ranked wave-producing
storms) and hindcast these through a well-validated model, such as the ODGP spectral model. The recent study supported by PERD and AES was used to provide the extreme design conditions.

The requirements for accurate estimates of the extreme wind speed, wave height, and current speed are as follows:

- Sufficient data to input to an extremal analysis
- Techniques used in describing the population distribution (i.e., Gumbel and Weibull distributions)
- The fitting techniques used, such as linear regression, method of moments, or maximum likelihood

General Description of Extremal Analysis Techniques

The most common approach to predicting long-term design parameters is to use the theory of extreme value statistics. The theory assumes that the data are independent, identically distributed random variables, which do not contain cycles or trends. The Gumbel, Borgman, and Weibull distributions are commonly used in predicting extreme wind and wave values.

\[
\begin{align*}
\text{Gumbel: } & \quad \Pr(X < x) = \exp(-\exp((X - a)/b)) \\
\text{Borgman: } & \quad \Pr(X < x) = \exp(-\exp(X^2 - a)/b)) \\
\text{Weibull: } & \quad \Pr(X < x) = 1 - \exp(-(X - a)/b)^c)
\end{align*}
\]

Before fitting the variables to a distribution, one should remember that the exact distribution is unknown, and that there is no reason to choose one over the other. However, one distribution may fit the data better than another. In most situations, extreme values from a period of 20-30 years are used to predict a maximum wave height or wind speed in a 100-year period (probability of 0.01). Extreme values predicted for periods greater than 30 years are an extrapolation of the distribution curve. The further the
extrapolation of the distribution is extended, the more error is associated with the predicted value.

Fitting the Data

The following method was used to fit the data to the distributions:

- The top 20-30 storm values over a period of 20-30 years were selected.
- The coefficients were calculated by fitting the values to the distributions.

6.2 ENVIRONMENTAL DESIGN CRITERIA

Table 6.2-1 presents the preliminary environmental design criteria for the Panuke location and Table 6.2-2 for the Cohasset location. Preliminary design criteria will be submitted to the Certifying Agency for confirmation and acceptance as final Design Criteria.

6.3 METEOROLOGICAL DATA

This section will discuss the meteorological data categorized as follows:

- Winds
- Precipitation
- Air temperature
- Relative humidity
### TABLE 6.2-1

PANUKE PRELIMINARY ENVIRONMENTAL DESIGN CRITERIA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinates</td>
<td>43°49'00&quot;N, 60°43'30&quot;W</td>
</tr>
<tr>
<td>Water depth (m)</td>
<td>46</td>
</tr>
<tr>
<td>Water depth (m)</td>
<td>46</td>
</tr>
<tr>
<td>Sea surface temperature range (°C)</td>
<td>2.29 to 17.08</td>
</tr>
<tr>
<td>Sea surface salinity range (ppm)</td>
<td>30.84 to 32.39</td>
</tr>
<tr>
<td>Return Period (a)</td>
<td>10  20  50  100</td>
</tr>
<tr>
<td>1-h mean wind speed (knots)</td>
<td>86  90  97  101</td>
</tr>
<tr>
<td>3-s gust wind speed (knots)</td>
<td>118 123 133 138</td>
</tr>
<tr>
<td>Maximum tide range (m)</td>
<td>1.6  1.6  1.6  1.6</td>
</tr>
<tr>
<td>Storm surge level above MSL (m)</td>
<td>-   -   0.55  0.61</td>
</tr>
<tr>
<td>Tsunami level above MSL (m)</td>
<td>0.5  0.5  0.5  0.5</td>
</tr>
<tr>
<td>Significant wave height (m)</td>
<td>9.6  10.3 11.1 11.8</td>
</tr>
<tr>
<td>Maximum wave height (m)</td>
<td>15.9 17.0 18.4 19.4</td>
</tr>
<tr>
<td>Predominant wave direction</td>
<td>SW  SW  SW  SW</td>
</tr>
<tr>
<td>Peak wave period (s)</td>
<td>15.1 15.9 17.0 17.8</td>
</tr>
<tr>
<td>Peak period associated with Hₜ (s)</td>
<td>14.9 15.6 16.5 17.2</td>
</tr>
<tr>
<td>Maximum crest height above MSL (m)</td>
<td>8.9  9.5  10.3 11.0</td>
</tr>
<tr>
<td>Maximum surface current speed (cm/s)</td>
<td>133 140 150 160</td>
</tr>
</tbody>
</table>

MARCH 7, 1990
### TABLE 6.2-2

COHASSET PRELIMINARY ENVIRONMENTAL DESIGN CRITERIA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinates</td>
<td>43°51'00&quot;N, 60°38'00&quot;W</td>
</tr>
<tr>
<td>Water Depth (m)</td>
<td>40</td>
</tr>
<tr>
<td>Sea surface temperature range (°C)</td>
<td>2.29 to 17.08</td>
</tr>
<tr>
<td>Sea surface salinity range (ppm)</td>
<td>30.84 to 32.39</td>
</tr>
<tr>
<td>Return Period (a)</td>
<td></td>
</tr>
<tr>
<td>10  20  50  100</td>
<td></td>
</tr>
<tr>
<td>1-h mean wind speed (knots)</td>
<td>86  90  97  101</td>
</tr>
<tr>
<td>3-s gust wind speed (knots)</td>
<td>118 123 133 138</td>
</tr>
<tr>
<td>Maximum tide range (m)</td>
<td>1.6  1.6  1.6  1.6</td>
</tr>
<tr>
<td>Storm surge level above MSL (m)</td>
<td>-    -    0.55 0.61</td>
</tr>
<tr>
<td>Tsunami level above MSL (m)</td>
<td>0.5  0.5  0.5  0.5</td>
</tr>
<tr>
<td>Significant wave height (m)</td>
<td>9.6 10.3 11.1 11.8</td>
</tr>
<tr>
<td>Maximum wave height (m)</td>
<td>15.9 17.0 18.4 19.4</td>
</tr>
<tr>
<td>Predominant wave direction</td>
<td>SW   SW   SW   SW</td>
</tr>
<tr>
<td>Peak wave period (s)</td>
<td>15.1 15.9 17.0 17.8</td>
</tr>
<tr>
<td>Peak period associated with $H_s$ (s)</td>
<td>14.9 15.6 16.5 17.7</td>
</tr>
<tr>
<td>Maximum crest height above MSL (m)</td>
<td>9.0  9.6  10.5 11.1</td>
</tr>
<tr>
<td>Maximum surface current speed (cm/s)</td>
<td>133  140  150  160</td>
</tr>
</tbody>
</table>

MARCH 7, 1990  

6.11
6.3.1 WINDS

6.3.1.1 Normal Climatology

The marine climatological database was accessed to establish monthly and annual wind speed and direction characteristics. The area of interest was defined as 42°45'N-45°00'N and 59°00'W-63°00'W.

Table 6.3-1 presents average monthly wind speeds and the most frequently recorded wind direction. Maximum reported wind speeds are also indicated in Table 6.3-1. Median wind speeds for each month are given in Figure 6.3-1. The monthly frequency of occurrence of storm force winds (48 knots or greater) is less than 4 percent of the time (Figure 6.3-2).

6.3.1.2 Extreme Winds

The method of calculating the extreme winds for the Cohasset-Panuke site is outlined in Section 6.1.3. The results of the PERD-AES study were used where a list of 300 wind storms was compiled for an area including Georges Banks, Scotian Shelf, and part of the Grand Banks.

For this application, the study area was reduced to a region around Sable Island centred at the Cohasset-Panuke site. Using the PERD storm list as a guide, the location of the peak wind speed in each of the top storms was determined from MAST ship and rig observation listings. Storms with peak wind speeds outside the study area, 41.5°-46°N, 57°-66°W, were considered unsuitable and were not used in the final analysis. The top 30 suitable storms, listed in Table 6.3-2, were determined and the peak wind speeds fitted to the Gumbel and Borgman distribution. The results are given in Table 6.3-3. As the table shows, Gumbel distribution with linear regression fit provides slightly higher estimates. This may be
<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Wind Speed (knots)</th>
<th>Most Frequent Direction (°T)</th>
<th>Maximum Wind Speed (knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>23.3</td>
<td>279</td>
<td>80</td>
</tr>
<tr>
<td>February</td>
<td>22.4</td>
<td>294</td>
<td>68</td>
</tr>
<tr>
<td>March</td>
<td>21.2</td>
<td>288</td>
<td>71</td>
</tr>
<tr>
<td>April</td>
<td>19.1</td>
<td>309</td>
<td>80</td>
</tr>
<tr>
<td>May</td>
<td>17.0</td>
<td>213</td>
<td>50</td>
</tr>
<tr>
<td>June</td>
<td>17.3</td>
<td>210</td>
<td>94</td>
</tr>
<tr>
<td>July</td>
<td>15.4</td>
<td>219</td>
<td>50</td>
</tr>
<tr>
<td>August</td>
<td>13.3</td>
<td>230</td>
<td>55</td>
</tr>
<tr>
<td>September</td>
<td>15.7</td>
<td>263</td>
<td>90</td>
</tr>
<tr>
<td>October</td>
<td>18.5</td>
<td>292</td>
<td>55</td>
</tr>
<tr>
<td>November</td>
<td>20.8</td>
<td>282</td>
<td>68</td>
</tr>
<tr>
<td>December</td>
<td>22.3</td>
<td>268</td>
<td>70</td>
</tr>
<tr>
<td>Annual</td>
<td>18.9</td>
<td>258</td>
<td>94</td>
</tr>
</tbody>
</table>
WIND SPEED

MONTH

W W NW W W SW SW SW SW W W W W

50

40

30

20

10

0

J F M A M J J A S O N D

WIND SPEED (KTS)

95% UPPER LIMIT

MEDIAN

95% LOWER LIMIT

FIGURE 6.3-1
WIND SPEED PERSISTENCE

MONTH

FREQUENCY
(\%)

0-10 KNOTS
10-20 KNOTS
20-34 KNOTS
34-48 KNOTS
48-64 KNOTS
STORM

FIGURE 6.3-2
TABLE 6.3-2
LIST OF STORMS WITHIN STUDY AREA

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Speed (knots)</th>
<th>Dir (°T)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74-03-12-00</td>
<td>97</td>
<td>310</td>
<td>45.7</td>
</tr>
<tr>
<td>2</td>
<td>74-02-18-00</td>
<td>97</td>
<td>60</td>
<td>44.7</td>
</tr>
<tr>
<td>3</td>
<td>76-03-18-00</td>
<td>85</td>
<td>240</td>
<td>43.7</td>
</tr>
<tr>
<td>4</td>
<td>68-01-08-00</td>
<td>80</td>
<td>300</td>
<td>42.5</td>
</tr>
<tr>
<td>5</td>
<td>66-01-09-21</td>
<td>80</td>
<td>330</td>
<td>43.2</td>
</tr>
<tr>
<td>6</td>
<td>68-12-06-18</td>
<td>80</td>
<td>290</td>
<td>42.2</td>
</tr>
<tr>
<td>7</td>
<td>76-11-09-03</td>
<td>80</td>
<td>340</td>
<td>42.2</td>
</tr>
<tr>
<td>8</td>
<td>82-02-14-12</td>
<td>80</td>
<td>320</td>
<td>44.1</td>
</tr>
<tr>
<td>9</td>
<td>73-11-04-00</td>
<td>78</td>
<td>290</td>
<td>42.0</td>
</tr>
<tr>
<td>10</td>
<td>68-01-07-18</td>
<td>76</td>
<td>230</td>
<td>42.9</td>
</tr>
<tr>
<td>11</td>
<td>60-01-16-18</td>
<td>75</td>
<td>260</td>
<td>41.5</td>
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<tr>
<td>12</td>
<td>80-01-25-00</td>
<td>73</td>
<td>270</td>
<td>42.1</td>
</tr>
<tr>
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<td>74-02-01-12</td>
<td>72</td>
<td>50</td>
<td>44.1</td>
</tr>
<tr>
<td>14</td>
<td>74-02-08-12</td>
<td>72</td>
<td>330</td>
<td>45.9</td>
</tr>
<tr>
<td>15</td>
<td>85-01-06-00</td>
<td>71</td>
<td>260</td>
<td>44.0</td>
</tr>
<tr>
<td>16</td>
<td>58-09-29-03</td>
<td>70</td>
<td>320</td>
<td>42.5</td>
</tr>
<tr>
<td>17</td>
<td>60-03-05-00</td>
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<td>70</td>
<td>42.3</td>
</tr>
<tr>
<td>18</td>
<td>64-02-09-06</td>
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<td>220</td>
<td>45.2</td>
</tr>
<tr>
<td>19</td>
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<td>140</td>
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<td>320</td>
<td>43.9</td>
</tr>
<tr>
<td>21</td>
<td>83-02-13-06</td>
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<td>350</td>
<td>44.0</td>
</tr>
<tr>
<td>22</td>
<td>83-10-25-12</td>
<td>70</td>
<td>50</td>
<td>44.0</td>
</tr>
<tr>
<td>23</td>
<td>85-03-19-18</td>
<td>70</td>
<td>40</td>
<td>43.5</td>
</tr>
<tr>
<td>24</td>
<td>60-03-14-00</td>
<td>68</td>
<td>350</td>
<td>42.5</td>
</tr>
<tr>
<td>25</td>
<td>63-02-25-12</td>
<td>68</td>
<td>260</td>
<td>41.7</td>
</tr>
<tr>
<td>26</td>
<td>64-02-17-20</td>
<td>68</td>
<td>320</td>
<td>43.5</td>
</tr>
<tr>
<td>27</td>
<td>64-03-31-18</td>
<td>68</td>
<td>200</td>
<td>44.5</td>
</tr>
<tr>
<td>28</td>
<td>68-11-26-12</td>
<td>68</td>
<td>330</td>
<td>45.7</td>
</tr>
<tr>
<td>29</td>
<td>79-12-10-18</td>
<td>68</td>
<td>300</td>
<td>43.9</td>
</tr>
<tr>
<td>30</td>
<td>78-03-06-18</td>
<td>66</td>
<td>260</td>
<td>42.6</td>
</tr>
<tr>
<td>31</td>
<td>84-03-10-12</td>
<td>66</td>
<td>300</td>
<td>43.7</td>
</tr>
</tbody>
</table>


TABLE 6.3-3

EXTREME WIND SPEEDS FOR GIVEN RETURN PERIODS

<table>
<thead>
<tr>
<th>Return Period (years)</th>
<th>Linear Regression</th>
<th>Method of Moments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wind Speed Limit</td>
<td>Wind Speed Limit</td>
</tr>
<tr>
<td></td>
<td>(kts)</td>
<td>(kts)</td>
</tr>
<tr>
<td></td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Gumbel Distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>73.25</td>
<td>4.26</td>
</tr>
<tr>
<td>5</td>
<td>80.65</td>
<td>5.69</td>
</tr>
<tr>
<td>10</td>
<td>85.59</td>
<td>7.87</td>
</tr>
<tr>
<td>20</td>
<td>90.32</td>
<td>10.28</td>
</tr>
<tr>
<td>30</td>
<td>93.05</td>
<td>11.73</td>
</tr>
<tr>
<td>50</td>
<td>96.46</td>
<td>13.58</td>
</tr>
<tr>
<td>100</td>
<td>101.06</td>
<td>16.11</td>
</tr>
<tr>
<td>Borgman Distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>73.60</td>
<td>3.94</td>
</tr>
<tr>
<td>5</td>
<td>81.17</td>
<td>4.55</td>
</tr>
<tr>
<td>10</td>
<td>85.84</td>
<td>5.35</td>
</tr>
<tr>
<td>20</td>
<td>90.11</td>
<td>6.11</td>
</tr>
<tr>
<td>30</td>
<td>92.47</td>
<td>6.53</td>
</tr>
<tr>
<td>50</td>
<td>95.34</td>
<td>7.03</td>
</tr>
<tr>
<td>100</td>
<td>99.09</td>
<td>7.66</td>
</tr>
</tbody>
</table>

Source: PERD Extreme Hindcast Study (MacLaren Plansearch Limited, 1989).
used to provide conservative design conditions. A graphical presentation of the results is given in Figures 6.3-3 and 6.3-4.

In addition, extreme wind speeds were calculated from several other data sources for comparison, including the marine climatological database, SOWM, WES, and GWC. The AERS DUST software package was applied to the above data sets except for the PERD study. The software used Gumbel distribution with the method of moments for fitting. Each database provided extreme wind speeds for given return periods (10, 20, 50, and 100 years). Results from these sources are presented in Table 6.3-4. Design wind speeds reported in the Venture Development Project EIS are also provided for comparison.

6.3.1.3 Gust Factor

Means for converting extreme wind estimates to different elevations and different averaging periods are presented. The extreme values given in Tables 6.3-3 and 6.3-4 may be considered to represent 1-hour mean wind measured 10 to 20 m above mean sea level. The U.K. Department of Energy (1984) gust factors have been used in Table 6.3-5 (for consistency with the North Sea Practice) for the calculation of the design wind speeds for given averaging periods.

6.3.2 PRECIPITATION

The monthly percentage frequency of precipitation was determined from historical observation archived in the marine climatological database. Table 6.3-6 presents the monthly percentage frequency of precipitation. Figure 6.3-5 illustrates the annual distribution of rain and snow within the study area. Precipitation occurs most frequently during the winter months, December through March.
EXTREME WIND SPEED DISTRIBUTION: GUMBLE

GUMBEL
LINEAR
REGRESSION
CORRELATION - 0.947

2. YR - 73.25
5. YR - 80.65
10. YR - 88.59
5. YR - 90.32
30. YR - 93.05
2. YR - 96.46
100. YR - 101.06

GUMBEL
METHOD OF
MOMENTS
CORRELATION - 0.947

2. YR - 73.06
5. YR - 79.97
10. YR - 84.58
5. YR - 89.00
30. YR - 91.55
2. YR - 94.73
100. YR - 99.03

FIGURE 6.3-3
EXTREME WIND SPEED DISTRIBUTION: BORGMAN

![Diagram showing extremal wind speed distribution with probability and wind speed axes, along with correlation coefficients and sample data points.]

**BORGMAN LINEAR REGRESSION CORRELATION - 0.931**
- 2 YR - 73.60
- 5 YR - 81.17
- 10 YR - 85.84
- 20 YR - 90.11
- 30 YR - 92.47
- 50 YR - 95.34
- 100 YR - 99.09

**BORGMAN METHOD OF MOMENTS CORRELATION - 0.931**
- 2 YR - 73.37
- 5 YR - 80.60
- 10 YR - 85.06
- 20 YR - 89.17
- 30 YR - 91.44
- 50 YR - 94.21
- 100 YR - 97.81

FIGURE 6.3-4
TABLE 6.3-4
EXTREME WIND SPEEDS FOR VARIOUS RETURN PERIODS
(knots)

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Return Period (yrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Spectral Ocean Wave Model (SCOMM)</td>
<td>31.6</td>
</tr>
<tr>
<td>Marine Climatological Database</td>
<td>77.5</td>
</tr>
<tr>
<td>Waterways Experiment Station (WES)</td>
<td>44.4</td>
</tr>
<tr>
<td>Geostrophic Wind Climatology (GWC)</td>
<td>86.9</td>
</tr>
<tr>
<td>FERD Extreme Analysis</td>
<td>85.6</td>
</tr>
<tr>
<td>Design Wind Speed - Venture EIS</td>
<td>75.1</td>
</tr>
</tbody>
</table>

* Value refers to 25-year return period.

TABLE 6.3-5
DESIGN WIND SPEED CRITERIA
(knots)

<table>
<thead>
<tr>
<th>Speed Parameter</th>
<th>Ratio* to 1-h</th>
<th>Return Period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>1-h mean</td>
<td>1.0</td>
<td>86</td>
</tr>
<tr>
<td>10-min mean</td>
<td>1.05</td>
<td>90</td>
</tr>
<tr>
<td>1-min mean</td>
<td>1.17</td>
<td>101</td>
</tr>
<tr>
<td>5-s gust</td>
<td>1.34</td>
<td>115</td>
</tr>
<tr>
<td>3-s gust</td>
<td>1.37</td>
<td>118</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month</th>
<th>Rain</th>
<th>Snow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>12.7</td>
<td>28.4</td>
<td>41.1</td>
</tr>
<tr>
<td>February</td>
<td>13.8</td>
<td>22.4</td>
<td>36.2</td>
</tr>
<tr>
<td>March</td>
<td>13.6</td>
<td>14.2</td>
<td>27.8</td>
</tr>
<tr>
<td>April</td>
<td>15.6</td>
<td>4.4</td>
<td>20.0</td>
</tr>
<tr>
<td>May</td>
<td>13.6</td>
<td>0.2</td>
<td>13.0</td>
</tr>
<tr>
<td>June</td>
<td>12.7</td>
<td>-</td>
<td>12.8</td>
</tr>
<tr>
<td>July</td>
<td>9.0</td>
<td>-</td>
<td>9.0</td>
</tr>
<tr>
<td>August</td>
<td>10.1</td>
<td>-</td>
<td>10.1</td>
</tr>
<tr>
<td>September</td>
<td>14.0</td>
<td>-</td>
<td>14.0</td>
</tr>
<tr>
<td>October</td>
<td>16.0</td>
<td>0.4</td>
<td>16.4</td>
</tr>
<tr>
<td>November</td>
<td>18.4</td>
<td>3.0</td>
<td>21.4</td>
</tr>
<tr>
<td>December</td>
<td>15.8</td>
<td>14.8</td>
<td>30.7</td>
</tr>
</tbody>
</table>
FREQUENCY OF PRECIPITATION (%)

MONTH

FIGURE 6.3-5
6.3.3 AIR TEMPERATURE

The annual temperature regime is shown in Figures 6.3-6 and 6.3-7. The data source was the marine climatological database. Minimum, maximum, and mean monthly air temperatures are summarized in Table 6.3-7.

6.3.4 RELATIVE HUMIDITY

Mean monthly relative humidity was derived from the marine climatological database (Table 6.3-8). Median relative humidity values as well as the 95 percent upper and lower confidence limits are shown in Figure 6.3-8.

6.4 OCEANOGRAPHIC DATA

This section will review the oceanographic data categorized as follows:

- Bathymetry
- Tides
- Currents
- Waves
- Extreme waves
- Storm surges
- Tsunamis
- Water temperature and salinity
- Marine fouling
- Sea ice and icebergs
- Sea spray and atmospheric icing
AIR TEMPERATURE

MONTH

-10 0 10 20 30

AIR TEMPERATURE (°C)

- 95% UPPER LIMIT
- MEDIAN
- 95% LOWER LIMIT

FIGURE 6.3-6
AIR TEMPERATURE PERSISTENCE

FIGURE 6.3-7
### TABLE 6.3-7
MONTHLY AIR TEMPERATURES

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td>Mean</td>
</tr>
<tr>
<td>January</td>
<td>-19.5</td>
<td>30.0</td>
<td>0.4</td>
</tr>
<tr>
<td>February</td>
<td>-20.2</td>
<td>26.0</td>
<td>-0.1</td>
</tr>
<tr>
<td>March</td>
<td>-15.0</td>
<td>23.8</td>
<td>1.3</td>
</tr>
<tr>
<td>April</td>
<td>-13.2</td>
<td>29.0</td>
<td>3.9</td>
</tr>
<tr>
<td>May</td>
<td>-0.8</td>
<td>35.0</td>
<td>7.5</td>
</tr>
<tr>
<td>June</td>
<td>-6.5</td>
<td>33.8</td>
<td>11.4</td>
</tr>
<tr>
<td>July</td>
<td>0.0</td>
<td>30.5</td>
<td>16.1</td>
</tr>
<tr>
<td>August</td>
<td>5.5</td>
<td>33.2</td>
<td>18.2</td>
</tr>
<tr>
<td>September</td>
<td>3.5</td>
<td>31.5</td>
<td>16.2</td>
</tr>
<tr>
<td>October</td>
<td>0.3</td>
<td>27.0</td>
<td>12.0</td>
</tr>
<tr>
<td>November</td>
<td>-6.0</td>
<td>29.5</td>
<td>7.6</td>
</tr>
<tr>
<td>December</td>
<td>-12.5</td>
<td>31.3</td>
<td>3.3</td>
</tr>
</tbody>
</table>

### TABLE 6.3-8
AVERAGE RELATIVE HUMIDITY (%)

<table>
<thead>
<tr>
<th>Month</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>85</td>
</tr>
<tr>
<td>February</td>
<td>87</td>
</tr>
<tr>
<td>March</td>
<td>86</td>
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<tr>
<td>April</td>
<td>90</td>
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<tr>
<td>May</td>
<td>91</td>
</tr>
<tr>
<td>June</td>
<td>92</td>
</tr>
<tr>
<td>July</td>
<td>94</td>
</tr>
<tr>
<td>August</td>
<td>89</td>
</tr>
<tr>
<td>September</td>
<td>84</td>
</tr>
<tr>
<td>October</td>
<td>80</td>
</tr>
<tr>
<td>November</td>
<td>82</td>
</tr>
<tr>
<td>December</td>
<td>83</td>
</tr>
</tbody>
</table>
HUMIDITY

FIGURE 6.3-8
6.4.1 **BATHYMETRY**

Figure 6.4-1 identifies the location of the proposed development. Preliminary latitude and longitude coordinates for Panuke are 43°49'N, 60°43.5'W and for Cohasset, 43°51'N 60°37.5'W. Water depths at the two sites (Panuke, 46 m and Cohasset, 36 m) are based on chart datum field sheets prepared by the Canadian Hydrographic Service, supplemented by detailed geotechnical site surveys.

6.4.2 **TIDES**

This section discusses tidal heights and tidal currents.

6.4.2.1 **Tidal Height**

A tidal height prediction model (Godin 1972; Foreman 1977) was used to estimate the maximum astronomical tide. Analyses of sea level fluctuations in the study area have revealed that the most dominant component is the lunar semidiurnal component. Tidal heights were determined by summing all in-phase tidal constituents. The maximum predicted tidal height at Panuke was 0.874 m. Tidal heights were slightly higher (0.909 m) at Cohasset. These maxima occur at the peak of tidal cycle (two cycles each day) during spring tides (twice each month).

Based on the Canadian Hydrographic Services (CHS) datum (plane of lowest normal tides), the maximum astronomical tide elevation on Sable Island Bank is 1.6 m. This figure will be used to provide the design astronomical tide range of 1.6 m at the Cohasset-Panuke site.

6.4.2.2 **Tidal Currents**

Based on the current meter measurements obtained at Panuke B-90 (August 9 to September 21, 1986), all of the major tidal current constituents were generated for a 2-year interval (1986-1987) at
LOCATION OF PROPOSED DEVELOPMENT SITE

Source: Canadian Hydrographic Services 1978

FIGURE 6.4-1
three discrete depths (10.0 m, 24.6 m, and 43.6 m). Maximum tidal current speeds calculated along eight cardinal directions are provided in Table 6.4-1.

### TABLE 6.4-1

MAXIMUM PREDICTED TIDAL CURRENTS AT PANUKE

<table>
<thead>
<tr>
<th>Cardinal Direction</th>
<th>Tidal Current Speed (cm/s)</th>
<th>10 m</th>
<th>24.6 m</th>
<th>43.6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>68.70</td>
<td>53.16</td>
<td>37.29</td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td>60.26</td>
<td>48.30</td>
<td>26.57</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>50.13</td>
<td>34.28</td>
<td>22.99</td>
<td></td>
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<tr>
<td>SE</td>
<td>44.65</td>
<td>33.50</td>
<td>32.40</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>39.18</td>
<td>31.26</td>
<td>37.46</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>34.93</td>
<td>35.33</td>
<td>38.27</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>44.02</td>
<td>38.42</td>
<td>30.72</td>
<td></td>
</tr>
<tr>
<td>NW</td>
<td>67.85</td>
<td>48.72</td>
<td>37.72</td>
<td></td>
</tr>
</tbody>
</table>

Tidal ellipses for spring tides were calculated from the measured currents at the Panuke B-90 site. The results are shown in Figures 6.4-2 and 6.4-3 for Panuke and Figure 6.4-4 for Cohasset for the largest semidiurnal component (M2) and diurnal component (k1) at the three measuring depths. As shown, the dominant direction or major axis is along the NNW-SSE direction. Similar analysis is currently underway for the Cohasset site.

#### 6.4.3 CURRENTS

Gregory and Smith (1988) compiled all historical current speed and direction measurements collected on the Scotian Shelf. Table 6.4-2 presents the monthly range of current speeds records within the study area. The maximum near-surface current is 111.7 cm/s.
TIDAL ELLIPSES: PANUKE B-90

10.0 m DEPTH

24.6 m DEPTH

43.6 m DEPTH

SCALE: \[ \text{20 cm/s} \]

FIGURE 6.4-2
TIDAL ELLIPSES: PANUKE F-99

11.0 m DEPTH

<table>
<thead>
<tr>
<th>M2</th>
<th>K1</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
</tbody>
</table>

30.4 m DEPTH

<table>
<thead>
<tr>
<th>M2</th>
<th>K1</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Diagram" /></td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
</tbody>
</table>

SCALE: 20 cm/s

FIGURE 6.4-3
TIDAL ELLIPSES: COHASSET A-52

19.7 m DEPTH

SCALE: ---. ---I. 15 cm/s

M2

K1

30.4 m DEPTH

M2

K1

FIGURE 6.4-4
**TABLE 6.4-2**
NEAR-SURFACE MAXIMUM AND MEAN CURRENT SPEEDS

<table>
<thead>
<tr>
<th>Month</th>
<th>Range of Current Speeds (cm/s)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>January</td>
<td>36.3 - 74.6</td>
<td>2.8 - 20.9</td>
</tr>
<tr>
<td>February</td>
<td>36.5 - 75.7</td>
<td>2.0 - 22.0</td>
</tr>
<tr>
<td>March</td>
<td>42.3 - 78.9</td>
<td>0.8 - 20.6</td>
</tr>
<tr>
<td>April</td>
<td>36.0 - 79.2</td>
<td>1.7 - 15.2</td>
</tr>
<tr>
<td>May</td>
<td>7.2 - 88.0</td>
<td>0.2 - 15.3</td>
</tr>
<tr>
<td>June</td>
<td>37.6 - 80.6</td>
<td>2.9 - 17.8</td>
</tr>
<tr>
<td>July</td>
<td>30.3 - 111.7</td>
<td>2.8 - 16.4</td>
</tr>
<tr>
<td>August</td>
<td>29.9 - 82.6</td>
<td>2.3 - 10.3</td>
</tr>
<tr>
<td>September</td>
<td>29.3 - 78.5</td>
<td>1.3 - 10.3</td>
</tr>
<tr>
<td>October</td>
<td>29.7 - 68.4</td>
<td>1.9 - 19.4</td>
</tr>
<tr>
<td>November</td>
<td>19.0 - 73.0</td>
<td>1.1 - 13.2</td>
</tr>
<tr>
<td>December</td>
<td>41.6 - 80.8</td>
<td>1.2 - 15.5</td>
</tr>
</tbody>
</table>

Note: (After Gregory and Smith, 1988).
In 1986, MacLaren Plansearch conducted a study to summarize all current meter information acquired by Shell Canada Limited in support of exploratory drilling operations on the Scotian Shelf. Near-surface mean current speeds determined for the area south of Sable Island are presented in Table 6.4-3. Maximum measured current speed was 82.28 cm/s. The 5 percent exceedance value for near-surface waters (0-20 m) was 58 cm/s, and the near-bottom (within 15 m of the seafloor) exceedance value was 38 cm/s.

Site-specific current measurements were obtained at Panuke B-90 between August 9 and September 21, 1986. Table 6.4-4 presents maximum measured current speeds, tidal currents, and residual or wind-driven currents at three depths along the eight principal cardinal directions. Maximum measured currents were found to be within the ranges presented in Gregory and Smith (1988). Tidal currents accounted for approximately 65-70 percent of the total measured current.

A direct approach was taken to estimate maximum current speeds in the vicinity of Panuke. The maximum surface current was assumed to be 3 percent of the maximum wind speed corresponding to a peak current of 160 cm/s. This first-order estimate lies within the range of current speeds presented in Table 6.4-2. A representative current profile was then developed, relying primarily on the site-specific measurements obtained at Panuke B-90. Using this scenario, mid-depth (approximately 25 m) maximum current speeds would be 114 cm/s, while near bottom maximum speeds would be 100 cm/s.

The 100-year return period design current speed established for the Venture site was 155 cm/s, which compares reasonably well with the preliminary value estimated for Panuke. Also, the 100-year current near the Sable Island Bank was approximately 110 cm/s in the Venture EIS. In the absence of a detailed and comprehensive hindcast-hydrodynamic modelling program, maximum current speeds


<table>
<thead>
<tr>
<th>Month</th>
<th>Near-Surface</th>
<th></th>
<th>Mid-Depth</th>
<th></th>
<th>Near-Bottom</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Mean/SD</td>
<td>Maximum</td>
<td>Mean/SD</td>
<td>Maximum</td>
<td>Mean/SD</td>
</tr>
<tr>
<td>January</td>
<td>62.04</td>
<td>19.54 ± 9.40</td>
<td>59.88</td>
<td>25.17 ± 8.83</td>
<td>55.82</td>
<td>19.38 ± 9.5</td>
</tr>
<tr>
<td>February</td>
<td>62.68</td>
<td>19.56 ± 9.96</td>
<td>29.92</td>
<td>17.71 ± 4.00</td>
<td>48.82</td>
<td>15.32 ± 6.6</td>
</tr>
<tr>
<td>March</td>
<td>82.28</td>
<td>22.83 ± 12.41</td>
<td>59.18</td>
<td>18.54 ± 6.50</td>
<td>37.30</td>
<td>17.75 ± 5.95</td>
</tr>
<tr>
<td>April</td>
<td>53.58</td>
<td>18.89 ± 9.24</td>
<td>40.42</td>
<td>16.21 ± 6.18</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May</td>
<td>46.48</td>
<td>15.25 ± 6.69</td>
<td>41.68</td>
<td>15.82 ± 6.91</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>June</td>
<td>55.60</td>
<td>18.05 ± 9.55</td>
<td>46.16</td>
<td>17.05 ± 7.65</td>
<td>38.74</td>
<td>16.83 ± 6.5</td>
</tr>
<tr>
<td>July</td>
<td>75.18</td>
<td>21.04 ± 12.21</td>
<td>61.00</td>
<td>20.69 ± 10.15</td>
<td>46.16</td>
<td>16.24 ± 7.1</td>
</tr>
<tr>
<td>August</td>
<td>61.13</td>
<td>27.51 ± 15.38</td>
<td>67.48</td>
<td>17.25 ± 8.65</td>
<td>50.08</td>
<td>16.32 ± 7.8</td>
</tr>
<tr>
<td>September</td>
<td>-</td>
<td>-</td>
<td>66.88</td>
<td>20.15 ± 10.14</td>
<td>48.54</td>
<td>16.50 ± 7.7</td>
</tr>
<tr>
<td>October</td>
<td>50.24</td>
<td>24.62 ± 10.76</td>
<td>66.60</td>
<td>23.31 ± 10.79</td>
<td>62.96</td>
<td>19.78 ± 9.4</td>
</tr>
<tr>
<td>November</td>
<td>58.00</td>
<td>19.22 ± 10.44</td>
<td>61.56</td>
<td>20.39 ± 8.58</td>
<td>70.38</td>
<td>18.16 ± 8.52</td>
</tr>
<tr>
<td>December</td>
<td>61.82</td>
<td>19.97 ± 10.58</td>
<td>76.12</td>
<td>28.91 ± 12.20</td>
<td>62.54</td>
<td>17.86 ± 9.06</td>
</tr>
</tbody>
</table>

Note: (After MacLaren Plansearch).

MARCH 7, 1990 6.37
### TABLE 6.4-4

MAXIMUM MEASURED TIDAL AND RESIDUAL CURRENTS AT PANUKE B-90

<table>
<thead>
<tr>
<th>Cardinal Direction</th>
<th>Current Speeds (cm/s)</th>
<th>10.0 m below Sea Surface</th>
<th>24.6 m below Sea Surface</th>
<th>43.6 m below Sea Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Measured</td>
<td>Tidal</td>
<td>Residual</td>
</tr>
<tr>
<td>N</td>
<td>74.82</td>
<td>57.13</td>
<td>23.65</td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td>50.10</td>
<td>42.89</td>
<td>18.59</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>56.31</td>
<td>38.37</td>
<td>31.83</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>70.17</td>
<td>40.48</td>
<td>36.59</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>66.96</td>
<td>37.33</td>
<td>38.05</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>61.44</td>
<td>34.35</td>
<td>34.51</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>60.07</td>
<td>38.10</td>
<td>37.91</td>
<td></td>
</tr>
<tr>
<td>NW</td>
<td>82.63</td>
<td>56.73</td>
<td>48.49</td>
<td></td>
</tr>
</tbody>
</table>
This section includes a description and assessment of existing wave data sets and a discussion of the wave climate in the study area.

6.4.4.1 Description and Assessment of Existing Wave Data Sets

The most appropriate data set available for establishing the wave climate near the Cohasset-Panuke site is the ODGP. The data set consists of a 3-year time series of directional wave information calculated for selected grid point locations. Wave height, period, and spectral wave energies are available for each grid point every 6 hours.

Another potential source of wave information is the waverider buoy data set archived by MEDS. Data quality of wave height and period is excellent; however, the data set does not include wave direction information. Waverider measurements are extremely valuable for validating model or hindcast wave height predictions, especially in the shallow waters surrounding Sable Island. However, the short deployment intervals restrict the use of this data set for extreme wave height analysis.

Other wave data sets include the visually estimated wave observations archived in the marine climatological database, the WES wave hindcast and the SOWM hindcast results. Wave data quality in the marine climatological database is questionable and is not considered suitable for engineering design. Both the WES and SOWM data sets are unable to accurately predict wave height design criteria for the study area. The ODGP 3-year hindcast data set and the PEERD extreme hindcast provide the best data sets for this application.
Wave Climate in the Study Area

The monthly deepwater wave climate (wave height and peak period) was determined from the ODGP data set (Table 6.4-5). Grid point 3590 (Figure 6.4-5) was considered to be representative of the Cohasset-Panuke area. Additional analyses performed using data from this grid point include a scattergram of significant wave height versus peak period (Figure 6.4-6), a peak period histogram (Figure 6.4-7), and a wave height exceedance diagram (Figure 6.4-8).

EXTREME WAVES

In the recent study by MacIaren Plansearch (1989), PERD Extreme Hindcast, the top fifty extreme storms from a 30-year period (1957-1987) were hindcast for the Scotian Shelf and Grand Banks region (Figure 6.4-5). From these hindcasts, the wind and wave fields were extracted at the time of the peak significant wave height at grid point 3590, as listed in Table 6.4-6. Although the location of grid point 3590 (43.75°N, 60.0°W) was some distance from the Cohasset-Panuke site, less than model grid spacing, it was felt that it represented the conditions at the study sites, and would provide suitable results for the extremal analysis at these sites.

In the extremal analysis, the top 30 storm wave heights and wind speeds were selected from Table 6.4-6. In the final selection, storms with waves travelling towards 205 through 260 degrees (i.e. coming from 25 to 80 degrees) were discarded and replaced with the next highest eligible wave height. These waves would not have affected the Cohasset-Panuke site due to the sheltering effect of Sable Island. The effects of the island were not considered in the model.
TABLE 6.4–5
MONTHLY WAVE HEIGHT AND
PEAK PERIOD STATISTICS

<table>
<thead>
<tr>
<th>Month</th>
<th>Min</th>
<th>Mean</th>
<th>Max</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Mean</th>
<th>Max</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0.6</td>
<td>2.9</td>
<td>7.7</td>
<td>1.40</td>
<td>4.0</td>
<td>8.5</td>
<td>12.3</td>
<td>1.77</td>
</tr>
<tr>
<td>Feb</td>
<td>0.7</td>
<td>2.6</td>
<td>7.0</td>
<td>1.19</td>
<td>3.9</td>
<td>8.1</td>
<td>13.9</td>
<td>1.95</td>
</tr>
<tr>
<td>Mar</td>
<td>0.6</td>
<td>2.8</td>
<td>7.3</td>
<td>1.32</td>
<td>3.9</td>
<td>8.7</td>
<td>13.2</td>
<td>1.87</td>
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<td>0.5</td>
<td>2.6</td>
<td>6.1</td>
<td>1.23</td>
<td>3.9</td>
<td>8.2</td>
<td>11.8</td>
<td>1.81</td>
</tr>
<tr>
<td>May</td>
<td>0.5</td>
<td>2.1</td>
<td>6.8</td>
<td>1.12</td>
<td>3.9</td>
<td>7.9</td>
<td>13.2</td>
<td>1.74</td>
</tr>
<tr>
<td>Jun</td>
<td>0.5</td>
<td>2.1</td>
<td>4.4</td>
<td>0.87</td>
<td>3.9</td>
<td>7.6</td>
<td>10.6</td>
<td>1.33</td>
</tr>
<tr>
<td>Jul</td>
<td>0.5</td>
<td>1.7</td>
<td>4.5</td>
<td>0.65</td>
<td>3.9</td>
<td>7.1</td>
<td>11.7</td>
<td>1.39</td>
</tr>
<tr>
<td>Aug</td>
<td>0.1</td>
<td>1.2</td>
<td>4.6</td>
<td>0.75</td>
<td>2.3</td>
<td>6.3</td>
<td>13.2</td>
<td>1.89</td>
</tr>
<tr>
<td>Sep</td>
<td>0.3</td>
<td>1.6</td>
<td>5.1</td>
<td>0.91</td>
<td>3.5</td>
<td>7.7</td>
<td>17.6</td>
<td>2.62</td>
</tr>
<tr>
<td>Oct</td>
<td>0.5</td>
<td>2.1</td>
<td>9.9</td>
<td>1.27</td>
<td>3.5</td>
<td>7.7</td>
<td>14.5</td>
<td>2.33</td>
</tr>
<tr>
<td>Nov</td>
<td>0.4</td>
<td>2.4</td>
<td>7.9</td>
<td>1.24</td>
<td>3.9</td>
<td>7.9</td>
<td>13.4</td>
<td>2.05</td>
</tr>
<tr>
<td>Dec</td>
<td>0.7</td>
<td>2.6</td>
<td>7.5</td>
<td>1.18</td>
<td>3.9</td>
<td>8.3</td>
<td>14.9</td>
<td>1.83</td>
</tr>
</tbody>
</table>

Note: Data Source is ODGP 3-year wave climate database grid point 1012.
LOCATION OF ODGP GRID POINT 3950
PEAK PERIOD SCATTERGRAM
GRID POINT 3590

SIGNIFICANT WAVE HEIGHT (m)

PEAK PERIOD (s)

FIGURE 6.4-6
PEAK PERIOD HISTOGRAM
GRID POINT 3590

FREQUENCY OF OCCURRENCE (%)

0 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 20

PEAK PERIOD (s)

FIGURE 6.4-7
SIGNIFICANT WAVE HEIGHT EXCEEDANCE

![Graph showing significant wave height exceedance vs wave height in meters. The x-axis represents wave height in meters (m), ranging from 3 to 30, and the y-axis represents exceedance percentage (%), ranging from 0 to 100. Two curves are shown: one for significant wave height (X-X) and another for maximum wave height (O-O).](image-url)
TABLE 6.4-6
LIST OF PERD EXTREME HINDCAST STORM EVENTS
Storm Period
Storm
No.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

From

To

71030300
67022100
70122600
64113000
83112400
81031512
82011300
74021612
61011912
73110100
84012912
78010812
72121512
67042700
83121900
85010400
72021812
74031012
83102400
84032812
66012612
74020400
73032112
62111412
60010900
66010812
82021200
76110512
69020900
80011412
86010212
66021318
72032612
80021000
83030700
80112106
83021000
85121512
61121412
79020300
62030600
85012312
70012000
62123000
n011900
64031512
78030100
83021412

71030700
67022500
70123012
64120312
83113012
81032000
82011900
74022000
61012312
73110512
84020312
78011212
72121912
67050200
83122400
85010900
72022212
74031412
83102800
84040112
66013012
74020800
73032500
61121912
60011300
66011212
82021600
76111000
69021218
80011812
86010612
66021812
72033100
80021400
88031012
80112418
83021500
85122112
61121912
79020712
62030912
85013012
70012400
63010218
n012300
64031912
78030500
83021900
59021012

59020~12

Wind
Wind
Speed Direction
(m/s)

U*

(Deg. n

20.61
234.78
233.66
22.72
26.24
270.00
23.04
235.79
22.03
248.21
21.22
231.12
25.06
265.71
21.61
270.00
25.37
290.00
22.45
276.66
21.61
260.00
16.95
212.78
21.61
260.00
21.11
89.83
23.93
333.85
276.87
23.55
18.52
210.00
28.29
330.00
19.03
40.00
21.20
61.62
20.58
30.00
25.41
308.48
23.66
50.00
19.62
79.88
20.39
327.12
21.61
330.00
26.00
309.12
19.96
236.10
16.98
130.00
20.58
BO.OO
22.34 . 294.04
18.71
270.86
25.44
22.47
24.56
351. 71
23.66
340.00
20.58
20.00
20.91
320.27
19.55
270.00
20.13
337.37
300.00
20.58
18.08
46.65
19.55
270.00
17.36
325.69
18.45
147.82
19.55
280.00
17.39
290.09
22.16
316.76
16.78
360.00
16.98
290.00

0.957
1.091
1.325
1.112
1.046
0.995
1.245
1.020
1.266
1.073
1.020
0.737
1.020
0.989
1.170
1.145
0.829
1.469
0.860
0.994
0.955
1.269
1.152
0.896
0.943
1.020
1.309
0.917
0.738
0.955
1.066
0.841
1.075
1.212
1.152
0.955
0.976
0.892
0.927
0.955
0.803
0.892
0.761
0.825
0.892
0.762
1.055
0.727
0.738

Notes: 1. Wind directions are "coming fromt l •
2. Wave directions are "going towards ll •
3. Wind speeds are 19.5 m neutral wind speeds.

Sign.
\lave
Height
(m)
10.37
9.93
9.75
9.56
9.40
9.29
8.96
8.83
8.75
8.43
8.36
8.36
8.22
8.15
8.10
7.93
7.70
7.52
7.48
7.44
7.40
7.37
7.30
7.20
7.18

7.13
7.07
7.03
7.03
7.01
6.86
6.86
6.66
6.58
6.58
6.57
6.53
6.41
6.37
6.25
6.04
5.93
5.85
5.59
5.55
5.49
5.44
5.30
4.75

Sign.
\lave
Period
(s)
12.20
11.33
10.80
11.06
11.19
10.98
10.34
10.97
10.49
10.42
10.54
10.80
10.47
10.03
10.18
9.87
10.61
9.05
9.44
9.41
9.71
9.29
9.40
9.34
9.58
9.34
8.80
9.67
9.67
9.29
9.16
9.73
8.96
8.72
8.71
9.07
9.00
8.97
8.85
9.22
8.99
8.80
8.52
8.37
8.48
8.61
8.10
8.33
7.81

Mean
Wave
Dir.
(deg T)

Peak
Period

59.60
83.90
50.79
45.03
64.81
29.36
51.59
44.20
71.25
72.15
54.06
40.26
69.69
301.01
157.31
94.55
19.39
159.43
246.40
267.91
260.18
92.79
254.65
288.51
164.33
170.34
112.54
82.29
333.63
272.13
79.96
69.40
231.06
197.11
172.41
231.68
136.38
87.63
154.31
99.30
247.22
95.08
154.01
326.85
92.n
85.22
159.78
210.80
104.87

16.83
14.88
13.87
14.53
14.73
14.19
13.30
14.67
14.42
13.04
13.65
13.95
14.06
12.29
14.40
12.42
13.29
11.79
11.82
11.69
12.28
10.95
11.81
11. 78
12.16
11.76
10.92
12.41
11.96
11.94
11.45
12.50
11.38
11.12
9.95
11.26
10.29
11.62
11.13
12.04
11.76
11.44
10.38
10.61
10.86
10.80
9.89
10.26
9.69

(s)


Gumbel and Borgman Distributions

In the extremal analysis, the top 30 values were fitted to both the Gumbel and Borgman distributions.

A linear regression method and the method of moments were used to fit the storm population to the distribution. Both methods provide somewhat similar results, with the former providing higher values. Table 6.4-7 presents extreme significant wave heights at ODGP Grid Point 3590. In Table 6.4-7, the results of the extremal analysis show minor differences between the two methods and the two distributions. The ± 90 percent and 95 percent confidence intervals are also shown. Table 6.4-8 presents the extreme wind speeds corresponding to extreme waves. Plots of the fitted distributions are shown in Figures 6.4-9 and 6.4-10.

From Table 6.4-7, the maximum 100 year extreme significant wave height is 11.75 m, and from Table 6.4-8 the maximum corresponding wind speed is 29.95 m/s (52 knots). The 100-year wind speed which corresponds to the 100 year wave height is quite low because the wind speed population used was selected at the time of the maximum significant wave height, and not from maximum wind events.

The extreme peak period was also estimated from the above data set. In this estimation, the significant wave height and the associated peak period were fitted to the regression curve:

\[ Tp = A(Hs)^8 \]

The regression results (Table 6.4-9) indicate that the 100 year peak period for a 11.75 m significant wave height is 17.23 s.
### TABLE 6.4-7
EXTREME SIGNIFICANT WAVE HEIGHTS AT ODGP GRID POINT 3590

<table>
<thead>
<tr>
<th>Return Period (m)</th>
<th>Linear Regression</th>
<th>Method of Moments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wave Ht (m)</td>
<td>90% Limit (m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7.95</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8.97</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>9.64</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>10.29</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>10.66</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>11.12</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>11.75</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Gumbel Distribution**

<table>
<thead>
<tr>
<th>Return Period (m)</th>
<th>Wave Ht (m)</th>
<th>90% Limit (m)</th>
<th>95% Limit (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8.01</td>
<td>1.10</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>7.99</td>
<td>1.09</td>
<td>1.19</td>
</tr>
<tr>
<td>5</td>
<td>9.01</td>
<td>1.26</td>
<td>1.38</td>
</tr>
<tr>
<td></td>
<td>8.90</td>
<td>1.41</td>
<td>1.55</td>
</tr>
<tr>
<td>10</td>
<td>9.62</td>
<td>1.48</td>
<td>1.63</td>
</tr>
<tr>
<td></td>
<td>9.45</td>
<td>1.64</td>
<td>1.80</td>
</tr>
<tr>
<td>20</td>
<td>10.17</td>
<td>1.70</td>
<td>1.87</td>
</tr>
<tr>
<td></td>
<td>9.95</td>
<td>1.84</td>
<td>2.03</td>
</tr>
<tr>
<td>30</td>
<td>10.47</td>
<td>1.82</td>
<td>1.99</td>
</tr>
<tr>
<td></td>
<td>10.23</td>
<td>1.95</td>
<td>2.15</td>
</tr>
<tr>
<td>50</td>
<td>10.84</td>
<td>1.96</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td>10.56</td>
<td>2.08</td>
<td>2.29</td>
</tr>
<tr>
<td>100</td>
<td>11.31</td>
<td>2.13</td>
<td>2.34</td>
</tr>
<tr>
<td></td>
<td>11.00</td>
<td>2.25</td>
<td>2.47</td>
</tr>
</tbody>
</table>

**Borgman Distribution**

MARCH 7, 1990
### TABLE 6.4-8

**EXTREME WIND SPEEDS CORRESPONDING TO EXTREME WAVES**

<table>
<thead>
<tr>
<th>Return Period</th>
<th>Linear Regression</th>
<th>Method of Moments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wind Speed Limit</td>
<td>Wind Speed Limit</td>
</tr>
<tr>
<td></td>
<td>(kts) (kts)</td>
<td>(kts) (kts)</td>
</tr>
<tr>
<td>Gumbel Distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>43.91 1.22 1.47</td>
<td>43.83 1.14 1.37</td>
</tr>
<tr>
<td>5</td>
<td>47.88 1.63 1.96</td>
<td>47.40 1.92 2.31</td>
</tr>
<tr>
<td>10</td>
<td>50.53 2.26 2.71</td>
<td>49.78 2.60 3.12</td>
</tr>
<tr>
<td>20</td>
<td>53.07 2.95 3.54</td>
<td>52.06 3.28 3.94</td>
</tr>
<tr>
<td>30</td>
<td>54.54 3.37 4.04</td>
<td>53.38 3.68 4.42</td>
</tr>
<tr>
<td>50</td>
<td>56.37 3.90 4.68</td>
<td>55.02 4.19 5.03</td>
</tr>
<tr>
<td>100</td>
<td>58.83 4.63 5.56</td>
<td>57.24 4.88 5.86</td>
</tr>
</tbody>
</table>

| Borgman Distribution |                  |                  |
| 2                 | 44.07 2.56 2.80   | 43.98 2.36 2.58   |
| 5                 | 48.07 2.96 3.24   | 47.62 3.06 3.35   |
| 10                | 50.55 3.48 3.81   | 49.90 3.55 3.89   |
| 20                | 52.83 3.98 4.35   | 51.99 3.98 4.36   |
| 30                | 54.09 4.25 4.65   | 53.16 4.22 4.62   |
| 50                | 55.64 4.57 5.01   | 54.58 4.50 4.93   |
| 100               | 57.66 4.98 5.45   | 56.45 4.85 5.31   |
EXTREME WAVE HEIGHT DISTRIBUTION: GUMBLE

GUMBEL
LINEAR
REGRESSION
CORRELATION - 0.986

2. YR - 7.95
5. YR - 8.97
10. YR - 9.64
20. YR - 10.29
30. YR - 10.66
50. YR - 11.12
100. YR - 11.75

GUMBEL
METHOD OF
MOMENTS
CORRELATION - 0.986

2. YR - 7.94
5. YR - 8.85
10. YR - 9.45
20. YR - 10.02
30. YR - 10.36
50. YR - 10.77
100. YR - 11.33

FIGURE 6.4-9
EXTREME WAVE HEIGHT DISTRIBUTION: BORGMAN

**BORGMAN LINEAR REGRESSION**
CORRELATION - 0.987

- 2. YR - 8.01
- 5. YR - 9.01
- 10. YR - 9.62
- 20. YR - 10.17
- 30. YR - 10.47
- 50. YR - 10.84
- 100. YR - 11.31

**BORGMAN METHOD OF MOMENTS**
CORRELATION - 0.987

- 2. YR - 7.99
- 5. YR - 8.90
- 10. YR - 9.45
- 20. YR - 9.95
- 30. YR - 10.23
- 50. YR - 10.56
- 100. YR - 11.00

**FIGURE 6.4-10**
### 6.4.5.2 Summary of Design Wave Criteria

The recommended design wave criteria are summarized in Table 6.4-10.

#### Table 6.4-10

**WAVE HEIGHT DESIGN CRITERIA**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Return Period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Significant wave height $H_s$ (m)</td>
<td>9.64</td>
</tr>
<tr>
<td>Maximum wave height $H_{max}$ (m)</td>
<td>15.90</td>
</tr>
<tr>
<td>Maximum crest height $H_c$ (m)</td>
<td>8.97</td>
</tr>
<tr>
<td>Period associated with $H_c$ (s)</td>
<td>14.9</td>
</tr>
</tbody>
</table>
6.4.6 **STORM SURGES**

The maximum water level changes caused by the passage of severe storms through the study area have been estimated for the Sable Island area. The 50 and 100-year return period values for a site located west of Sable Island were 0.55 and 0.61 m respectively. These values are considered representative of conditions likely to be encountered near Cohasset and Panuke.

6.4.7 **TSUNAMIS**

Documented tsunami events are very rare on the Scotian Shelf. The Grand Banks earthquake of 1929 resulted in a maximum wave amplitude of 0.5 m. This value is appropriate for design at Cohasset and Panuke.

6.4.8 **WATER TEMPERATURE AND SALINITY**

Monthly minimum, maximum, and mean surface temperature and salinity values were supplied by MEDS. All observations within the area 43°40'-44°00'N and 60°20'-60°50'W were included in the analysis. Table 6.4-11 presents mean temperature and salinity values at three depths: near-surface, 20 m, and near-bottom (within 10 m of the seafloor).

Mean sea surface temperatures ranged from 2.29°C to 17.08°C; average surface salinities varied from 30.84 ppt to 32.39 ppt. Near-bottom mean values ranged from 2.08°C to 10.01°C and 31.13 ppt to 32.47 ppt.

6.4.9 **MARINE FOULING**

(Currently under study).

MARCH 7, 1990
### Table 6.4-11

**Mean Monthly Temperature and Salinity**

<table>
<thead>
<tr>
<th>Month</th>
<th>Near-Surface</th>
<th>20 m</th>
<th>Near-Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temp. (°C)</td>
<td>Salinity (ppt)</td>
<td>Temp. (°C)</td>
</tr>
<tr>
<td>Jan</td>
<td>3.00</td>
<td>32.07</td>
<td>2.11</td>
</tr>
<tr>
<td>Feb</td>
<td>2.72</td>
<td>31.25</td>
<td>2.01</td>
</tr>
<tr>
<td>Mar</td>
<td>2.29</td>
<td>32.00</td>
<td>2.16</td>
</tr>
<tr>
<td>Apr</td>
<td>3.63</td>
<td>32.17</td>
<td>3.52</td>
</tr>
<tr>
<td>May</td>
<td>5.76</td>
<td>32.11</td>
<td>4.91</td>
</tr>
<tr>
<td>June</td>
<td>7.81</td>
<td>32.39</td>
<td>5.26</td>
</tr>
<tr>
<td>July</td>
<td>14.21</td>
<td>31.66</td>
<td>10.47</td>
</tr>
<tr>
<td>Aug</td>
<td>17.08</td>
<td>31.32</td>
<td>14.28</td>
</tr>
<tr>
<td>Sept</td>
<td>16.88</td>
<td>31.28</td>
<td>14.63</td>
</tr>
<tr>
<td>Oct</td>
<td>13.60</td>
<td>31.22</td>
<td>13.28</td>
</tr>
<tr>
<td>Nov</td>
<td>10.44</td>
<td>30.84</td>
<td>9.90</td>
</tr>
<tr>
<td>Dec</td>
<td>5.33</td>
<td>31.57</td>
<td>5.28</td>
</tr>
</tbody>
</table>

MARCH 7, 1990
6.4.10 SEA ICE

Gulf of St. Lawrence composite ice charts from 1979 to 1989 were examined. The examination revealed no significant change in the maximum southward penetration of sea ice originally reported by Markham (1980). Figure 6.4-11 taken from the Venture Development Project EIS, shows that historical sea ice distributions do not extend west of Sable Island. Sea ice is not predicted to have any effect on the design or operation of structures at Panuke or Cohasset.

6.4.11 SEA SPRAY AND ATMOSPHERIC ICING

The potential for sea spray or atmospheric icing was determined by accessing the marine climatological database. Figure 6.4-12 and Table 6.4-12 summarize the results obtained following application of the MAST software. The possibility of icing is essentially restricted to the months December through March. The greatest potential for icing (25.3 percent) occurs during February (Figure 6.4-13).

6.5 OPERATIONAL CRITERIA

Monthly frequency of occurrence histograms and percentage exceedance diagrams were produced for the following operational criteria: winds, waves, visibility, and ceiling. The marine climatological database (wind speed, horizontal visibility, and ceiling height) and the WES wave hindcast time series (wave height) were analyzed using DUST software.

6.6 ENVIRONMENTAL MONITORING AND OPERATIONAL CONSTRAINTS

A detailed monitoring program for physical environmental parameters will be made available later.
SEA ICE DISTRIBUTION

FIGURE 6.4-11

AVERAGE LIMIT OF SEA ICE EDGE

EXTREME LIMIT OF SEA ICE EDGE
FREEZING PRECIPITATION

FIGURE 6.4-12
# TABLE 6.4-12
PERCENTAGE FREQUENCY OCCURRENCE
OF ICING DUE TO FREEZING SPRAY

<table>
<thead>
<tr>
<th>Month</th>
<th>Nil</th>
<th>Light</th>
<th>Moderate</th>
<th>Heavy</th>
<th>Severe</th>
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MARCH 7, 1990
FREEZING SPRAY POTENTIAL

MONTH

FREQUENCY OF OCCURRENCE (%)

0
10
20
30

J F M A M J J A S O N D

SEVERE
HEAVY
MODERATE
LIGHT

FIGURE 6.4-13
## Section 7

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SECTION 7. GEOTECHNICAL ENGINEERING

7.1 INTRODUCTION

The following data sources were used to determine the preliminary geotechnical properties for the Cohasset-Panuke development sites:

- Atlantic Geoscience Centre
- Canada Oil and Gas Land Administration
- Canadian Hydrographic Service
- Existing literature
- Unpublished data and industry consultants

7.1.1 ATLANTIC GEOSCIENCE CENTRE

Scientific research into the modern-day processes and geologic history of Sable Island Bank has been ongoing at the Atlantic Geoscience Centre (AGC) for several years. The result is the collection of a large body of public data. The data utilized from this source included high resolution and airgun subbottom profiles, sidescan sonograms, and cruise reports.

7.1.2 CANADA OIL AND GAS LAND ADMINISTRATION

The Canada Oil and Gas Land Administration (COGIA) acts as the repository for wellsite survey reports and data. The wellsite survey reports for the Cohasset and Panuke fields were accessed through COGIA and the data incorporated in the work. These data included geotechnical borings conducted at the wellsites for jack-up rig foundation assessments.

11 DEC 1989

7.1
7.1.3 **CANADIAN HYDROGRAPHIC SERVICE**

The Canadian Hydrographic Service (CHS) Field Sheet Number 4993, showing hydrographic survey data collected over the development sites in 1982, was used to infill bathymetric information in areas not covered by the wellsite surveys.

7.1.4 **EXISTING LITERATURE**

Existing literature (published papers and conference proceedings) was reviewed, and pertinent information incorporated in the work. Unpublished manuscripts were also used with the authors' permission.

7.1.5 **UNPUBLISHED DATA AND INDUSTRY CONSULTANTS**

Some of the data regarding the development area is unpublished. In particular, the geotechnical test data for the Cohasset A-52 wellsite is proprietary to Petro-Canada Inc., and is used herein with their permission. Other data comes from the files of Jacques/McClelland Geosciences Inc., and although not always directly quoted, has been used as a basis for the development of the understanding of the region.

7.2 **BATHYMETRY**

The bathymetric description of the Cohasset-Panuke area, presented in the following paragraphs and shown graphically in Figure 7.2-1, is derived from three sources. The bathymetry of Panuke is taken from the wellsite survey report for the area (McElhanney Services Limited, 1985). The bathymetry for the Cohasset area is similarly taken from the wellsite survey report for that area (McGregor Geoscientific Limited, 1986). Regionally, and in the zone between the two wellsite survey areas, the bathymetry is based on CHS data (1982). Because three independent data sets, each with differing data densities, accuracies, assumptions, and navigation systems, were being integrated, it was found that minor adjustments were required to produce agreement. In
FIGURE 7.2-1
particular, the wellsite survey data for the Panuke site was not tide-corrected. A one-metre correction was applied to these data to account for tide. Otherwise, where the data sets overlapped, good agreement was found.

The water depths to the southwest of Sable Island, in the region of the Cohasset-Panuke development area, generally increase to the south. The average dip of the seafloor is approximately 1:1000. The seafloor topography is strongly modified, however, by a series of ridges and troughs. In the Cohasset-Panuke development area, the longitudinal axes of these features are aligned roughly east-west. Closer to Sable Island (into shallower water), the alignment swings to northwest-southeast. The ridges are in the order of 2 to 3 km in width, and 10 to 15 m in height.

The morphology of the Panuke development area is dominated by an east-west trough which runs across the site (Figure 7.2-1).

About 5 km to the west of the Panuke site the water depth at the base of the trough is about 52 m (chart datum), whereas 4 km to the east, it is about 45 m. The proposed site is located on the southerly side of the trough, in a water depth of about 46 m.

To the north of the trough, the seafloor rises gently to a water depth of about 42 m, and then somewhat more steeply (1:50) to a water depth of 34 m at the north edge of the wellsite survey area. To the south, a smaller trough is located parallel to and 1.1 to 1.5 km distant from the main trough. The intervening ridge rises to a water depth of about 42 m. To the south of the minor trough, the seafloor rises gently to a depth of 36 m at the south edge of the wellsite survey area.

Like Panuke, the morphology of the Cohasset area is dominated by an east-west trough which runs across the site (Figure 7.2-1). The base of the trough is relatively level, with water depths between 40 m and 44 m, averaging 42 m. The proposed site is located on the southerly side of the trough, in a water depth of about 40 m.
To the north of the trough, the seafloor rises at a maximum slope of 1:40 to a water depth of about 32 m, descends gently to 38 m in an elongated depression, and then rises again to a water depth of 30 m at the north edge of the wellsite survey area. To the south, an elongated depression is located about 1.5 km distant from the site. The intervening ridge rises to a water depth of about 34 m.

The maximum seafloor slopes observed are in the order of 2 to 3 degrees. These are consistent with the maximum slopes observed regionally.

Along the planned flowline route, running between the Panuke well jacket and the Cohassett production facilities, the seabed profile is relatively smooth and gentle. The first 300 m of the route descends 1 m from the Panuke site to the base of the trough. Over the next 6000 m, the flowline route rises fairly steadily from a water depth of 48 m to 36 m, and then descends to 39 m at the Cohassett site over the final 1600 m of the route.

7.3

SURFICIAL GEOLOGY

This section discusses the geological history and the surficial geology of the study area.

7.3.1 GEOLOGICAL HISTORY

The geological history of the Scotian Shelf over the past 70 000 years began with the advance of a thick continental ice sheet, which may have extended to the shelf edge and was probably responsible for extensive glacial erosion of the underlying Tertiary and Cretaceous sediments (King and Fader, 1986). These events are marked on the outer shelf by the Pleistocene-Tertiary Unconformity. A general recession of the ice began to occur approximately 50 000 years before Pleistocene (BP) which led to the development of an extensive floating ice shelf, pinned by contact with the seabed in the shallow bank areas. During this stage, glacial drift and glaciomarine sediments
were laid down as subglacial deposits. Sometime during the mid-Wisconsinan (in the order of 33 000 to 38 000 years BP), the ice appears to have receded to the land areas and then re-advanced by 30 000 years BP to deposit glaciomarine sediments on the central Scotian Shelf.

The period between 16 000 and 10 000 years BP covers the time of lowest sea level, its subsequent transgression, and the disappearance of ice influence in the offshore. A prominent submarine terrace was cut sometime between 15 000 and 17 000 years BP at a depth of about 120 m below present sea level. The terrace indicates the beginning of the Late Wisconsinan-Holocene transgression during which time sediments between the old and present shorelines were modified in response to a high-energy beach environment, and during which time a Late Wisconsinan-Holocene unconformity was formed. As the transgression progressed across the outer banks, it produced large areas of clean, poorly graded sands and gravels, the winnowed fines being deposited in the basins. Subsequent developments during the Holocene and up to the present include the reworking of the sand deposits in response to the hydrodynamic regime to form the various bedforms found offshore today.

7.3.2 GEOLOGY

The major factors that dominated the surficial geological evolution of the Scotian Shelf are as follows:

- The morphology of the surface of the Mesozoic-Cenozoic sequence of sediments, which to a large degree was inherited from a former coastal plain environment

- The advance and retreat of the continental ice sheet and its boundary relationships with the ocean

- The low stand of the Late Wisconsinan sea level at about 120 m below the present, and its subsequent transgression
A thick sequence of Mesozoic-Cenozoic sediments underlies much of the Scotian Shelf. A stratigraphic framework for the sedimentary column is given by McIver (1972). He adopts the five informal formations of King (1970) to subdivide the Quaternary sequence of the Scotian Shelf: Sable Island Sand and Gravel, Emerald Silt, Sambro Sand, Lahave Clay, and Scotian Shelf Drift. It is unclear how the formations of King (1970) relate to the "Laurentian Formation" of Jansa and Wade (1974), which they define as consisting of glacial drift and stratified, subaerial, proglacial material.

On the banks of the Scotian Shelf, the Quaternary sequence may be represented by the following formations:

- Sable Island Sand and Gravel
- Emerald Silt
- Scotian Shelf Drift (King and Fader, 1986)

Recent work concentrating on Sable Island Bank to the southwest of Sable Island indicates that, in this area, Sable Island Sand and Gravel and Emerald Silt are to be found in the upper 80 m of the sedimentary column (Amos and Miller, 1989). It is unclear if Emerald Silt comprises the entire lower quaternary section. Amos and Miller (1989) take the Laurentian Formation to make up the lower portion of the Quaternary section.

The Sable Island Sand and Gravel Formation covers most of the present surface of Sable Island Bank, including the Cohasset and Panuke areas. Here the formation is 18 - 32 m thick (Amos and Nadeau, 1989) and is composed of sediments, originally mapped by Pezzetta (1962), which were considered by James and Stanley (1968) to be relict material, derived as glacial outwash during the Pleistocene era (Figure 7.3-1). By contrast, King (1970) interpreted the sediments to be post-glacial sand, reworked from glacial deposits laid down during the late Wisconsinan-Holocene transgression of the Scotian Shelf (King and Fader, 1986). Amos and Miller (1989) divide the Sable Island Sand and Gravel Formation into three members, based on the analysis of high resolution seismic surveys, vibrocores, and boreholes. They interpret
FIGURE 7.3-1

INTERPRETED DEPOSITIONAL PROFILE: COHASSET

APPROXIMATE DEPTH BELOW SEA LEVEL (M)

DISTANCE ALONG PROFILE (KM)

TWO-WAY TRAVEL TIME (MS)

TROUGH-BEDDED SAND
CROSS-BEDDED SAND
CONFORMABLY-BEDDED SAND
REGIONAL ACOUSTIC REFLECTOR
CHANNEL GRAVEL
UPPER STRATIFIED SANDFINES
BARREN GRAVELLY SAND
LOWER STRATIFIED SANDFINES
REGIONAL ACOUSTIC REFLECTOR
LAURENTIAN FORMATION
BANQUEREAU FORMATION (TERIARY)
the upper two members to have formed during post-transgressional, open-water conditions during the Holocene. The lowermost member they interpret to be glaciomarine in origin, and correlate it with the Younger Dryas event (11 000 to 10 000 years before present) described by Mott (1986).

The Emerald Silt Formation, a pro-glacial, mid to late Wisconsinan marine deposit, has been mapped principally in the basins of the Scotian Shelf. Amos and Knoll (1987) also identify it under much of Banquereau, where it underlies the Sable Island Sand and Gravel Formation. Amos and Miller (1989) identify Emerald Silt below the Sable Island Sand and Gravel Formation to the southwest of Sable Island in the region of Cohasset and Panuke, where they interpret it to be in the order of 60 m thick. There they divide the Emerald Silt Formation into four members. The uppermost member they interpret to be a glacio-fluvial deposit correlated with the late Wisconsinan low stand of sea level. The second member is characterized by open marine nearshore conditions at its top and ice-covered nearshore conditions at its base; The third member is a glacio-fluvial deposit formed during the mid-Wisconsinan low stand of sea level, and is correlated with the end of the Digby Stade (Grant and King, 1984). The lowermost member of the formation is interpreted to be glacio-marine in origin, deposited beneath an ice shelf, and is correlated with the Digby Stade. Only the uppermost and lowermost members were identified by Amos and Miller (1989) at Cohasset, whereas at Panuke all four members are identified.

A fault area was noted in the northwest corner of the Panuke wellsite survey area (McElhanney Services, 1985); however, the fault lies outside the Panuke field. No faults were noted in the Cohasset wellsite survey area (McGregor Geoscience, 1986).

The survey data show no evidence of slumps, unstable sediments, or marginally stable sediments.
7.4 SEABED SEDIMENT TRANSPORT

It is important to have an understanding of the sediment conditions of the Sable Island Bank area for the design of production facilities. The area surrounding Sable Island has long been assumed to be a region of constant bedform activity and "shifting sands." It has been shown, however, that these assumptions may not be strictly correct (Amos and Nadeau, 1989). For example, features previously identified as sand waves (James and Stanley, 1968) are actually sand ridges connected to the shoreline. Observations of shifting shoals are restricted to the region above the 20 m isobath, where sand transport is considered to be high.

There are few data on bedform activity. Geophysical records show existing conditions, but few observations on sediment transport exist. The methodology used by most researchers has been to first determine the regions where bedforms are known to exist, then to classify these bedforms, and finally to determine the magnitudes and probabilities of events that could lead to hazards for production facilities.

7.4.1 BEDFORMS

Bedforms are defined as any deviations from a flat seabed generated by flow over the bed. These deviations are formed by the erosional and constructive effects of sediment transport by waves or currents. Bedforms may be classified according to their creation and morphology (Amos and King, 1984). The primary subdivision is the direction of the feature relative to the forming mechanism; hence the bedforms are categorized as either flow-transverse or flow-parallel. Figure 7.4-1 is a schematic summary of the bedform classification system. The secondary subdivision is large-scale and small-scale, with the division set at 0.3 m.
BEDFORM CLASSIFICATION SYSTEM

BEDFORM

FLOW - TRANSVERSE

CURRENT-FORMED RIPPLES

FLOW - PARALLEL

WAVE-FORMED RIPPLES

MEGARIPPLES

SAND WAVES

SAND RIDGES

SAND RIBBONS

STORM RIDGES

TIDAL CURRENT RIDGES

NEARSHORE RIDGES

SHOREFACE RIDGES

OFFSHORE RIDGES

SHOREFACE-CONNECTED RIDGES

SUBMERGED BARRIER ISLANDS

FIGURE 7.4-1
Based on geophysical records and some visual observations, Sable Island Bank has been divided into eight broad zones (A, B, C, D, E₁, E₂, F, G) according to bathymetry and bedforms (Amos and Nadeau, 1989). These are shown in Figure 7.4-2 (from Amos and Nadeau, 1989). The zones within the Cohasset-Panuke development area are described briefly in the following paragraphs.

Zone B

Zone B is characterized by shoreface-connected ridges, but also has hummocky megaripples, sand ribbons, wave ripples, current ripples, and specks. This zone is considered to be beyond the influence of breaking waves, but subject to the influence of strong, wind-driven currents, which cause sand ridge migration. The orientation of the shoreface-connected ridges indicates a net transport of sediment from west to east.

Zone D

The largest zone on the southeastern portion of the bank, Zone D, is bounded approximately by the 100 m contour. It is characterized by offshore ridges of medium sand covering almost half its area. Small isolated storm ridges (1 m high, 1000 m long) have been found on sidescan sonograms. It is considered to be a region of low and intermittent sediment transport. Wave rippling of the bed that has been observed shows the periodic influence of waves.

Net sediment transport is clockwise and is driven by three circulation patterns:

(1) Wind-driven currents that move sediment northeast and east

(2) Geostrophic flows on eastern Sable Island Bank that move sediment towards the shelf edge

(3) Shelf edge geostrophic currents that transport sediment to the southwest
THE ZONATION OF BEDFORMS ON SABLE ISLAND BANK AND BANQUEREAU

A HIGHLY ENERGETIC WAVE ZONE: DEFINED AS AREA OF PLANE-BEDDED SANDS, WAVE-FORMED RIPPLES, AND SHORE-PARALLEL SAND BARS.

STORM-DOMINATED ENERGETIC ZONE, NEARSHORE: CHARACTERIZED BY SHOREFACE CONNECTED SAND RIDGES.

CURRENT-DOMINATED ENERGETIC ZONE, CHARACTERIZED BY MORIBUND AND ACTIVE SAND WAVES, AND ACTIVE MEGARIPPLES.

STORM-DOMINATED INTERMEDIATE-ENERGETIC ZONE, SHELF, CHARACTERIZED BY ACTIVE STORM RIDGES MIGRATING OVER LARGER SCALE OFFSHORE RIDGES.

LOW-ENERGY ZONE, SHELF, CHARACTERIZED BY LARGE SCALE RELICT OR MORIBUND WAVEFORMS, INCLUDING BATHYMETRY DEFINED OFFSHORE RIDGES.

LOW-ENERGY SHELF ZONE, SHELF EDGE (-100 M); CHARACTERIZED BY MORIBUND MEGARIPPLE FIELDS.

LOW-ENERGY ZONE, SHELF; DOMINATED BY SPECKS AND SHELL BEDS OVER FLAT, FEATURELESS SEABED.

QUIESCENT ZONE: FEATURELESS SAND, SILT, GRAVEL, BOULDER FIELDS, AND TRAWL MARKS.
As Figure 7.4-2 shows, the Cohasset and Panuke sites are located in Zones B and D, respectively, although they are only about 8 km apart. It must be recognized, however, that the boundaries between zones are approximate and do not signify a distinct change in seabed conditions, but rather indicate a gradational change from an area where one set of characteristics predominates to an area where another set predominates. Thus, in Zone B the sand ridges are for the most part shoreface-connected whereas in Zone D the ridges are mostly storm-created and migrate over large offshore ridges.

7.4.2 SEDIMENT TRANSPORT

Amos and Nadeau (1989) have formulated a model of the sand transport pathways on the Sable Island Bank (Figure 7.4-3) based on recent surveying and sand transport measurements. This model shows that the sands do not move clockwise around Sable Island as had previously been theorized, but instead move generally from west to east on both sides of the island, except for a smaller clockwise pattern centred 20 km to the southeast.

The region around the island is dominated by storms generated in Central and North America (Neu, 1982). The sediment transport rates can thus be compared to the eastern seaboard of the United States, where transport rates have been estimated at 0.014 m³/m/d (Vincent, 1981; Gadd, 1978). There has only been one study of sediment transport rates on Sable Island Bank (Amos, 1985), which determined a rate of 0.02 m³/m/d. The study locations were at Olympia to the north of the island and at Venture on the south side. Work specific to the Cohasset and Panuke sites is necessary to quantify sediment transport rates there.
INFERRED BEDLOAD TRANSPORT PATHS: SABLE ISLAND AREA

FIGURE 7.4-3
Empirical models are available to calculate sediment transport on continental shelves (reviewed by Seaconsult, 1984) but are not necessarily appropriate for the Sable Island Bank area. Typical input parameters needed to run these models include specific in situ current and wave data that are not yet available. Hindcast data can be used for these models, but cannot be as reliable as actual site-specific data.

7.4.2.1 Bedform Activity

The movement of seafloor sediments around Sable Island is of concern in the design of production facilities. Physical processes that affect bedform activity include storm-generated currents and waves over the banks, tidal currents around the island, and baroclinic flow at the bank margins. These processes have been documented and published only in part.

The potential impact of bedform activity on production facilities can occur in several ways. For example, bedforms can impact flowline installations as follows:

- Excessive flowline curvature due to bedform morphology
- Flowline bridging between bedform crests
- Exposure due to bedform migration

The bedforms that are of sufficient magnitude to affect a flowline or production facility are sand ridges and megaripples. Both of these types of bedforms have been observed in the development area.

It has been estimated that the rate of migration of the sand ridges on Sable Island Bank is less than 2.5 m/year (C.L. Amos, pers. comm.). Given the dimensions of these bedforms, this migration rate would have a relatively low impact on a flowline or production facility over the short term, but the long-term effects of migration require evaluation.
None of the wellsite surveys conducted on the Panuke and Cohasset fields (McElhanney Services, 1985; McGregor Geoscience, 1986) note megaripples. Amos and Nadeau (1989), however, state that megaripples are characteristic of Zones B and D in which the proposed development area is located. One observation of megaripples on the Cohasset site was made during winter storm conditions. These bedforms were seen to degrade as the storm waned (Amos and Nadeau, 1989). It is inferred that megaripples may be present on the sites during winter storms, but are not generally observed due to the difficulties of surveying under such conditions.

The type, size, and frequency of bedforms, and the conditions under which they are generated in the development area, are at present poorly understood. Some quantification of the parameters is required in order that rational design measures can be instituted to safeguard against the potential impacts of bedform activity.

7.4.2.2 **Scour**

A potential impact of sediment transport is scour around structure supports and wellhead facilities. Scour is directly related to seafloor currents and local currents rather than to bedform migration. Local accelerations of bottom currents due to the introduction of fixed platforms or other foreign objects into the hydrodynamic regime will upset the present equilibrium conditions temporarily. In response to the hydrodynamic changes, seafloor sands adjacent to the objects will be redistributed until a new equilibrium condition is established. In general, the redistribution results in erosion of the seabed adjacent to the foreign objects. Unless accounted for in design, this in turn can result in the loss of support for the structure or structural element.
Design measures to account for the possibility of scour generally take one of two approaches. In the first of these, attempts are made to modify the hydraulic characteristics of the seafloor so scouring will not occur. This involves armouring with material such as gravel, sandbags, or oyster shells, or introducing "artificial seaweed" or fibrous mats to trap sand. In the second approach, the depth to which scour will occur is predicted, and any elements that would be affected by such scour are placed below the scour level.

7.5 STRATIGRAPHY AND SOIL PROPERTIES

No soil borings have been conducted to date at the proposed Cohasset development site. For the purposes of this description, the development site is taken to be the proposed wellhead jacket location. Two soils investigations have taken place, however, in the nearby area. The first of these was conducted by Jacques/McClelland Geosciences Inc. on behalf of Petro-Canada Resources approximately 450 m at a bearing of 336° T from the proposed development site, at the Cohasset A-52 wellsite. The second was conducted by Jacques/McClelland Geosciences Inc. on behalf of Mobil Oil Canada, Ltd. approximately 675 m at a bearing of 52° T from the proposed development site, at the Cohasset D-42 wellsite.

Similarly, no soil borings have been conducted to date at the proposed Panuke development site. A boring was made at the Panuke F-99 wellsite by Jacques/McClelland Geosciences Inc., on behalf of Petro-Canada Resources and the Atlantic Geoscience Centre, approximately 2410 m at a bearing of 242° T from the proposed development site.

The geophysical data that are available for examination suggest that the stratigraphy is relatively uniform in a regional sense. It is judged, therefore, that the results from the geotechnical borings conducted at the wellsites are indicative of the conditions that can be expected at the respective development sites. This judgement is confirmed by the similarity in the soil strata revealed in the borings.
at the Cohasset A-52 and D-42 wellsites. Furthermore, when placed in the regional geologic context, there are clear similarities between the borings conducted at the Cohasset and Panuke wellsites, particularly in the upper 20 m.

7.5.1 COHASSET

The Cohasset D-42 investigation was conducted marginally farther from the development site than the Cohasset A-52 investigation. In addition, the data are less valuable due to somewhat less penetration of the boring into the seafloor, and a lack of advanced laboratory testing and analysis. The following paragraphs, therefore, are based primarily on the more detailed information available from the Cohasset A-52 geotechnical investigation.

7.5.1.1 Soil Boring Program: Cohasset A-52

The field work for the investigation was conducted during the period of December 11 to 20, 1985. The vessel was positioned into location using transit satellite and ARGO survey equipment, and was held on location during drilling operations with a dynamic positioning system.

The soil conditions were explored using a Failing 1500S drill rig positioned over the moonpool of the vessel. The borings were drilled as an open hole, with drilling mud used to carry away cuttings and to improve hole stability. Both polymer-based and bentonite-based fresh water gel were used as drilling fluids. Drilling fluids were mixed on board the vessel, and were not recirculated.

The standard wireline hammer was used when ground conditions precluded push sampling. The sampler was operated through the bore of the drill pipe after the boring had been advanced to the desired sampling depth. Where suitable ground conditions prevailed, samples were obtained with a latch-in push sampler.
Two borings were conducted on the site, as presented in Table 7.5-1.

**TABLE 7.5-1**

**COHASSET A-52 BORINGS**

<table>
<thead>
<tr>
<th>Boring</th>
<th>Location</th>
<th>Seafloor Elevation (m) (Chart Datum)</th>
<th>Penetration (m) From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43° 51' 06.60&quot; N 60° 37' 40.11&quot; W</td>
<td>-37.4 m 0</td>
<td>30.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>43° 51' 04.76&quot; N 60° 37' 38.16&quot; W</td>
<td>-40.2 m 29.0</td>
<td>46.2</td>
<td></td>
</tr>
</tbody>
</table>

The two borings were separated by less than 100 m. Samples were obtained at intervals of approximately 1 to 10 m penetration, approximately 1.5 to 30 m penetration, and approximately 2 m thereafter.

**7.5.1.2 Stratigraphy**

A generalized summary of the major strata encountered at the Cohasset A-52 wellsite, based on a composite of Borings 1 and 2, is given in Table 7.5-2. In order to provide the composite description of the stratigraphy, it has been assumed that the strata are flat lying and continuous. This assumption is based on the relatively small separation of the borings, the geophysical evidence, and experience in the region.
TABLE 7.5-2
COHASSET A-52: BORINGS 1 AND 2

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Elevation (m) (Chart Datum)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>-37.4 -45.9</td>
<td>Brown to dark grey fine sand</td>
</tr>
<tr>
<td>II</td>
<td>-45.9 -53.4</td>
<td>Grey medium to fine sand</td>
</tr>
<tr>
<td>III</td>
<td>-53.4 -62.2</td>
<td>Brown fine sand and silt</td>
</tr>
<tr>
<td>IV</td>
<td>-62.2 -64.9</td>
<td>Olive grey silty clay</td>
</tr>
<tr>
<td>V</td>
<td>-64.9 -74.5</td>
<td>Grey fine to medium sand</td>
</tr>
<tr>
<td>VI</td>
<td>-74.5 -80.5</td>
<td>Grey sand silt and silty sand</td>
</tr>
<tr>
<td>VII</td>
<td>-80.5 -86.7*</td>
<td>Brown to grey silty clay</td>
</tr>
</tbody>
</table>

*Termination of boring. Stratum may continue to greater depth.

**Stratum I**

Stratum I, extending from the seafloor to el. -45.9 m, is dark brown to dark grey, fine sand that contains occasional shell fragments. Occasional black, organic, silty, fine sand seams and partings were observed in the upper 4 m of the stratum. The sand is relatively clean with generally less than 5 percent by weight finer than 74 micrometres. The average water content of the sand is 24 percent. Microscopic examination of the sand grains from this stratum shows that they have a grain shape of angular to sub-rounded. Testing on a silty fine sand seam indicated a moisture content of 105 percent and size 25 percent finer than 74 micrometres.

**Stratum II**

Stratum II extends from el. -45.9 m to el. -53.4 m and consists of light to dark grey, medium to fine sand. It contains occasional shell fragments, pebbles, and organic black silty inclusions. The particles are less than 5 percent by weight finer than 74 micrometres, and have
an average moisture content of 25 percent. Microscopic examination of the sand grains from this stratum shows that they have a grain shape of sub-rounded to rounded.

**Stratum III**

Stratum III, which extends from el. -53.4 m to el. -62.2 m, is made up of dark olive brown to dark greyish brown, fine sand and silt. The stratum shows evidence of layering. The particles are 15 to 92 percent by weight finer than 74 micrometres, with an average of 51 percent on samples tested. The average moisture content was 26 percent. Silt layers are nonplastic. Microscopic examination of the sand grains from this stratum shows that they have a grain shape of sub-rounded to sub-angular.

**Stratum IV**

Stratum IV extends from el. -62.2 m to el. -64.9 m. It is composed of dark olive grey, silty clay with light brown silt partings. The silt and clay size particles vary from 91 to 99 percent by weight with an average of 94 percent in samples tested. Moisture content for this stratum varies from 29 to 33 percent with an average of 31 percent. Atterberg Limit tests indicate medium plasticity. The liquid limit ranges from 21 to 24 percent, averaging 23 percent. The clay is hard, with undrained shear strengths measured between 200 and 265 kPa, with an average of 233 kPa.

**Stratum V**

Stratum V, extending from el. -64.9 m to el. -74.5 m, is grey to dark olive grey, fine to medium sand with some gravel and silty clay seams. The proportion of soil finer than 74 micrometres varies from 4 to 18 percent by weight with an average of 10 percent in the samples tested. Particles coarser than 4.7 mm range from 0 to 60 percent by weight, with an average of 12 percent. Moisture content ranges from 18 to 26 percent, with an average of 22 percent.

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Stratum VI

Stratum VI is dark olive grey layers of sandy silt and silty sand with occasional clay seams, extending from el. -74.5 m to el. -80.5 m. The particles are 29 to 99 percent by weight finer than 74 micrometres, with an average of 72 percent on samples tested. The high value of this range is associated with a clay seam with a measured undrained shear strength of 100 to 135 kPa; otherwise, the fines are nonplastic. Moisture content is between 26 and 28 percent, with an average of 27 percent.

Stratum VII

Stratum VII extends from el. -80.5 m to at least el. -85.7 m. The boring was terminated on a probable boulder at el. -86.7 m. The stratum is composed of dark greyish brown to dark olive grey, silty clay. A silty sand seam was observed in the stratum, in addition to occasional silt partings. The silt and clay size particles generally vary in the range of 80 to 95 percent by weight with an average of 87 percent, although a value of 28 percent was measured in the sand seam. Moisture content was measured between 20 and 38 percent, with an average of 29 percent. The undrained shear strength of 345 kPa was determined, with an average of 140 kPa. These measured strengths indicate a very stiff to hard consistency.

7.5.1.3 Soil Properties

Granular Soils

The granular soils at the Cohasset A-52 site consist of Strata I, II, III, and V. Stratum VI is transitional. It is inferred that the strata become more dense with depth.

The shearing resistance of the granular soils was investigated by a series of multistage drained triaxial tests. This testing program was performed to evaluate the shear strength characteristics of the typical sands encountered at the site, over the probable range of...
densities that would occur in situ. Samples from different depths in the uppermost strata were combined on the basis of similarity of grain size distribution, to make up a batch size suitable for triaxial testing. The results of the testing program are summarized in Figures 7.5-1 to 7.5-3.

Figure 7.5-4 shows the angle of internal friction ($\phi_f$) plotted against porosity at the beginning of shear. The results of Groups B, C, and D fall within a continuum, and display a trend towards lower $\phi_f$ values with increasing porosity. This is a classic pattern. The higher $\phi_f$ values shown by Group D are mainly due to its lower porosity, which may be due to its broader gradation (Figure 7.5-3). The angles of friction for Group A are clearly separated from the others, possibly because the sand particles are the most angular.

Data for Brasted sand and Ham River sands (Cornforth, 1964; Bishop, 1966) are shown in Figure 7.5-4. Group A falls within the same range, whereas the other groups lie distinctly below. Since the Brasted and Ham River sands are well known, their properties may be said to be the norm, against which the Group A sand is judged to be normal, and Groups B, C, and D are judged to be of lower than typical shearing resistance.

Rowe's energy correction (Rowe, 1971) was applied to the test results. This correction accounts for the component of the angle of friction which represents the work done to change the sample volume during shear, and thus accounts for the effects of initial density and particle packing. For the four groups, the resulting angles of friction, $\phi_f$, were found to be in the range of $29.5^0$ to $30.4^0$. This narrow range indicates that the differences in the angle of internal friction are due primarily to differences in states of density and grain packing, and that the mineralogy of the grains is similar.
**SUMMARY OF COMBINED SAMPLES AND TESTING**

<table>
<thead>
<tr>
<th>COMBINED SAMPLE</th>
<th>GRAIN SIZE DISTRIBUTION</th>
<th>CID TRIAXIAL TEST (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% GRAVEL, 4.7 mm</td>
<td>% COARSE TO MEDIUM SAND, 0.425 mm – 4.7 mm</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>49</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**NOTES:**

1. COMBINED SAMPLE
2. STRATUM
3. SAMPLES

- A
- B
- C
- D

- I
- II
- III

- 1,2A,4,5,6
- 3A,3C,7
- 8A,9B,10,12
- 13B,14B,15

(2) GRAIN SIZE CURVE PRESENTED SEPARATELY

(3) R - ROUNDED
SR - SUBROUNDED
SA - SUBANGULAR
A - ANGULAR

(4) (A) CID - CONSOLIDATED ISOTROPICALLY AND DRAINED
(B) EFFECTIVE COHESION = C' = 0 KPA IN ALL CASES
(C) MULTISTAGE TESTS AT CONFINING PressURES OF 100 KPA, 200 KPA, AND 500 KPA
(D) CID RESULTS PRESENTED SEPARATELY

FIGURE 7.5-1
RESULTS OF GRAIN SIZE ANALYSIS A AND B

FIGURE 7.5-2
RESULTS OF GRAIN SIZE ANALYSIS C AND D

U.S. STANDARD SIEVE SIZE
OPENINGS IN INCHES
MESHES PER INCH

PERCENT PASSING

GRAIN SIZE (MM)

HYDROMETER
EQUIVALENT GRAIN SIZE (MM)

GRAVEL
SAND
SILT & CLAY

COARSE | FINE | COARSE | MEDIUM | FINE

COMBINED SAMPLE
- - - - GROUP C
- - - - GROUP D

STRATUM
II
III

SAMPLES
8A,9B,10,12
13B,14B,15

FIGURE 7.5-3
ANGLE OF INTERNAL FRICTION

![Graph showing the angle of internal friction versus porosity prior to shear with various lines and points indicating the range of angles for different samples.]

FIGURE 7.5-4
All of the failure envelopes exhibited slight degrees of curvature, indicating that the angle of friction decreases slightly with increasing confining pressure. This is consistent with observations made on a wide variety of sands.

Fine-Grained Soils

The cohesive soils at the Cohasset A-52 site consist of Strata IV and VII. Stratum VI is transitional. Grain size analyses performed on representative samples show that Stratum IV soil is slightly finer-grained than Stratum VII. Atterberg Limits for the samples indicate that the soils are of medium plasticity, classed as CL under the Unified Soil Classification System.

The strength of the clays was investigated by means of miniature laboratory vane and hand penetrometer tests. One sample was of sufficient size and quality for triaxial and oedometer consolidation testing.

The measured undrained shear strengths of the clays displayed a wide variation, ranging from a value of 34 kPa to 345 kPa, with no distinguishable trend. The low value is anomalous and probably reflects a sample disturbed during the drilling or sampling operations.

The strength data were analyzed for evidence of overconsolidation of the clays. Estimates of overconsolidation can be made using empirical correlations between undrained shear strength, consolidation stress, and overconsolidation ratio (OCR).

When the analysis was carried out for the cohesive samples, values of OCR between 3 and 9 were obtained, indicating that the strata are overconsolidated. The triaxial test and the one-dimensional consolidation test carried out on one of the samples, however, provide more direct evidence of the stress history of the sample and suggest that it is normally consolidated or very nearly so. It was concluded,
therefore, that the relationships are probably not applicable to the soils at the site, and appear to overestimate the OCR by a factor of approximately 3.

It is tentatively put forward, based on the above discussion, that Stratum IV has an OCR of 2 - 3, whereas Stratum VII is essentially normally consolidated. The evidence for this hypothesis is limited, and would bear further investigation in a future survey.

7.5.2 PANUKE

7.5.2.1 Soil Boring Program: Panuke F-99

The field work for the investigation was conducted during the period of April 13 to 17, 1987. The vessel was positioned into location using Miniranger, transit satellite, and ARGO survey equipment, and was held on location during drilling operations with a dynamic positioning system.

The soil conditions were explored using a Pailing 1500S drill rig positioned over the moonpool of the vessel. The borings were drilled as an open hole with drilling mud used to carry away cuttings and to improve hole stability. Bentonite-based fresh water gel was used as the drilling fluid. Drilling fluids were mixed on board the vessel, and were not recirculated.

The standard wireline hammer was used to obtain soil samples. The sampler was operated through the bore of the drill pipe after the boring had been advanced to the desired sampling depth.

The boring was drilled at latitude 43° 48' 26.4" N, longitude 60° 44' 36.3" W. The seafloor was measured on the drill string to be at a depth of el. -44.9 m with respect to chart datum. Samples were obtained at approximately 1 m to 15 m penetration, and at intervals of approximately 1.5 m thereafter.

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7.5.2.2 Stratigraphy

A generalized summary of the major strata encountered at the Panuke F-99 wellsight is given in Table 7.5-3.

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Elevation (m) (Chart Datum)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I &amp; II</td>
<td>-44.9 -54.8</td>
<td>Olive grey fine to medium sand</td>
</tr>
<tr>
<td>III</td>
<td>-54.8 -62.9</td>
<td>Grey fine to medium sand, some silt</td>
</tr>
<tr>
<td>IV</td>
<td>-62.9 -67.7</td>
<td>Greyish brown clay</td>
</tr>
<tr>
<td>V</td>
<td>-67.7 -75.4</td>
<td>Grey medium to coarse sand</td>
</tr>
<tr>
<td>VI</td>
<td>-75.4 -83.6</td>
<td>Reddish brown clay</td>
</tr>
<tr>
<td>VII</td>
<td>-83.6 -99.3</td>
<td>Reddish brown to dark grey clay</td>
</tr>
<tr>
<td>VIII</td>
<td>-99.3 -105.0*</td>
<td>Grey fine sand and clay</td>
</tr>
</tbody>
</table>

*Termination of boring. Stratum may continue to greater depth.

Strata I and II

The sampling and testing program conducted at the site did not distinguish differences in the samples in the interval from the seafloor to el. -54.8 m. This was a function of the purpose of the investigation and the level of detail required. The interval has been assigned a composite descriptor, Strata I and II, so that the underlying strata will retain correspondence to those observed at the Cohasset A-52 location. Strata I and II, extending from the seafloor to el. -54.8 m, is made up of olive grey fine to medium sand that contains occasional shell fragments and occasional gravel. The sand is relatively clean with particles generally less than 5 percent by weight finer than 74 micrometres. The water content of the sand is between 20 and 30 percent.
Stratum III

Stratum III, which extends from el. -54.8 m to el. -62.9 m, is made up of olive grey fine to medium sand, with some silt. The particles are 8 to 14 percent by weight finer than 74 micrometres on the samples tested. Moisture content ranges from 24 to 26 percent.

Stratum IV

Stratum IV extends from el. -62.9 m to el. -67.7 m. It is composed of greyish brown clay. The silt and clay size particles vary in the range of 80 to 97 percent by weight in samples tested. Moisture content for this stratum varied from 27 to 28 percent. Atterberg Limit tests indicate high plasticity. The clay is stiff, with undrained shear strengths measured between 80 and 220 kPa.

Stratum V

Stratum V, extending from el. -67.7 m to el. -75.4 m, is grey medium to coarse sand with a trace of some gravel. It is interbedded with very stiff to hard, greyish brown clay containing some gravel. The proportion of soil finer than 74 micrometres varies from 8 to 42 percent by weight in samples tested. Moisture content ranged from 11 to 36 percent.

Stratum VI

Stratum VI extends from el. -75.4 m to el. -83.1 m. The stratum is composed of reddish brown clay, interbedded with red fine silty sand. The silt and clay size particles vary from 23 to 96 percent by weight. Moisture content was between 21 and 24 percent. Undrained shear strengths, measured by hand penetrometer, were 230 kPa and greater. These measured strengths indicate a hard consistency.
Stratum VII

Stratum VII extends from el. -83.6 m to el. -99.3 m. The stratum is composed of reddish brown to dark olive grey clay. Silt and fine sand partings were common. Undrained shear strengths, measured by hand penetrometer, ranged from 180 to 320 kPa. These measured strengths indicate a very stiff to hard consistency. No other geotechnical tests were conducted on the samples from this stratum.

Stratum VIII

Stratum VIII extends from el. -99.3 m to at least el. -105.0 m, at which depth the boring was terminated. The stratum is composed of very dark grey to light grey fine sand and clay. The stratum is layered. No geotechnical tests were conducted on the samples from this stratum.

7.5.2.3 Soil Properties

The boring at the Panuke F-99 wellsite was made to assess the suitability of the site with respect to the placement of a jack-up drilling rig. Because of this restricted scope and purpose of the field work, no advanced laboratory testing was conducted on the samples. Lacking such test data, the geotechnical properties of the soils are not as well defined as for the soils at the Cohasset location. Parallels may be drawn between the properties for Strata I, II, and III at the two sites, and hence the data from these strata at the Cohasset site can be used to complement those from Panuke. The values of the geotechnical parameters of the remaining strata at the Panuke site are less certain.

7.5.3 SUMMARY OF SOIL PROPERTIES

The soils at the Cohasset A-52 and Panuke F-99 wellsites have been assigned geotechnical properties based on the results of testing, visual examination of the recovered samples, detailed analysis of the
drilling and sampling records, and our judgement. These properties are summarized in Tables 7.5-4 and 7.5-5. In using these properties in design calculations, the following must be considered:

(1) The samples were taken with relatively small diameter sample tubes, most were obtained by means of percussion sampling, and no in situ testing was conducted. Sample disturbance, therefore, cannot be discounted, and it was necessary to assign soil strengths based on inference as much as on actual measurement.

**TABLE 7.5-4**

**SUMMARY OF SOIL PROPERTIES: COHASSET A-52**

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Saturated Density (kN/m$^3$)</th>
<th>Angle of Internal Friction (degrees)</th>
<th>Undrained Shear Strength (kPa)</th>
<th>OCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>19 - 20</td>
<td>30 - 34</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>II</td>
<td>19 - 20</td>
<td>29 - 33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>III</td>
<td>19 - 20</td>
<td>31 - 35</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IV</td>
<td>19 - 20</td>
<td>-</td>
<td>150 - 250</td>
<td>2 - 3</td>
</tr>
<tr>
<td>V</td>
<td>19 - 20</td>
<td>35 - 39</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VI</td>
<td>19 - 20</td>
<td>32 - 36</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VII</td>
<td>19 - 20</td>
<td>-</td>
<td>150 - 250</td>
<td>1</td>
</tr>
</tbody>
</table>

**TABLE 7.5-5**

**SUMMARY OF SOIL PROPERTIES: PANUKE F-99**

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Saturated Density (kN/m$^3$)</th>
<th>Angle of Internal Friction (degrees)</th>
<th>Undrained Shear Strength (kPa)</th>
<th>OCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>I &amp; II</td>
<td>19 - 20</td>
<td>29 - 34</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>III</td>
<td>19 - 20</td>
<td>31 - 35</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IV</td>
<td>19 - 20</td>
<td>-</td>
<td>100 - 200</td>
<td>-</td>
</tr>
<tr>
<td>V</td>
<td>19 - 20</td>
<td>35 - 39</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VI</td>
<td>19 - 20</td>
<td>-</td>
<td>200 - 300</td>
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<td>VII</td>
<td>19 - 20</td>
<td>-</td>
<td>200 - 300</td>
<td>-</td>
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<td>VIII</td>
<td>19 - 20</td>
<td>35 - 39</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
(2) The soils data apply strictly to the boring locations. Some lateral variation in the properties of the strata should be expected between the boring locations and the proposed development sites.

(3) The knowledge of the soils at the wellsite is limited to the depth explored by the borings. Extrapolation of the soil properties to depths greater than this would be speculative.

(4) The soils from the Panuke borehole were not subjected to laboratory testing other than index tests conducted offshore. To assign values, judgement and inference have been more heavily relied on than would be normal. Accordingly, the values presented for the Panuke site should be used with caution.

7.5.4 CORRELATION OF STRATA WITH GEOLOGIC MODEL

Amos and Miller (1989) interpret the sediments from the seafloor to el. -61.5 at the Cohasset A-52 location and to el. -65 at the Panuke F-99 location to be the Sable Island Sand and Gravel Formation (Figures 7.5-5 and 7.5-6). Below this level, to the depth explored by the borings, they interpret the sediments to be the Emerald Silt Formation. These interpretations are based on grain size parameters, seismostratigraphy, and biostratigraphic data.

The base of the Sable Island Sand and Gravel Formation is demarcated by a regional reflector seen on high resolution sub-bottom profiles, and is taken by Amos and Miller (1989) to represent the late Wisconsinan-Holocene transgression surface. This correlates closely with the base of Stratum III at el. -62.2 m at Cohasset A-52 and at el. -62.9 m at Panuke F-99.
## COMPARISON OF BOREHOLE LOGS TO GEOLOGICAL MODEL

### COHASSET A-52

#### GEOTECHNICAL LOG

<table>
<thead>
<tr>
<th>ELEVATION (m)</th>
<th>STRATUM</th>
<th>BOREHOLE LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>--40--</td>
<td>STRATUM I: BROWN TO DARK GREY FINE SAND</td>
<td></td>
</tr>
<tr>
<td>--50--</td>
<td>STRATUM II: LIGHT TO DARK GREY MEDIUM TO FINE SAND</td>
<td></td>
</tr>
<tr>
<td>--60--</td>
<td>STRATUM III: DARK OLIVE BROWN TO DARK GREYISH BROWN FINE SAND AND SILT</td>
<td></td>
</tr>
<tr>
<td>--70--</td>
<td>STRATUM IV: OLIVE GREY SILTY CLAY</td>
<td></td>
</tr>
<tr>
<td>--80--</td>
<td>STRATUM V: GREY TO DARK OLIVE GREY FINE TO MEDIUM SAND</td>
<td></td>
</tr>
<tr>
<td>--90--</td>
<td>STRATUM VI: DARK OLIVE GREY LAYERS OF SANDY SILT AND SILTY SAND</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STRATUM VII: DARK GREYISH BROWN TO DARK OLIVE GREY SILTY CLAY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>END OF BORING</td>
<td></td>
</tr>
</tbody>
</table>

#### SEISMOSTRATIGRAPHIC LOG

<table>
<thead>
<tr>
<th>ELEVATION (m)</th>
<th>SEISMOSTRATIGRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>--40--</td>
<td>UNIT A: TROUGH-BEDDED SAND</td>
</tr>
<tr>
<td>--50--</td>
<td>UNIT B: CROSS-BEDDED SAND</td>
</tr>
<tr>
<td>--60--</td>
<td>UNIT C: CONFORMABLY-BEDDED SAND</td>
</tr>
<tr>
<td>--70--</td>
<td>UNIT D1: CHANNEL GRAVEL</td>
</tr>
<tr>
<td>--80--</td>
<td>UNIT E1: LOWER STRATIFIED SAND/FINES</td>
</tr>
<tr>
<td></td>
<td>END OF BORING</td>
</tr>
</tbody>
</table>

#### FIGURE 7.5-5
# COMPARISON OF BOREHOLE LOGS TO GEOLOGICAL MODEL

**PANUKE F-99**

<table>
<thead>
<tr>
<th>ELEVATION (M)</th>
<th>GEOTECHNICAL LOG</th>
<th>SEISMOSTRATIGRAPHIC LOG</th>
<th>GEOLOGICAL MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50</td>
<td>STRATUM I &amp; II: OLIVE GREY TO MEDIUM SAND</td>
<td>UNIT A: TROUGH-BEDDED SAND</td>
<td>SABLE ISLAND SAND AND GRAVEL</td>
</tr>
<tr>
<td>-60</td>
<td>STRATUM III: OLIVE GREY FINE TO MEDIUM SAND, SOME SILT</td>
<td>UNIT B: CROSS-BEDDED SAND</td>
<td></td>
</tr>
<tr>
<td>-70</td>
<td>STRATUM VI: GREYISH BROWN CLAY</td>
<td>UNIT C: CONFORMABLY-BEDDED SAND</td>
<td></td>
</tr>
<tr>
<td>-80</td>
<td>STRATUM V: GREY MEDIUM TO COARSE SAND INTERBEDDED WITH GREYISH BROWN CLAY, SOME GRAVEL</td>
<td>UNIT D1: CHANNEL GRAVEL (CLAY FACIES)</td>
<td></td>
</tr>
<tr>
<td>-90</td>
<td>STRATUM VI: REDDISH BROWN CLAY INTER-BEDDED WITH RED FINE SILTY SAND</td>
<td>UNIT D2: UPPER STRATIFIED SAND/FINES</td>
<td></td>
</tr>
<tr>
<td>-100</td>
<td>STRATUM VII: REDDISH BROWN TO DARK GREY CLAY WITH SOME SILT AND FINE SAND</td>
<td>BARREN GRAVELLY SAND</td>
<td>EMERALD SILT</td>
</tr>
<tr>
<td></td>
<td>STRATUM VIII: GREY FINE SAND AND CLAY</td>
<td>UNIT E2: LOWER STRATIFIED SAND/FINES</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>END OF BORING</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 7.5-6**
Amos and Miller (1989) divide the Sable Island Sand and Gravel Formation into three members: Unit A (trough-bedded sand), Unit B (cross-bedded sand), and Unit C (conformably-bedded sand). These units correspond roughly with Strata I, II, and III seen in the borings. The elevations of the boundaries between the strata differ from those between the geologic units by up to 3.5 m. These differences, however, can be accounted for by the different criteria used in geotechnical engineering and geology to define the layers. In the case of geotechnical engineering, soil properties such as relative density and particle size distribution are important considerations, and acoustic-seismic character and depositional environment are not taken directly into account.

In the area, Stratum IV is usually encountered at about el. -62. The stratum dips southward at roughly 1:1000, and so to the north it would be expected at a slightly higher elevation and to the south at a slightly lower elevation. The stratum has been observed to vary in thickness from less than 1 m to about 8 m. Occasionally the stratum is absent. This may be due to erosion during sea level transgression.

Experience shows that below about el. -65 m, the strata are quite variable on a regional basis. This character is also reflected in the seismic data. Comparison of Strata V through VIII in the Cohasset and Panuke boreholes illustrates this. The strata are, however, characteristically interbedded sands, silts, and clays, with the cohesive materials being very stiff to hard.

7.5.5 FACTORS OF SAFETY

The Canadian Standards Association has prepared a preliminary standard relating to the design of foundations of fixed offshore production structures (CSA, Preliminary Standard S472, Foundations, Part II - Code for the Design, Construction, and Installation of Fixed Offshore Production Structures). This document is not an adopted standard, and has only been issued as a Preliminary Standard for critical review. Nonetheless, the document provides valuable and generally accepted guidance on the topics of foundation design and factors of safety for
the Cohasset and Panuke structures. CAN/CSA Z187-M87, Offshore Flowlines also provides guidance for flowline right-of-way surveys and surficial geology exploration programs.

7.5.6 PILE DRIVEABILITY

After an onsite soil boring has been completed, pile driveability should be assessed to determine whether the piles can be driven to design penetration with the selected equipment.

A preliminary prediction of the ultimate axial capacity of single 1219 mm diameter, open-ended steel pipe piles indicates that the piles supporting the proposed jacket structure will have to penetrate to depths below the depth of the boreholes that have been drilled to date. Given the unknown nature of the soils between the limit of the boreholes and the founding level, and the sensitivity of the analyses to the geotechnical properties of the soils, it is not warranted to conduct a driveability assessment at this time. It is expected, however, that available equipment and methods will be able to achieve the required penetrations.

It should be noted that the borehole conducted at the Cohasset A-52 wellsite terminated on a probable boulder at a sub-seafloor depth of 46 m. It is unknown whether this boulder was an isolated obstacle at that particular location, or whether it is representative of a boulder layer of some areal extent. Driving piles onto boulders can cause pile damage and premature refusal. The investigation of the possible presence of boulders should be an objective of future borehole drilling on the site.
7.6 SEAFLOOR STABILITY

This section discusses seafloor stability including the following:

- Regional tectonics
- Regional seismicity
- Seismotectonic zone
- Seismic design parameters
- Soil liquefaction

7.6.1 REGIONAL TECTONICS

The Scotian Shelf is made up of a series of shallow basins inshore from a line of banks that lie along the shelf break. Emery and Uchupi (1972) suggest that this irregular bathymetry indicates glacial erosion guided by a preglacial fluvial topography; this geometry is in turn controlled by basement blocks containing thick mobile salt masses (Jansa and Wade, 1974).

Seismic reflection profiles and analyses have been completed for the Scotian Shelf region by many researchers. Reconstruction of the geologic history of the region suggests that at the end of Paleozoic time the land mass of the earth began to break up into the various continents. The separation of the North American and African continents began in Late Triassic and was completed by early Jurassic (Uchupi and Austin, 1979). Two different actions occurred near the study area. A translational motion was dominant along the southwestern side of the Grand Banks, and divergence or seafloor spreading occurred from the Laurentian Channel to Georges Bank. Rift structures and valleys resulted from this divergence, trending eastward along the Glooscap fault system (King, 1975).

The separation of the continents probably occurred along a northeast-trending basement hinge zone that divides the Scotian Basin into the ancient relatively stable platform and the subsiding basin. On seismic profiles the hinge zone appears as a series of faults or flexures in the basement rock; the gradient of the basement surface
increases from approximately 3° landward of the hinge to an average of 20° seaward of the hinge (Jansa and Wade, 1974; Uchupi and Austin, 1979). It has been found (Keen and Keen, 1974) that seismic velocities landward of the hinge are typical of continental crust, and that velocities on the seaward side are typical for oceanic crusts.

Sediment deposition has been occurring continuously on the Scotian Shelf area for about 200 million years resulting in about 10 000 metres of accumulation. Numerous growth faults have developed in the basement shales and salt formations parallel to the shelf edge because of the weight of the accumulated sediment. These faults provide evidence of the general geological instability and seaward movement of the entire shelf edge zone.

7.6.2 REGIONAL SEISMICITY

The eastern Canadian offshore region has a low to moderate level of seismic activity. Earthquakes of Richter magnitude 6 or higher (the level at which significant damage occurs) are extremely rare; the only such event known to have occurred in this region was the Grand Banks earthquake of 1929 (magnitude 7.2), which was centred at the mouth of the Laurentian Channel.

Figure 7.6-1 shows the epicentres of all known seismic events on the Canadian eastern continental shelf with magnitudes greater than 3 (from Atkinson, 1987). It is apparent from this figure that there are three areas of concentrated seismic activity: at Baffin Bay and the Labrador Shelf edge, and near the Laurentian Slope.

The most active zone on the eastern continental shelf is located about 300 km northeast of the Cohasset-Panuke development area at the mouth of the Laurentian Channel. This zone is usually called the Laurentian Slope (LSP) and is highlighted in Figure 7.6-2 (from Basham and Adams, 1982). Over half of the earthquakes in this region, including the 1929 Grand Banks earthquake, have had their epicentres within a 100 km x 35 km area of this zone.
SEISMIC SOURCE ZONES OF MODEL 1

FIGURE 7.6-1
The National Building Code of Canada (NBCC, 1985) provides seismic zoning maps and standards for earthquake-resistant design of structures onshore. The maps are based on the peak horizontal ground acceleration and velocity having a probability of exceedance of 10 percent in 50 years or $2.1 \times 10^{-3}$ per annum; this is equivalent to a recurrence interval of about 475 years. The earthquake source zones are as shown in Figure 7.6-3 for the eastern Canadian continental margin. The zones in which earthquakes of magnitude 7 are known to occur are the Laurentian Slope (LSP), Baffin Bay (BAB), and Labrador Shelf (LAB). These zones have been extended and modified by Basham (1983) to spread the seismic risk along the entire margin; the new zone is labelled ESX and includes the Cohasset-Panuke development area. The authors have suggested that the areas within the zone are susceptible to earthquakes of magnitude 7 at a rate of one per 1000 years per 1000 kilometres of margin. This model therefore implies that currently inactive areas of this zone are dormant and that earthquakes in active areas such as the Laurentian Slope are only delayed aftershocks of high-magnitude earthquakes (Basham and Adams, 1983).

The seismicity of the region has also been modelled by Atkinson et al. (1987) in the form of zones which are defined on the basis of geology and regional tectonics as well as historical earthquake distributions. The authors have formulated two different seismotectonic zoning models. The first is based on the assumption that future seismic events will follow historical patterns; the model is shown in Figure 7.6-3. The second model uses the same historical data but assumes that the probability of an earthquake is equal along the entire continental slope zone (Figure 7.6-4); this model therefore combines the Model 1 zones labelled LSP, SHELF, LAB, BBS, and BHN into one zone labelled ESX. Figure 7.6-4 also compares Model 2 with that of Basham and Adams; it can be seen that the models are quite similar, the main difference being the width of the continental margin zone.
ALTERNATIVE EARTHQUAKE SOURCE ZONE MODELS

(FROM BASHAM ET AL. 1983)
COMPARISON OF MODEL 2 WITH BASHAM AND ADAMS MODEL

(FROM ATKINSON ET AL. 1987)
The figure also includes the three most active zones from the NBCC 1985 model: Laurentian Slope (ISP), Baffin Bay (BAB), and Labrador Shelf (LAB).

7.6.4 SEISMIC DESIGN PARAMETERS

The seismicity for a particular site or region will be determined using a two-level approach, according to the recommendations of the American Petroleum Institute (1984).

The first level is termed the Strength Level Earthquake (SLE) and can be determined using a combination of the following:

- A probabilistic exposure analysis of the study area that considers the relative probability and ground motion contribution of earthquakes occurring in all source zones within the region.

- A deterministic assessment of all major historical earthquakes and known individual faults to account for local anomalies and potential special sources not otherwise considered. Earthquake exceedance predictions and analyses of representative accelerograms for the study area are acceptable parameters for this analysis though computed ground motion values are sensitive to the assumed attenuation relationship. The typical recurrence interval recommended for high seismic risk regions is 100 to 400 years.

The second level is the ground motion intensity of a Rare Intense Earthquake (RIE) which may have a recurrence interval of several hundred to a few thousand years. A deterministic approach will be used to select and analyze the intensity of representative rare intense earthquakes, based on the geologic and seismotectonic evaluations used in the SLE evaluation.

A similar approach is outlined in CSA Standard Z276-M1981 for site investigation requirements for LNG facilities.
The investigation will determine the Safe Shutdown Earthquake (SSE) and the Operating Base Earthquake (OBE), which is determined either probabilistically or deterministically as follows:

- Probabilistically determined earthquakes are defined as those that would produce ground motions with a mean recurrence interval of 10,000 years for the SSE and 475 years for the OBE.

- The deterministic approach will be used in regions where the uncertainties are difficult to quantify because of the lack of geological data. In this approach, the SSE is defined as the event that produces the maximum credible ground motion at the site based upon the seismology, geology, and seismic and geologic history of the site and region, and where the ground motion for the OBE is one-half of that determined for the SSE.

To establish the SLE, exceedance predictions for earthquake ground motions for the Cohasset-Panuke area are required to establish the probabilities and average return periods of peak ground accelerations and velocities. Representative accelerograms from earthquakes of magnitude 5 to 6 (Richter scale) at sites with conditions similar to the study area are required to determine the shape of the response spectra. An example of the use of these techniques is given by Foo and Crouse (1986) for the Hibernia development.

The RIE is determined from the maximum postulated near-field and far-field earthquake; both cases are required because the magnitude of the ground motion varies with the frequency. Typical events for an analysis of the Cohasset-Panuke area are a magnitude of 5 to 6 within 20 km and a magnitude of 7.2 to 7.5 centred on the Glooscap-Newfoundland Fracture Zone on the Laurentian Slope.

The Canadian Standards Association has prepared a preliminary standard for the determination of loads for fixed offshore structures (CSA Preliminary Standard S471 General Requirements, Environment and Loads, Part II - Code for the Design of Offshore Structure). This document is not an adopted standard and has only been issued as a
preliminary standard for critical review. Nonetheless, the document provides generally accepted guidance on the topic of design for seismic loadings. S471 and the COGIA hazard maps will be considered in the design of structures for the Cohasset and Panuke sites.

7.6.5 **SOIL LIQUEFACTION**

Soil liquefaction results from a build-up of excess pore pressure in the soil during an earthquake. Excess pore pressure causes a decrease in the strength that can be mobilized by a soil and can also cause an increase in the amount of post-event settlement.

The saturated sands and cohesionless silts of the Cohasset-Panuke study area may be susceptible to liquefaction under certain dynamic loading conditions. The extent of the liquefaction depends on the density of the soils, grain size distribution, soil structure, geologic age, previous strain, stress history, and intensity of the earthquake (Seed, 1979).

The liquefaction potential of a site can be evaluated using computer models that utilize the results of the OLE and SIE analyses. One such program is DESRA II (Martin, 1976; Lee, 1978), which can estimate increases in porewater pressure resulting from earthquake-induced shear stresses. The program can also model the redistribution of porewater pressure during and after the event. A simpler program developed by Atkinson (1984) is based on the work of Seed and Idriss (1983).

7.7 **SEAFLOOR FEATURES AND BOTTOM IMPEDIMENTS**

This section discusses the seafloor features and bottom impediments known to exist in the study area.

7.7.1 **SAND RIDGES**

The most prominent seafloor features in the area of the proposed development are the sand ridges. These large-scale bedforms are
discussed in more detail in Section 7.4. The rate of migration of these features is estimated to be less than 2.5 m per year to the south (C.L. Amos, pers. comm.). Where the seabed slope is 3°, this rate corresponds to a mean change of seafloor elevation of 0.13 m/year, and correspondingly less change at locations where the slopes are less. The reliability of this estimate, however, has never been tested with field observations on Sable Island Bank.

The migration process of the sand ridges involves the erosion of sand material from the northern flank of a ridge and deposition on the southern flank. Evidence of this process has been noted on the sidescan sonar records from the wellsite surveys (McElhanney Services, 1985; McGregor Geoscience, 1986). The evidence appears in the form of sharp boundaries of sediment grain size (Figure 7.7-1). These boundaries are aligned east-west, and correspond with the troughs of the sand ridges. On the sidescan sonar records, finer-grained sand occurs at the seafloor to the north of these boundaries, abruptly changing to coarser-grained material south of the boundary and gradually becoming finer in the southerly direction. The coarser material in the troughs is residual lag left from the transport of finer sand to the south. The finer material immediately to the north of the boundaries has been transported there from the upstream trough, and hence overlies lag material.

7.7.2 **CANTAT II TELECOMMUNICATION CABLE**

The only man-made feature noted in the wellsite survey reports, other than the wellheads, is the CANTAT II telecommunication cable, operated by Teleglobe Canada. The cable is shown on navigation charts as noted on Figure 7.7-1. It was located by magnetometer as much as 200 m from the chart location (McElhanney Services, 1985). The cable is only shallowly buried, and in several instances is exposed at the seafloor.

7.7.3 **PALEO-CHANNEL**

The wellsite survey report for Cohasset identified an infilled channel running roughly north–south across the site. The position of this
subsurface feature is shown on Figure 7.7-1. The feature is also shown in profile in Figure 7.3-1. The channel is seen from about 30 m to 90 m below the seafloor, and is overlain by younger materials. (Note: In Figure 7.3-1, the Cohasset A-52 wellhead is shown within the channel boundaries, whereas in Figure 7.7-1, the wellhead appears to the west of channel. Figure 7.3-1 may be in error in this respect due to inaccurate navigation.)

7.7.4 SHALLOW GAS

The possible occurrence of shallow gas was noted in the Cohasset wellsite survey, 1280 m to the northwest of the A-52 drilling location (McGregor Geoscience, 1986). The possible gas zone was seen at a depth of 94 to 108 m below the seafloor, in a zone 52 to 55 m thick. This zone corresponds roughly to the base of the paleo-channel discussed in the preceding section. It is not known whether there is any significance to this.

No shallow gas was noted within the Panuke wellsite survey area.

7.7.5 FAULTS

A fault area was noted in the northwest corner of the Panuke wellsite area (McElhanney Services, 1985); however, the fault lies outside the Panuke field.

7.7.6 OTHER FEATURES

Other than the large-scale sand ridges, the only bedforms observed in the Cohasset-Panuke area are sand ribbons and wave ripples. The sand ribbons may be indicators of periodic high bottom currents. Megaripples have not been observed, although it has been postulated that megaripples form during storms and degrade as the storm spins down (C.L. Amos, pers. comm.). According to one theory, surveying cannot be conducted during such storms and therefore the features are not observed. Sandwaves have neither been observed nor postulated in the Cohasset-Panuke area.
SEABED FEATURES

LEGEND

- ABRUPT CONTACT BETWEEN GRANULAR MATERIALS OF DIFFERING GRAIN SIZES
- PALEO-CHANNEL BOUNDARY

SCALE 1:50,000
No evidence has been observed that boulder beds, ice pits, hydrates, permafrost, slumps or slides, density or turbidity flows, mud volcanoes, seafloor subsidence, or pock marks are present within the development area.

7.8 **ICEBERGS AND ICEBERG SCOUR**

Icebergs found along the east coast of Canada during the spring and summer months originate from the glaciers of Greenland and Baffin Island. Large blocks of ice break off from land-based parent glaciers and are carried southward by ocean currents. As they slowly drift along the east coast, they are subjected to increasingly higher air and water temperatures that cause them to gradually deteriorate by melting and calving.

Normal iceberg drift patterns are shown in Figure 7.8-1. In an average year 15,000 icebergs drift southward through Baffin Bay, 1000 pass the Strait of Belle Isle between Labrador and the Island of Newfoundland, and 400 cross 48° N latitude onto the Grand Banks of Newfoundland (Dinsmore, 1972). Very few icebergs survive beyond the limits of the Grand Banks; only one iceberg has been sighted on the Scotian Shelf in the last 60 years (Markham, 1980). There were, however, nine other reported sightings within a 300 km radius of the Cohasset-Panuke study area between the years 1913 and 1923, perhaps due to the higher ship traffic during World War II or the sinking of the Titanic cruise ship after a collision with an iceberg. These sightings are considered to be exceptional and not a large enough sample for statistical analysis.

7.9 **DESIGN CRITERIA**

This section discusses criteria, codes, and standards that will apply to the design of the pile foundations for the proposed jacket structures. The requirements for foundation analysis of the jack-up spud cans, while less detailed, are also discussed.
ICEBERG DRIFT PATTERNS OFF THE CANADIAN EAST COAST

FIGURE 7.8-1
Accepted practice is to employ the document API RP2A "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms" (API, 1984). The Canadian Standards Association (CSA) code that is currently being prepared, "Code for the Design, Construction, and Installation of Fixed Offshore Production Structures," will also be adhered to. Regulations are also currently being prepared by COGIA, and will be issued as "COGIA Production Installations Regulations."

The following paragraphs give a brief description of the geotechnical design criteria.

**Engineering Properties**

Parameters will be based on site investigation, and selected to consider geological history, in situ stresses, temperature, pore water and gas chemistry, soil fabric, density, composition, loading paths, rates, and cyclic processes.

**Factor of Safety**

Within the overall requirement to ensure safe operations, either required overall factors of safety or appropriate resistance factors will be stated in the design documents. These will provide a margin of safety against failure; they will not specifically provide a margin against excessive movements.

**Deformations**

Deformation response will be within the limits required for the structure to fulfil its intended purpose. These limits will include horizontal and vertical deflections and rotations.
Failure Method of Analysis

The analyses will examine the stability of the foundation units and the stability of the seabed as it may affect the structure (i.e., slope stability, liquefaction). The methods will be compatible with all potential failure modes and will normally be based on mathematical analysis support by precedent.

Deformation Method of Analysis

The methods will be compatible with anticipated mechanisms, material properties, and loads, and will be based on mathematical analysis, empirical relationships, or combinations of these.

Axial Capacity, Single Pile

Capacity of the pile will be based on combined shaft resistance plus toe resistance. The diameter and penetration will be made sufficient to resist both compression and tensile loads. Static equilibrium methods will normally be used. Pile load tests or empirical correlations are not likely to be available for this site.

Single Pile Lateral Capacity

Capacity of the pile will be based on static equilibrium methods. Allowable pile head deflection will normally govern design.

Single Pile Lateral Deformation

Load deflection analyses are iterative procedures which account for pile-head restraints, properties of the pile, and properties of the supporting soil, including nonlinear soil response.

Pile Load Tests

Pile load tests will not be run for this project.
Pile Dynamic Measurements

Dynamic measurements made during pile driving may be used for the design process, but will not form the sole basis for design.

Pile Group Action

The effects of neighbouring piles on soil resistance and stiffness (group effects) will be taken into account in both axial and lateral analyses. For the proposed structures, pile spacing will likely be great enough to eliminate group effects.

Scour

Engineering studies will be performed to evaluate the scour potential and protection methods for the wellhead jackets, the jack-up drilling and production unit and the subsea flowlines and loading lines.

Pile Wall Thickness

The required wall thickness will be based on allowable stresses during installation and service, and premature pile refusal will be taken into account.

Pile Driveability

A driveability study will be conducted to evaluate whether the pile can be driven to the design penetration with the selected equipment and within the allowable driving stresses, and to develop a contingency plan to ensure that adequate penetration is achieved.
Pile Installation

Installation procedures will be included in the design process to ensure that penetration can be achieved, that pile add-on sections and connections are adequate for the design and compatible with the procedure, and that installation records and monitoring procedures can be designed to meet any requirements identified by the designer.

Pile Hammers

The influence of the hammers to be used will be evaluated as part of the design process. If alternative hammers are proposed by the erector, their use will be shown to be consistent with the design.

Spud Can Bearing Capacity

Spud cans will be treated as shallow foundations, and bearing capacity will be evaluated using general theories of bearing capacity, modified to account for variations such as layered soil profiles and horizontal load components. The effects of scour on reduction of bearing capacity and embedment of spud cans for scour protection will be considered in the analyses. The effects of seabed irregularities, including old spud can footprints, will also be considered.

Abandonment, Removal

The design of the foundation will include consideration of decommissioning, abandonment, or removal.
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8.1 INTRODUCTION

This section of the Application is an Environmental Assessment of the Cohasset/Panuke Development Project (Figure 8.1-1) and has been prepared following draft guidelines from the Canada Nova Scotia Offshore Petroleum Board (CNSOPB).

The development of hydrocarbons on the Scotian Shelf has previously undergone a thorough public review for biophysical and socio-economic impacts during the Federal Environmental Assessment Review Office (FEARO) review of the proposed Venture Development Project (FEARO 1983). While there are many similarities between the proposed Venture Development Project and the proposed Cohasset/Panuke Development Project, there are important differences that have a direct bearing on the magnitude and nature of the potential impacts. This assessment has been prepared giving due consideration to the conclusions and recommendations of FEARO (1983), information collected from the Venture Environmental Impact Statement (Mobil 1983a, 1983b, 1983c) and the relevant information from the Cohasset/Panuke Project.

This assessment is presented in ten sections. Following this introduction, the project facilities and activities are summarized in the context of components likely to interact with the environment (Section 8.2). This is followed by a summary of the existing environment (Section 8.3) and the identification of environmental issues (Section 8.4). Valued Ecosystem Components are identified in Section 8.5 and study boundaries are described in Section 8.6. The identification and analysis of impacts are presented in Section 8.7 and mitigative measures in Section 8.8. Section 8.9 outlines a monitoring framework for the development. The literature cited in this assessment is listed in Section 8.10.
Location of Cohasset / Panuke Development Project

NEW BRUNSWICK

CAPE BRETON ISLAND

NEWFOUNDLAND

Source: Canadian Hydrographic Service 1978

FIGURE 8.1-1
The assessment addresses the potential impacts of the project on the environment. It encompasses the biophysical and biological environment and the resource-harvesting components of the offshore fisheries. Impacts of the environment on the project are addressed in the Development Application, Section 6 (Meteorology and Oceanography) and Section 7 (Geotechnical Engineering). The social and economic aspects of this project are addressed in Section 9 (Socio-Economic Considerations).

The development of the Cohasset and Panuke fields will provide fiscal and employment opportunities for Nova Scotia and Canada without endangering the long-term viability of renewable resources on sensitive ecosystems such as the fishery and Sable Island respectively. With implementation of appropriate environmental policies and procedures, this project can be developed, operated, and abandoned without significant long-term environmental impacts.

**PROJECT DESCRIPTION**

LASMO Nova Scotia Limited proposes to develop and produce condensate (light oil) concurrently from two adjacent fields, Cohasset and Panuke, located offshore Nova Scotia, Canada on the Sable Island Bank approximately 40 km west-southwest of Sable Island.

Using existing technology and proven methods for construction, operation, and abandonment, it will be possible to produce an estimated $5.6 \times 10^6$ m$^3$ of condensate from the Cohasset and Panuke fields. With adequate planning and implementation, the project can be undertaken with minimal negative impacts on the natural environment or on resource use activities.

This section provides a general project description with respect to those aspects with the potential for interaction with the biophysical environment.
8.2.1 PROJECT COMPONENTS

The project comprises seven components (Figure 8.2-1):

- wellhead jackets
- jack-up drilling and production unit
- subsea flowlines
- storage vessel mooring and offloading system
- floating storage vessel
- export system
- project supply and support system

These are described in the following subsections.

8.2.1.1 Wellhead Jackets

Wells at both fields will be drilled through wellhead jackets (Figure 8.2-2) located 9 km apart. These structural steel platforms provide lateral support to the drilling conductors and vertical support to deck facilities. The wellhead jackets will be secured in place by piles driven into the seabed.

The Cohasset wellhead jacket will include a production manifold, flowline isolating valves, and a heat exchanger to warm incoming Panuke fluids. The Panuke wellhead jacket will incorporate a boat landing and helideck for access to the Panuke wellheads.

8.2.1.2 Jack-Up Drilling and Production Unit

The production facilities and ancillary support systems will be located on a jack-up drilling unit located adjacent to the Cohasset wellhead jacket (Figure 8.2-3). A pipe and conduit rack will interconnect the wellhead jacket structure with the production facilities on the drilling unit. The production unit comprises
process facilities and ancillary systems. These facilities and systems are described in the following sections.

Process Facilities

The fluid recovered from production wells is a mixture of condensate, gas and water. Process facilities to separate, handle, and treat these components consist of the production separation, well test, condensate transfer, and produced water treatment systems.

Production Separation. The production separation system uses pressure (under controlled temperature) to separate out the production fluid constituents. It will consist of a two-stage process, one operating at 554 kPa(g), the other at 71 kPa(g). The separation products will be condensate, liberated gas (which will be flared), and produced water.

Well Test System. The well test facilities will consist of a test separator and a heater. The test separator will meter the production from one well at a time for well test purposes. The heater is necessary to achieve the required test-separator temperature for produced fluids from the Panuke wells.

The test separator will operate at a pressure of 554 kPa(g) and separate the condensate, liberated gas, and produced water for measurement, after which the products will be mixed with those of the production separation process. For testing the Panuke field wells, producing wells will be shut in and the production from the test well will flow through the flowline to the test separator.

Condensate Transfer. Stabilized condensate will be transferred to the floating storage vessel through a subsea transfer line and a catenary anchor leg mooring (CAIM) system. The transfer system will
be designed and operated to minimize the frequency and magnitude of potential spills.

Produced Water Treatment System. The produced water treatment system will collect water from the production separators, the test separator, and the drain separator. The water will pass through a flash drum, where volatile hydrocarbons (flash gas) are separated. Hydrocarbon concentrations in the water will be reduced to the regulated level before the produced water is discharged to the sea. The liquid hydrocarbons that are recovered from the produced water will be directed to a skimmed oil tank and recycled back to the inlet of the production separators.

Ancillary Systems

Ancillary systems required to support the operation of the production facilities will be placed on the jack-up unit. Those pertinent to the identification and analysis of impacts include water injection, well control, well kill, drain, gas, flare, chemical storage, and topsides safety systems.

Water Injection System. Disinfected and filtered seawater will be injected into the formation to maintain reservoir pressure. The flow rate will depend on the reservoir characteristics found.

Well Control System. The well control system will employ hydraulic pressure and a system of valves to counter and control the effect of formation pressures. The well control system will consist of a wellhead hydraulic control unit common to all wells, and electronically operated valves designed to operate in a fail-safe mode at each wellhead. The remote Panuke production wellheads will be controlled by pilot-operated hydraulic valves also configured in a fail-safe mode.
Well Kill System. The well kill system is an emergency back-up which delivers a reserve of seawater to the well. Through manifolding to the water injection system, the drilling rig mud pumps, and the cementing unit, the well kill system will be capable of injecting other fluids into a well as required.

Drain System. The operation of pumps, motors, and other mechanical and electrical equipment will result in the production of small quantities of waste liquids, including oils and lubricants that drain, leak, or spill from equipment during installation, operation, and maintenance. On the jack-up unit, a system of drain sumps will serve to collect these waste liquids from under the production separators, the test separator, and at the wellhead and manifold area. The liquids will be transferred to a drain separator where liquid hydrocarbons will be returned to the Stage 1 separator, and water to the produced water system. The system will be capable of handling and treating volumes generated by normal levels of activity; however, each sump and the drain separator will have overflows which will function in cases of very heavy rains or operation of the fire prevention sprinkler system.

Chemical Storage. A limited number of chemicals are required to support the drilling and production operations. Corrosion inhibitors, bacteriocides, and oxygen scavengers are used in the injection water system. Scaling inhibitors, foam inhibitors, and demulsifiers are employed for condensate processing.

These chemicals will be handled, stored, and transported in accordance with required safety procedures and regulations. They will be kept in small individual volumes (1.4-m³ portable tanks) and extracted directly from the tanks when required.

Topside Safety Systems. Topside safety systems will be provided for the protection of human life as well as the physical structure. Such systems will include emergency shut-down, emergency power,
8.2.1.3 Subsea Flowlines

A series of flowlines and subsea control lines will be positioned on the seafloor to interconnect project facilities. Production fluids will be transported along flowlines laid on the seabed and running from wellheads to the production facility. Stabilized condensate will be transported via a flowline from the production facility to the storage tanker. A water injection line will run from the Cohasset production facility to the Panuke injection well. Electric and hydraulic control cables will be installed between the Cohasset and Panuke wellhead jackets. Remote (microwave) control of the Panuke wellheads and manifold is also under review.

The Panuke wells will be interconnected to the Cohasset production facilities by a hydraulic hose bundle, a production line, and a water injection line. A submarine electric power cable may also be installed. This flowline system will be designed with flow and pressure monitoring to provide early detection of leaks. Valving will be provided to isolate this system.

8.2.1.4 Storage Vessel Mooring and Offloading System

The offloading system (Figure 8.2-4) will be a catenary anchor leg mooring (CALM) system consisting of a cylindrical buoy anchored by six or more radial mooring lines. A flexible semi-buoyant riser will connect the pipeline to the buoy. The buoy will be equipped with a turntable to allow the storage tanker to weathervane 360 degrees around the buoy.

While tanker operations will be conducted primarily from April through October, the CALM system will remain in place year-round.

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8.2.1.5 Floating Storage Vessel

A 60,000 DWT (dead weight ton) to 120,000 DWT tanker will be moored to the CAIM buoy throughout the operating season (Figure 8.2-4). The tanker will have the capability to store 10 to 30 days production volume. During producing operations, the storage tanker will remain under power and employ onboard dynamic positioning to weathervane into the prevailing wind and seas, thereby reducing the loading on the CAIM buoy. The specific tanker size selected will depend on market destinations.

The storage operation will be seasonal, and the vessel will be removed during the winter months (November to March). The annual decision on the exact date to suspend operations will be made on the basis of prevailing weather conditions.

8.2.1.6 Export System

Condensate will be transferred from the storage vessel to a shuttle tanker through a floating hose arrangement as shown in Figure 8.2-5. The shuttle tanker 40,000 to 80,000 DWT will transport the stabilized condensate to final market destinations.

8.2.1.7 Project Supply and Support System

An onshore supply and support base will be selected on mainland Nova Scotia. Existing dock and storage/warehousing facilities are available for purchase or lease, and thus, no new construction is expected to be required.

8.2.2 PROJECT ACTIVITIES

The project activities can be divided into four phases:
STORAGE VESSEL OFFLOADING

SHUTTLE TANKER

CENTER CENTER CENTER CENTER
CARGO CARGO CARGO CARGO
TANK 4 TANK 3 TANK 2 TANK 1

HAWSER

STORAGE TANKER

CENTER CENTER
CARGO CARGO
TANK 7 TANK 6

ENGINE ROOM

FLOATING HOSE

STERN MANIFOLD

PUMP ROOM

PROFILE

PROTECTIVELY LOCATED
SEGREGATED BALLAST
WING TANKS

BALLAST

BOW MANIFOLD

MIDSHIP MANIFOLD

PICK-UP ROPE
REEL

CHAIN STOPPER

HOSE RACK
- Construction and installation
- Drilling and completion
- Production
- Abandonment

The proposed scheduling of these phases is shown in Figure 8.2-6. Construction and installation activities will take place between mid-1990 and early 1992. Drilling and completion will occur intermittently between mid-1991 and early 1993. The fields will be in production from 1992 to 1997. Abandonment will take place in the final year. These four phases are described in the following subsections.

8.2.2.1 Construction and Installation

Wellhead Jackets, Production System, and Jack-Up Drilling and Production Unit

The wellhead jackets will be fabricated at existing onshore facilities. When completed, they will be barged to location and installed using either a derrick barge or the jack-up drilling rig. The development of specific installation plans is yet to be concluded.

The production process system will be manufactured, fabricated, assembled, and delivered to Halifax. This system will be installed on the production jack-up rig at an in-port location. The selected jack-up rig would also be modified at an inshore location prior to installation of the production equipment.

Flowlines

Flowlines will be laid by a reel barge and will rest on the seafloor. They will be anchored to the wellhead jacket at the Panuke end and the riser base at the Cohasset end.
PROPOSED SCHEDULE – COHASSET/PANUKE DEVELOPMENT PROJECT

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FIGURE 8.2-6
Mooring and Offloading System

The CALM buoy (of proprietary design) would possibly be fabricated in Canada. The specialized mooring chains, hawsers, floating hoses, etc., would be sourced internationally. Installation would require a special tug with crane capacity and a diving spread.

Floating Storage

An existing tanker with a segregated ballast system will be used. Several modifications including equipment for mooring to the loading buoy and shuttle tanker, for loading and discharging condensate, and perhaps thrusters to provide assistance for station keeping will be completed.

8.2.2.2 Drilling and Completion

Well Particulars and Drilling Method

Eleven wells are proposed for the development. Five producing wells and two injection wells will be drilled at Cohasset. Three producing wells and one injection well will be drilled at Panuke. The Cohasset wellhead jacket may contain extra well slots. The wells will be drilled from the jack-up unit located over the wellhead jacket. The Panuke wells may be drilled first. All wells will be drilled using water-based drilling mud. The use of low toxicity oil-based muds is currently under review and the impacts will be presented in an addendum if their use is likely. Conductor pipe and casing will run back to surface, where blowout preventers will be installed. Directional drilling methods will be used for several of the extended wells.
Drilling Duration

Between 21 and 23 days will be required to drill and complete each well. The cumulative time required to move, drill, and complete all wells is approximately 90 days for the Panuke reservoir and 142 days for the Cohasset reservoir, for a total of 232 days.

Cementing Program

Casings will be cemented in place using cement with extender and retarder additives, as required.

Completion Methods

Panuke production wells will be capable of natural flow for four years, after which electric submersible or hydraulic pumps will be required. Production in both the flowing and pumping modes will be through tubing inside a casing.

All five Cohasset production wells will require pumping from the start of production, so these wells will be equipped with electrical submersible pumps at the time of initial completion. Production equipment will be similar to Panuke.

Drilling and Completion Fluids

Fluids associated with drilling and completion activities and which may be released into the environment include drilling fluids, completion fluids, packer fluids, workover fluids, and kill fluids. The composition and volume of these fluids are shown in Tables 8.2-1 and 8.2-2.
### TABLE 8.2-1
TYPICAL COMPOSITION OF DRILLING MUDS

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<tr>
<th>Drilling Mud Type</th>
<th>Major Components</th>
<th>Used Rate in Whole Mud (kg/m²)</th>
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<tr>
<td><strong>Seawater gel mud</strong></td>
<td>Drilled solids</td>
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<td></td>
<td>Barite</td>
<td>0-140</td>
</tr>
<tr>
<td></td>
<td>Bentonite/Attapulgite</td>
<td>30-140</td>
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<td></td>
<td>Caustic (NaOH)</td>
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<tr>
<td></td>
<td>Cellulose Polymer</td>
<td>0-6</td>
</tr>
<tr>
<td></td>
<td>Lime</td>
<td>0-6</td>
</tr>
<tr>
<td></td>
<td>Soda Ash/Sodium Bicarbonate</td>
<td>0-6</td>
</tr>
<tr>
<td></td>
<td>Seawater</td>
<td>As needed</td>
</tr>
<tr>
<td><strong>KCl/polymer mud</strong></td>
<td>Barite</td>
<td>0-1280</td>
</tr>
<tr>
<td></td>
<td>Drilled SOLIDS</td>
<td>60-280</td>
</tr>
<tr>
<td></td>
<td>KCl</td>
<td>15-140</td>
</tr>
<tr>
<td></td>
<td>Starch</td>
<td>6-35</td>
</tr>
<tr>
<td></td>
<td>Cellulose Polymer</td>
<td>1-15</td>
</tr>
<tr>
<td></td>
<td>Caustic (NaOH)</td>
<td>1-9</td>
</tr>
<tr>
<td></td>
<td>Xanthum Gum Polymer</td>
<td>1-6</td>
</tr>
<tr>
<td></td>
<td>Seawater</td>
<td>As needed</td>
</tr>
</tbody>
</table>

Source: Adapted from Thomas et al. (1984).
TABLE 8.2-2
TYPICAL COMPOSITION OF OTHER WELL FLUIDS

<table>
<thead>
<tr>
<th>Fluid Type</th>
<th>Major Components</th>
<th>Dosage/Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completion Fluids</td>
<td>Calcium chloride</td>
<td>As needed</td>
</tr>
<tr>
<td>Clear Fluids</td>
<td>Sodium chloride</td>
<td></td>
</tr>
<tr>
<td>Viscosifiers and</td>
<td>Xanthum gum</td>
<td>10-40 kg/m³</td>
</tr>
<tr>
<td>Filtrate Control</td>
<td>Calcium carbonate</td>
<td></td>
</tr>
<tr>
<td>Corrosion Inhibitors</td>
<td>Amines</td>
<td>10-40 kg/m³</td>
</tr>
<tr>
<td>Biocides</td>
<td>Paraformaldehyde</td>
<td></td>
</tr>
<tr>
<td>Defoamers</td>
<td>Alkyalcohols</td>
<td>0.3 kg/m³</td>
</tr>
<tr>
<td>Sulfonated vegetable oils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packer Fluids</td>
<td>Calcium chloride</td>
<td>As needed</td>
</tr>
<tr>
<td>Clear Fluids</td>
<td>Sodium chloride</td>
<td></td>
</tr>
<tr>
<td>Viscosifiers</td>
<td>Xanthum gum</td>
<td>10-40 kg/m³</td>
</tr>
<tr>
<td>Sealing Material</td>
<td>Rubber</td>
<td>As needed</td>
</tr>
<tr>
<td>Biocides</td>
<td>Paraformaldehydes</td>
<td>10-40 kg/m³</td>
</tr>
<tr>
<td>Corrosion Inhibitors</td>
<td>Amines</td>
<td></td>
</tr>
<tr>
<td>Workover Fluids</td>
<td>Formation Acidizing Fluids</td>
<td>As needed</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrofluoric acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidic acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosion Inhibitors</td>
<td>Amines</td>
<td>As needed</td>
</tr>
<tr>
<td>Diverting Agents</td>
<td>Resins</td>
<td>As needed</td>
</tr>
<tr>
<td>Paraffins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demulsifiers</td>
<td>Fracturing Fluids</td>
<td>As needed</td>
</tr>
<tr>
<td>Liquid carbon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride and nitrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellulose enzymes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overbalancing Fluids</td>
<td>Sodium chloride</td>
<td>As needed</td>
</tr>
<tr>
<td>Sodium carbonate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted from Environment Canada (1984).
Drilling Fluids. The drilling fluids program for all wells will be similar and will involve water-based drilling mud or low toxicity mineral oil-based mud. After installing the initial 914-mm diameter conductor pipe, the 444-mm diameter hole will be drilled to 1000 m vertical depth using seawater-based drilling fluids (pre-hydrated gel sweeps). Once the 340-mm diameter casing has been cemented in place, the 311-mm diameter hole will then be drilled to total depth using a potassium chloride/polymer drilling fluid.

Completion Fluids. Once each well has been drilled to depth, and prior to perforating the casing wall to access the formations, pressure control will be maintained by injecting a completion fluid into the well. For this project, seawater will be used as a completion fluid until the wells are perforated, usually using the tubing-conveyed perforating technique. Where wells will be perforated before the tubing is installed, a 12 percent sodium chloride brine will provide the necessary weight (overbalance) to the completion fluid.

Packer Fluids. Inhibited 5 percent sodium chloride brine will be used to provide an overbalance on seals and packers. An oxygen scavenger and caustic will be used to inhibit casing corrosion.

Workover and Kill Fluids. During operations, down-hole maintenance will require the use of workover fluids. Seawater-based sodium chloride brine, formed by adding rock salt to seawater, will be used for this purpose. Additional rock salt will be kept on site to permit mixing of a second batch of kill fluids.

Production

Production will take place from the jack-up drilling unit at the Cohasset wellhead jacket location. The Cohasset facilities and the adjacent facilities (Panuke wellhead jacket; production storage/transfer), will exclude an area of 1700 hectares to shipping. All
facilities will be marked for navigation purposes. A standby vessel or supply vessel will be at site on a year-round basis to alert vessels to boundaries of the exclusion zone.

Primary production is proposed for the period April through October. During the winter period from November until March, the wells will be worked over and zones recompleted. In practice, the start and end of each producing season could vary somewhat based on weather conditions. Additional loads of condensate could be exported during suitable weather windows during the winter months, providing well capacity exists at the time.

Production Operations and Maintenance

The production facilities will be operated to optimize production and in a manner which maintains high safety standards to prevent injury to personnel, contamination of the environment, or damage to equipment. The production facilities and wells will be attended with 24-hour supervision. The day and night shifts will include supervisory, operating, and maintenance staff. While the Panuke wellhead jackets will be remotely operated, 24-hour continuous monitoring of all wellhead parameters will take place. Physical intervention will be possible as necessary for safe operation.

In order to ensure satisfactory and safe performance of the facilities, there will be a preventive maintenance program consisting of regular inspections and equipment monitoring. The program will involve scheduled checks of all equipment, monitoring of operational parameters, and vibration monitoring. Routine discharges from production activities will originate at the Cohasset location.

During production operations, crew transfers will occur every two weeks by helicopter. During the months of suspended production operations in the winter, crew transfers will be by helicopter.

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8.22
Routine inspection and maintenance of the offshore facilities will be done on location. Defective offshore components will be replaced from the onshore supply base.

Shuttle Tanker Operations

The shuttle tanker will transport the stabilized condensate to markets along existing shipping lanes.

8.2.2.4 Abandonment

Once the Cohasset and Panuke reservoirs reach economic limits, the site will be abandoned in accordance with regulatory requirements. Abandonment procedures will include the following:

- All wells will be cemented, packers set, and the casing removed to below the mud line.
- Wellhead jackets will be removed by cutting the piles below the seafloor and lifting the jackets onto a barge or workboat.
- Residual hydrocarbons in the flowlines will be flushed out to the Cohasset facility for treatment and the flowlines recovered.
- The jack-up unit will be towed into port and the production facilities will be removed.

8.2.3 PROJECT EMISSIONS

Gaseous emissions, and the generation of liquid and solid wastes will occur during all phases of the project. Emissions are identified below in terms of routine and accidental events.
8.2.3.1 Routine Emissions

During normal construction, drilling, and production operations, routine release of borehole cuttings, wellbore fluids, well treatment fluids, sanitary waste, and other liquids and solids will take place (Figure 8.2-7).

The amount of drilling effluent will change according to hole size and casing setting depths, changes in cementing practices, and the different mud systems and chemicals used.

The types of routine discharges are summarized in Tables 8.2-3 and 8.2-4.

The primary effluents of environmental concern that are discharged during development drilling are periodic bulk discharges of drilling fluid and continuous disposal of formation solids, or cuttings and mud. During production, the primary effluent of concern is produced water.

8.2.3.2 Accidental Emissions

Accidental emissions during all project phases include marine condensate spills from the jack-up drilling and production unit, flowlines, and tankers and minor fugitive air emissions. The potential frequencies and volumes of such spills are summarized in Table 8.2-5.

8.2.4 ALTERNATIVE DEVELOPMENT APPROACHES

A number of alternative development approaches were considered including floating production systems, fixed structures, and export pipeline, and a subsea system. Each of these systems is discussed below.
PRINCIPAL SOURCES OF ROUTINE DISCHARGES

Figure 8.2-7

KEY: — — DISCHARGES PRODUCED DURING INSTALLATION, DRILLING, AND COMPLETION OPERATIONS AT PANUKE

PANUKE

COHASSET
TABLE 8.2-3
ROUTINE DISCHARGES FROM CONSTRUCTION, INSTALLATION, DRILLING, AND COMPLETION ACTIVITIES COHASSET/PANUKE DEVELOPMENT PROJECT

<table>
<thead>
<tr>
<th>Type</th>
<th>Discharge</th>
<th>Quantity</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Emissions</td>
<td>Mudroom exhausts</td>
<td>Intermittent</td>
<td>Gases</td>
</tr>
<tr>
<td></td>
<td>Generator, engine and utilities exhausts</td>
<td>Minor</td>
<td>Gases, particulate and unburned hydrocarbons</td>
</tr>
<tr>
<td></td>
<td>Flaring during well testing and completions</td>
<td>Up to $5 \times 10^3$ m$^3$/d</td>
<td>Gases, particulate and unburned hydrocarbons</td>
</tr>
<tr>
<td>Liquid and Solid Effluents</td>
<td>Water-based drilling mud</td>
<td>770 m$^3$ (total) in one bulk discharge</td>
<td>KCl/polymer gel, seawater gel</td>
</tr>
<tr>
<td></td>
<td>Wellbore cuttings</td>
<td>308 m$^3$/well</td>
<td>Soil and rock cuttings</td>
</tr>
<tr>
<td></td>
<td>Cement</td>
<td>15 m$^3$/well</td>
<td>Cement slurry, high pH</td>
</tr>
<tr>
<td></td>
<td>Sanitary waste</td>
<td>10 m$^3$/d</td>
<td>Macerated domestic wastewater and suspended solids</td>
</tr>
<tr>
<td></td>
<td>Deck drainage</td>
<td>Varies</td>
<td>Oily water with some particulate matter</td>
</tr>
<tr>
<td></td>
<td>Hydrostatic test fluids</td>
<td>300 m$^3$</td>
<td>Water with particulate oxidized metal and corrosion inhibitors</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous solid wastes</td>
<td>Up to 2 m$^3$/d</td>
<td>Domestic solid waste and non-hazardous solids such as packing material</td>
</tr>
<tr>
<td>Type</td>
<td>Discharge</td>
<td>Quantity</td>
<td>Characteristics</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Air Emissions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flaring</td>
<td></td>
<td>Less than 85 x 10^3 m^3/d</td>
<td>Gases, particulate and unburned hydrocarbons</td>
</tr>
<tr>
<td>Exhaust gas</td>
<td></td>
<td>Minor</td>
<td>Gases, particulate and unburned hydrocarbons</td>
</tr>
<tr>
<td>Process cold venting</td>
<td></td>
<td>Minor</td>
<td>Hydrocarbon gases</td>
</tr>
<tr>
<td>Venting from loading</td>
<td></td>
<td>Minor</td>
<td>Hydrocarbon gases</td>
</tr>
<tr>
<td>tanker operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Liquid and Solid Effluents</strong></td>
<td>Produced water</td>
<td>6400 m^3/d (maximum)</td>
<td>40 mg/L hydrocarbon in water (maximum). Normally discharged overboard at a temperature of 68°C.</td>
</tr>
<tr>
<td></td>
<td>Cooling water</td>
<td>Up to 1000 m^3/d</td>
<td>Once through cooling water - temperature slightly above ambient</td>
</tr>
<tr>
<td></td>
<td>Deck drainage (platform and storage vessel)</td>
<td>Varies</td>
<td>Oily water with some particulate matter</td>
</tr>
<tr>
<td></td>
<td>Bilge water (storage vessel and shuttle tanker)</td>
<td>As required</td>
<td>Water with hydrocarbons</td>
</tr>
<tr>
<td></td>
<td>Produced sand</td>
<td>Minor</td>
<td>Sand with some condensate</td>
</tr>
<tr>
<td></td>
<td>Sanitary waste</td>
<td>10 m^3/d</td>
<td>Macerated domestic wastewater and suspended solids</td>
</tr>
<tr>
<td></td>
<td>Workover, kill and completion fluids</td>
<td>As required</td>
<td>Seawater-based NaCl brine</td>
</tr>
<tr>
<td><strong>Solid Wastes</strong></td>
<td>Miscellaneous solid wastes (transported to shore)</td>
<td>Up to 5 m^3/d</td>
<td>Domestic solid waste and non-hazardous solids such as packing material</td>
</tr>
</tbody>
</table>
TABLE 8.2-5
ESTIMATED FREQUENCIES FOR MARINE CONDENSATE SPILLS FROM COHASSET/PANUKE TANKERS, PLATFORM AND FLOWLINES

<table>
<thead>
<tr>
<th>Spill Size/Type</th>
<th>Base Frequency</th>
<th>Cohasset/Panuke (spills/year)</th>
<th>Mean Spill Size (bbl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catastrophic size tanker spill (&gt;150 000 bbl)</td>
<td>0.2</td>
<td>$1.2 \times 10^{-3}$</td>
<td>-</td>
</tr>
<tr>
<td>Medium to large tanker spill (&gt;1000 bbl)</td>
<td>1.3</td>
<td>$7.8 \times 10^{-3}$</td>
<td>108,917</td>
</tr>
<tr>
<td>Small tanker spill (1 bbl - 999 bbl)</td>
<td>69</td>
<td>$8.2 \times 10^{-1}$</td>
<td>20</td>
</tr>
<tr>
<td>Very large well blowout (&gt;50 000 bbl)</td>
<td>0.16</td>
<td>$9.6 \times 10^{-4}$</td>
<td>-</td>
</tr>
<tr>
<td>Medium to large platform spills (&gt;1000 bbl)</td>
<td>0.6</td>
<td>$3.6 \times 10^{-3}$</td>
<td>18,378</td>
</tr>
<tr>
<td>Small platform spills (1 bbl - 49 bbl)</td>
<td>381</td>
<td>2.3</td>
<td>4</td>
</tr>
<tr>
<td>(50 bbl - 999 bbl)</td>
<td>14</td>
<td>$8.4 \times 10^{-2}$</td>
<td>154</td>
</tr>
<tr>
<td>Flowline spill</td>
<td>$9.9 \times 10^{-4}$/km/a</td>
<td>$1.2 \times 10^{-2}$</td>
<td>1,500</td>
</tr>
</tbody>
</table>

* Spills per billion bbl transported or produced, except where noted.

Floating Production Systems

A floating production system, utilizing a drill ship or semi-submersible, with production systems on a storage tanker or the drilling unit was considered, but was not considered practical in the shallow water depths at the Panuke and Cohasset sites. As well, an additional drilling unit would be required on a year-round basis for drilling and workovers. Finally, a fixed jack-up rig is safer from a well control and production operations standpoint.

Fixed Structures

Other types of fixed structures, built of steel or steel and concrete, and containing internal storage were considered. These systems were rejected because of higher capital and operating costs and less flexibility of financial alternatives should the reservoir not perform as expected. The potential environmental impacts of floating and fixed structures are described in the Mobil Hibernia Environmental Impact Statement. There are no major differences in potential impact to the environment.

Export Pipeline

An export pipeline was considered as an alternative to the shuttle tanker system, but analyses indicated that the reserve base and production life would not support the capital investment required to construct a submarine pipeline to mainland Nova Scotia. By not constructing a submarine pipeline, potential impacts in the marine nearshore and terrestrial environments will be avoided.

Sub-Sea Systems

A sub-sea template and sub-sea wellheads were considered for use at the Panuke location as an alternative to the well jacket. The sub-sea system would require access for workovers, well and
production control through an additional drilling unit. The well jacket system was considered safer from a reliability point of view. Risk from surface collision was slightly increased, but offset by the controlled exclusion/safety zone. The area of impact from sub-sea systems are comparable to those associated with welljackets.

8.3

EXISTING ENVIRONMENT

8.3.1

INTRODUCTION

This section is an updated description of the existing environment in the study area (Figure 8.3-1) built upon information collected from Venture (Mobil 1983a, 1983b, 1983c), FEARO's review of Mobil's submissions and the public review process. A brief review of the local climate is also presented. Summaries of the physical, chemical, and biological marine environments of the study area are described. This is followed by a summary of the present status of the fisheries in the 4Vs and 4W regions. Other resource uses are identified and described, including general marine shipping, military use, ocean mining, and seabed cables.

Seasonal information is provided according to the following breakdown: winter from January to March, spring from April to June, summer from July to September, and fall from October to December.

8.3.2

CLIMATE

The climate within the study area is affected by transient disturbances associated with frontal activity, and semi-permanent features, including the Icelandic Low, which influences the region during the winter and spring and the Bermuda High, which provides warmer humid conditions during the spring and summer. Climatic conditions are strongly influenced by the ocean, which tends to moderate temperature. Detailed climatic information pertinent to
engineering design is presented in Section 6. Summaries of monthly temperatures, winds, and precipitation are presented in Tables 8.3-1 to 8.3-3 respectively.

The winter period is characterized by cold northwest winds (5-15 m/s) and frequent precipitation. During spring, winds tend to be moderate southerly. Periods of fog are common over Sable Island and along the coast. In summer, conditions are moderated by the ocean. Winds are predominantly southwesterly (2-10 m/s). Early summer tends to be foggy. Winds, precipitation, and cloudiness increase in the fall. Major storm events from the south (extratropical) can press through to the region.

8.3.3

PHYSICAL MARINE ENVIRONMENT

8.3.3.1

Bathymetry and Marine Physiography

The Scotian Shelf has been divided into three distinct physiographic zones (King 1967; 1970; MacLean and King 1971; and MacLean et al. 1977a,b):

- Inner Shelf
- Central Zone
- Outer Shelf

Inner Shelf

This zone borders mainland Nova Scotia, extending roughly 25 km offshore, with water depths less than 100 m. It is characterized by rough topography.
**TABLE 8.3-1**

MONTHLY AIR TEMPERATURES

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>-19.5</td>
<td>30.0</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>-20.2</td>
<td>26.0</td>
<td>-0.1</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>-15.0</td>
<td>23.8</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>-13.2</td>
<td>29.0</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>-0.8</td>
<td>35.0</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>-6.5</td>
<td>33.8</td>
<td>11.4</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>0.0</td>
<td>30.5</td>
<td>16.1</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>5.5</td>
<td>33.2</td>
<td>18.2</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>3.5</td>
<td>31.5</td>
<td>16.2</td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>0.3</td>
<td>27.0</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>-6.0</td>
<td>29.5</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>-12.5</td>
<td>31.3</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 8.3-2**

MEAN AND MAXIMUM WIND SPEEDS

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Wind Speed (kts)</th>
<th>Most Frequent Direction (°T)</th>
<th>Maximum Wind Speed (kts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>23.3</td>
<td>279</td>
<td>80</td>
</tr>
<tr>
<td>February</td>
<td>22.4</td>
<td>294</td>
<td>68</td>
</tr>
<tr>
<td>March</td>
<td>21.2</td>
<td>288</td>
<td>71</td>
</tr>
<tr>
<td>April</td>
<td>19.1</td>
<td>309</td>
<td>80</td>
</tr>
<tr>
<td>May</td>
<td>17.0</td>
<td>213</td>
<td>50</td>
</tr>
<tr>
<td>June</td>
<td>17.3</td>
<td>210</td>
<td>94</td>
</tr>
<tr>
<td>July</td>
<td>15.4</td>
<td>219</td>
<td>50</td>
</tr>
<tr>
<td>August</td>
<td>13.3</td>
<td>230</td>
<td>55</td>
</tr>
<tr>
<td>September</td>
<td>15.7</td>
<td>263</td>
<td>90</td>
</tr>
<tr>
<td>October</td>
<td>18.5</td>
<td>292</td>
<td>55</td>
</tr>
<tr>
<td>November</td>
<td>20.8</td>
<td>282</td>
<td>68</td>
</tr>
<tr>
<td>December</td>
<td>22.3</td>
<td>268</td>
<td>70</td>
</tr>
</tbody>
</table>

| ANNUAL    | 18.9                  | 258                         | 94                       |

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### Table 8.3-3

**Monthly Percentage Frequency of Precipitation**

<table>
<thead>
<tr>
<th>Month</th>
<th>Rain</th>
<th>Snow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>12.7</td>
<td>28.4</td>
<td>41.1</td>
</tr>
<tr>
<td>February</td>
<td>13.8</td>
<td>22.4</td>
<td>36.2</td>
</tr>
<tr>
<td>March</td>
<td>13.6</td>
<td>14.2</td>
<td>27.8</td>
</tr>
<tr>
<td>April</td>
<td>15.6</td>
<td>4.4</td>
<td>20.0</td>
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<tr>
<td>May</td>
<td>13.6</td>
<td>0.2</td>
<td>13.0</td>
</tr>
<tr>
<td>June</td>
<td>12.7</td>
<td>-</td>
<td>12.8</td>
</tr>
<tr>
<td>July</td>
<td>9.0</td>
<td>-</td>
<td>9.0</td>
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<tr>
<td>August</td>
<td>10.1</td>
<td>-</td>
<td>10.1</td>
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<tr>
<td>September</td>
<td>14.0</td>
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<tr>
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<td>16.0</td>
<td>0.4</td>
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<td>November</td>
<td>18.4</td>
<td>3.0</td>
<td>21.4</td>
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<tr>
<td>December</td>
<td>15.8</td>
<td>14.8</td>
<td>30.7</td>
</tr>
</tbody>
</table>

MARCH 7, 1990
Central Zone

This zone is 80-100 km in width and lies between the Inner Shelf and Outer Shelf. It is characterized by an inner trough running parallel to the coast, and isolated banks with intervening basins and valleys. Water depth varies from less than 100 m over the banks to 180 m in the inner trough, with some basins up to 300 m in depth (Figure 8.3-1).

Outer Shelf

This zone is bounded by the eastern shelf break and is 50-70 km wide. This shelf is characterized by broad flat banks with little relief. Sable Island Bank is the largest and most extensive bank on the Scotian Shelf, with water depths less than 100 m (Figure 8.3-1). The Cohasset/Panuke fields lie over a small section of Sable Island Bank southwest of Sable Island. Water depths in this vicinity are 37 to 45 m.

8.3.3.2 Water Column Physical Characteristics

The waters over the Scotian Shelf provide suitable habitat for a diverse community of marine plants and animals. The distribution and seasonal occurrence of these organisms are influenced by the dynamics of the marine environment. Bathymetry, tidal action, winds, waves, major ocean currents, and local currents must be considered in planning offshore development. Water movement is influenced by the density of water masses, which is affected by water temperature and salinity. The waters of the study area are derived from the Gulf of St. Lawrence (by way of the Cape Breton Current), the Labrador Current, and the Slope Water (a mix of Gulf Stream, Labrador Current, and coastal waters) and the southwest flow of water along the coast of Nova Scotia (Nova Scotia Current) (Figure 8.3-2).

MARCH 7, 1990
NEWBURY, _______

SCOTIA

STUDY AREA

PANUKE & COHASSET

SCALE

E 1000'

EAST

STUDY AREA BOUNDARY

PANUKE & COHASSET

Source: Canadian Hydrographic Service 1978

FIGURE 8.3-1
Source: Houghton et al. 1978; McLellan 1957; Smith 1978; Sutcliffe et al.

FIGURE 8.3-2
Bathymetry in the region influences the physical environment as it affects the movement of offshore waters onto the Shelf, and may induce mixing. The slope also induces the development of ocean fronts, which move nutrient-rich bottom waters to the surface. Tidal currents are also propagated up the slope with significant increases in velocity. Sable Island influences local current patterns with a persistent clockwise gyre (Evans-Hamilton Inc. 1978).

Upwelling of bottom water over the Scotian Shelf may also be wind-induced. The Gully northwest of Sable Island is an area of probable upwelling with enhanced biological productivity.

Waves are predominantly from the west and northwest during the winter, with no dominant direction during the rest of the year. Wave heights are greatest during storms in the late fall and winter. Mean wave height is greater than 2 m at this time, while the summer wave heights are approximately 1 m. Sea ice may occur in the region from mid-February to mid-May, but is not considered a hazard to shipping or offshore operations. More detail on the physical marine environment is found in Section 6.

8.3.4 CHEMICAL MARINE ENVIRONMENT

The biological productivity of marine organisms is dependent on the chemical characteristics of the bottom sediments and overlying water column. Thus, knowledge of the chemical environment of a given area is important for understanding and predicting subsequent biological events.

The Cohasset/Panuke fields are located on the Scotian Shelf which has an area of approximately 62,000 km² (to the 180 m depth contour) and an average depth of 90 m (Mills and Fournier 1984). The water column on the Scotian Shelf is composed of three major water masses, Coastal or Shelf Water, Slope Water, and North Atlantic
Central Water (NACW), each with characteristic chemical and physical features. The movement and upwelling of these water masses along the Continental Shelf creates favourable conditions for plankton growth resulting in an abundance of fish of commercial interest (Fournier et al. 1984).

As appropriate, for the water column, sediment, and marine organisms, this Section discusses the existing chemical environment of the Scotian Shelf (where data permits) including the following:

- Dissolved oxygen
- Suspended particulate matter
- Nutrients (in water and sediments)
- Trace metals (in water, sediments and organisms)
- Hydrocarbons and other contaminants (in water, sediment and organisms)

8.3.4.1 Water Column

Water temperatures and salinity for various sections along the Scotian Shelf are summarized in Section 6.4.8. Monthly means of temperature and salinity along the Scotian Shelf have recently been tabulated by Drinkwater and Trites (1987). Briefly, the well-mixed inshore waters become increasingly stratified offshore due to seasonal gradients in temperature and salinity (Fournier et al. 1984). Smith (1983) determined that the salinity or density field off southwest Nova Scotia was controlled principally by local circulation and mixing, with seasonal variations caused by southerly movement of the Nova Scotia Current along the Scotian Shelf. The physical, chemical, and biological characteristics of the western shelf in the vicinity of Browns Bank (NAFO Subarea 4X), an economically important fisheries area, has been extensively studied using a multidisciplinary approach called the Fisheries Ecology Program which has been described by Dickie and Smith (1989).
Seasonal water movements may contribute to slight variations in pH, especially in surface waters. The pH of seawater usually ranges from 7.5 to 8.5 (Parsons et al. 1984). Minor seasonal deviations in surface water pH may be due to localized gaseous exchanges with atmospheric carbon dioxide driven by wind action and/or uptake of carbon dioxide by phytoplankton during periods of intense photosynthetic activity, i.e., spring or fall "bloom" conditions (Godshall et al. 1980).

**Dissolved Oxygen**

Sources of dissolved oxygen in seawater include atmospheric exchange, mixing and upwelling of water masses, and photosynthesis by marine plants. The amount and availability of dissolved oxygen is affected by physical factors such as the temperature and salinity. The two major pathways of oxygen consumption are abiotic oxidation of chemical compounds, described as chemical oxygen demand (COD), and aerobic biological processes known as biological oxygen demand (BOD).

Fournier et al. (1977) conducted four seasonal cruises along a 270-km-long transect across the Scotian Shelf which intersected the known water masses present on the Shelf. Concentrations of dissolved oxygen (DO) varied with season as well as depth. During winter months, when surface water temperatures ranged from -1 to 5°C, the corresponding DO levels were 8–9 mL/L. By August, surface water temperatures were 18°C and corresponding DO levels had decreased slightly to 6 mL/L. As temperature and salinity increase, oxygen content of water masses decreases due to a reduction of solubility (Davis 1975). In deeper waters in March, Fournier et al. (1984) recorded oxygen concentrations of 5 to 6 mL/L, values slightly higher than the value of 4 mL/L determined by Levy (1983) for deep water stations on the Grand Banks. As with deeper waters on the Grand Banks, the supply of dissolved oxygen along the
Scotian Shelf is controlled by the movement of water masses (Fournier et al. 1977, 1984).

Biological oxygen demand (BOD) may rise in surface waters during periods of intense photosynthetic activity, such as during localized phytoplankton blooms. Although not observed by Fournier et al. (1977), oxygen levels in the euphotic zone may rise to 130 percent saturation or higher (Fairbridge 1966). Below this zone, water is characteristically less than saturation because oxygen is consumed by living organisms and the oxidation of detritus (Pickard and Emely 1982). Chemical oxygen demand (COD) is probably only of concern in inshore areas near industrial sewage outfalls and correspondingly higher levels of detritus material in the water column.

Suspended Particulate Matter

Suspended sediment, suspended particulate matter, total suspended matter, and suspended solids are all terms which have been used to describe the total amount of particles suspended within seawater (Boehm 1987). The amount and characteristics of the suspended particulate material (SPM) can affect the chemical and biological components of the water column. Particulate material can act to remove pollutants and trace metals from the water column by adsorption, flocculation, and complexation. SPM can also affect planktonic organisms by depleting oxygen (by the high oxygen demand of organic rich particles) and altering light availability which controls photosynthetic activity. The amount of SPM in the water column is also a reflection of location and bottom sediment type. In shallow coastal areas, wind and current-driven water movement of land discharges (such as rivers and sewer outfalls) can result in high levels of SPM in inshore regions. Storm induced suspension of fine-grained sediments can also cause elevated levels (tens to hundreds of milligrams per litre) in the water column (Boehm 1987).
Hence, the amount of SPM in a given region can vary considerably as a reflection of current, seasonality, and bottom type.

Light transmission profiles have frequently been used in studies of SPM over the Scotian Shelf by Fournier et al. (1977), Irwin et al. (1983), McCave (1983), Spinrad et al. (1983), and Herman and Platt (1986). Secchi disc readings (which semi-quantitatively measure the depth of light penetration) by Stoffyn (1984) determined that the photic zone (along the 200 m depth contour) extends to a depth of 10-20 m. Fournier et al. (1977) determined that Secchi disc readings demonstrated strong seasonal variations in the depth of light penetration. These were inversely correlated with chlorophyll concentrations, i.e., indications of phytoplankton biomass.

Reported total loading of SPM for the Grand Banks of Newfoundland ranges from 0.01 to 2.77 mg/L and are within the general range of values for other ocean sites (MacKnight et al. 1981).

Total organic carbon (TOC) is a measure of the carbon content of organic SPM in the water column. Gershey et al. (1979) reported concentrations of TOC from various depths on the Scotian Shelf ranging from 0.06 to 1.07 mg/L. Williams and LeBlanc (1975) determined near surface (<100 m) values of organic carbon for various oceans ranging from 0.6 to 2.0 mg/L, and deep water values of 0.4 to 1.5 mg/L.

Sedimentation rates and resuspension of bottom sediments also determine the amount of SPM in the water column. Amos and Nadeau (1988) have re-evaluated the attributes and origins of the surficial sedimentary features on Sable Island and Middle Banks and Banquereau to explain the movement of surficial sediments. Strong current patterns cause the predominantly sand bottom to form irregular bedform morphology. Using light transmission profiles, studies by Spinrad et al. (1983) revealed that the Scotian Rise
(the area which then merges into the Scotian Slope) benthic zone is characterized by highly refractive suspended particles. The size distribution of these particles does not vary considerably with height from the bottom or over periods of time of more than a year despite the dynamic nature of current movement in the area. A study of various stations on the Scotian Shelf revealed that <40 percent of bulk particulate organic carbon (POC) and particulate organic nitrogen (PON) were readily resuspended as SPM, reflecting the large portion of sand content in bottom sediments in this area. Studies from stations on the slope revealed that 85 percent of the bulk PON and POC was resuspensible, due to the high silt-clay content. A comparison of predicted and measured sedimentation rates suggested that enrichment of slope sediments could only be explained by horizontal transport of SPM resulting from biological production on the shelf (Grant et al. 1987).

Nutrients

Replenishment of nutrients in the water column occurs by biological regeneration and influx through physical processes such as upwelling and current movement of major water masses. Nitrates, nitrites, and phosphates are important to phytoplankton as sources of the elements nitrogen, phosphorus, and silicon which are essential for growth. In most marine systems, including the Scotian Shelf, the seasonal availability of nitrogen is the dominant nutrient regulating phytoplankton growth (Fournier et al. 1977, Cochlan 1986).

Fournier et al. (1977) observed strong seasonal patterns in the distribution of nitrate and phosphates in the photic zone at stations along the Scotian Shelf. In early spring, concentrations of nitrate were high (5.0 to 10.0 mg as NO₃-N/m³) dropping to 0.5 to 1.5 as phytoplankton used the nutrient for growth. In the autumn, values increased to 0.5 to 10 mg as NO₃-N/m³; phosphate values exhibited similar seasonal trends. Studies by Cochlan (1986)
have shown that in spring and summer, when nutrient levels are low, phytoplankton growth was supported by regenerated nitrogen as NH₄⁺. During the winter, phytoplankton growth was primarily light-limited, not nutrient-limited, and was supported by "new" nitrogen (NO₃⁻) contained in the advection of nutrient-rich Slope Water onto the Shelf. Below the photic zone, Fournier et al. (1977) determined an average of 13 mg as NO₃⁻/m³ which remained high throughout the year. Subsequent studies by Fournier et al. (1984) and Herman and Platt (1986) illustrated that despite the high availability of nutrients in deeper layers, the low biomass of phytoplankton (as measured by the distribution of chlorophyll) was not photosynthetically active because of the lack of light. Similar seasonal distributions and patterns of nutrients have been reported by Hollibaugh and Booth (1981) for the Grand Banks.

Trace Metals

The natural trace metal distributions in the study area are a function of the water masses circulating across the Scotian Shelf. Table 8.3-4 is a summary of values from the Scotian Shelf in relation to worldwide oceanic values. The data presented in Table 8.3-4 suggest that values from the Scotian Shelf are comparable to those from various oceans. Yeats (1987) noted that in general, for offshore regions worldwide, concentrations of nickel, chromium, zinc, and cadmium increase from surface minima to maxima at the depth of the nutrient maxima. In offshore areas, trace metal concentrations have characteristic relationships with some of the physical factors of water masses in a given area. For example, Yeats (1987) determined from transects between Nova Scotia and the Sargasso Sea that some of the trace metals had linear relationships with salinity, while phosphate and silicates were extensively used by the biota and had a non-linear relationship.
### TABLE 8.3-4
TRACE METALS IN SEAWATER

<table>
<thead>
<tr>
<th>Element</th>
<th>Location</th>
<th>Concentration (mg m⁻³)</th>
<th>References</th>
</tr>
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<tbody>
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<td>Arsenic</td>
<td></td>
<td>1-3</td>
<td>Riley 1975</td>
</tr>
<tr>
<td></td>
<td>Oceanic average</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sargasso Sea - North Atlantic</td>
<td>1.65</td>
<td>Ray &amp; Johnson 1972</td>
</tr>
<tr>
<td>Barium</td>
<td>Oceanic average</td>
<td>3-50</td>
<td>Riley 1975</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Sargasso Sea</td>
<td>0.010</td>
<td>Bender &amp; Gagner 1976</td>
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<tr>
<td></td>
<td>North Atlantic</td>
<td>0.06</td>
<td>Kranling &amp; Peterson 1977</td>
</tr>
<tr>
<td></td>
<td>Scotian Shelf (near coast)</td>
<td>0.04</td>
<td>Bewers et al. 1976</td>
</tr>
<tr>
<td></td>
<td>Scotian Shelf (slope water)</td>
<td>0.03</td>
<td>Bewers et al. 1976</td>
</tr>
<tr>
<td></td>
<td>Canso Strait (outer)</td>
<td>0.02</td>
<td>Cranston et al. 1974</td>
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<td>Chromium</td>
<td>Oceanic average</td>
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<td>Brewer &amp; Spencer 1975</td>
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<td></td>
<td>North Pacific</td>
<td>0.4</td>
<td>Cranston &amp; Murray 1978</td>
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<tr>
<td>Copper</td>
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<td>Mercury</td>
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<td>15 (ng L⁻¹)</td>
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<td></td>
<td>American coastal</td>
<td>40 (ng L⁻¹)</td>
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<td>Sargasso Sea</td>
<td>8 (ng L⁻¹)</td>
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<td>9-13</td>
<td>Head &amp; Burton 1970</td>
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<td>Northeast Atlantic (average)</td>
<td>10.7</td>
<td>Morris 1975</td>
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<td>Nickel</td>
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<td>Iron</td>
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<td>Atlantic Ocean (total)</td>
<td>0.9</td>
<td>Kranling &amp; Peterson 1977</td>
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<tr>
<td></td>
<td>(coastal-dissolved)</td>
<td>1.46</td>
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<tr>
<td></td>
<td>(slope-dissolved)</td>
<td>1.61</td>
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</tr>
<tr>
<td></td>
<td>(coastal-particulate)</td>
<td>1.77</td>
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<td></td>
<td>(slope-particulate)</td>
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<tr>
<td>Element</td>
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<td>Concentration (mg·m⁻³)</td>
<td>References</td>
</tr>
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<td>---------------------------</td>
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<td>---------------------</td>
</tr>
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<td>Manganese</td>
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<td>0.14</td>
<td>Bewers et al. 1976</td>
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<td>(slope dissolved)</td>
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</tr>
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<td>(coastal-particulate)</td>
<td>0.33</td>
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<td></td>
<td>(slope-particulate)</td>
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<td></td>
<td>Oceanic average (coastal-deep sea)</td>
<td>0.5-4</td>
<td>Riley 1975</td>
</tr>
</tbody>
</table>

Source: Mobil Oil 1983.
It is expected that values would follow seasonal variations as reflected by movement of water masses and physical factors along the Scotian Shelf and adjacent areas. It should be noted that changes in both salinity and pH may also affect the distribution of trace metals in aquatic systems. Hence, trace metal measurements alone are not indicative of their bioavailability. The presence of certain trace metals in the water column may affect the distribution of plankton. They, in turn, may modify trace metal chemistry in surface waters by releasing complexing agents or by ingestion. Release of trace metals in fecal material from zooplankton can result in complexing with SPM and thus affect rate of flux to bottom sediments (Morel and Morel-Laurens 1983).

Hydrocarbons

The five major sources of oil input to the oceans are natural oil seeps and erosion of sedimentary rock formations, offshore hydrocarbon development activities, marine vessel operations, atmospheric inputs, municipal and industrial wastes and runoff, as summarized in Table 8.3-5 (National Research Council 1985). Furthermore, hydrocarbons are also components of planktonic lipid material and are often difficult to separate from petroleum hydrocarbons due to similar origins in the living materials (Mobil 1985). Concentrations of hydrocarbons in seawater for various areas are presented in Table 8.3-6. Hydrocarbon contents measured by fluorescence spectrophotometry may be higher as it is difficult with this method to separate out the fluorescence caused by naturally-occurring substances. The hydrocarbon values presented for the Scotian Shelf are representative of worldwide values. However, they would probably increase in the event of industrial development in the region. More recent data have been collected describing the hydrocarbon environment in the water column and sediments of the Banquereau and Georges Bank areas. However, it has not been synthesized for publication (E. Levy, Bedford Institute of Oceanography, pers. comm.).
<table>
<thead>
<tr>
<th>Source</th>
<th>Probable Range</th>
<th>Best Estimate&lt;sup&gt;a&lt;/sup&gt;</th>
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<tbody>
<tr>
<td><strong>Natural Sources</strong></td>
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<tr>
<td>Marine seeps</td>
<td>0.02 - 2.0</td>
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<tr>
<td>(Total Natural Sources)</td>
<td>(0.025) - (2.5)</td>
<td>(0.25)</td>
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<tr>
<td><strong>Offshore Production</strong></td>
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<tr>
<td><strong>Transportation</strong></td>
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<tr>
<td>Tanker operations</td>
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<td>Dry-docking</td>
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<td>Marine terminals</td>
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<td>Bilge and fuel oils</td>
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<td>Tanker accidents</td>
<td>0.3 - 0.4</td>
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<tr>
<td>Nontanker accidents</td>
<td>0.02 - 0.04</td>
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<tr>
<td>(Total Transportation)</td>
<td>(0.95) - (2.62)</td>
<td>(1.47)</td>
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<td><strong>Atmosphere</strong></td>
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<tr>
<td><strong>Municipal and Industrial Wastes &amp; Runoff</strong></td>
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<tr>
<td>Municipal wastes</td>
<td>0.4 - 1.5</td>
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<td>Refineries</td>
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<td>Non-refining industrial wastes</td>
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<td>Urban runoff</td>
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<td>River runoff</td>
<td>0.01 - 0.5</td>
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<td>Ocean dumping</td>
<td>0.005 - 0.02</td>
<td>0.02</td>
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<tr>
<td>(Total Wastes and Runoff)</td>
<td>(0.585) - (3.12)</td>
<td>(1.18)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1.7 - 8.8</td>
<td>3.2</td>
</tr>
</tbody>
</table>

<sup>a</sup>The total best estimate, 3.2 mta, is a sum of the individual best estimates. A value of 0.3 was used for the atmospheric inputs to obtain the total, although we well realize that this best estimate is only a center point between the range limits and cannot be supported rigorously by the data and calculations used for estimation of this input.

<table>
<thead>
<tr>
<th>Region</th>
<th>Method</th>
<th>Concentration (mg/m³)</th>
<th>Reference</th>
</tr>
</thead>
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<td>Scotian Shelf</td>
<td>F</td>
<td>0.2 - 2.0</td>
<td>Keizer et al. 1977</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1.8 - 13.5</td>
<td>Levy 1971</td>
</tr>
<tr>
<td></td>
<td>GLC</td>
<td>0.8 - 0.15</td>
<td>Keizer et al. 1977</td>
</tr>
<tr>
<td>Gulf of St. Lawrence</td>
<td>F</td>
<td>0.6 - 1.5</td>
<td>Keizer et al. 1977</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>2.0 - 5.0</td>
<td>Levy 1971</td>
</tr>
<tr>
<td></td>
<td>GLC</td>
<td>0.02 - 1.0</td>
<td>Keizer et al. 1977</td>
</tr>
<tr>
<td>Open Atlantic and Pacific</td>
<td>IR</td>
<td>1.5</td>
<td>Brown &amp; Searl 1976</td>
</tr>
<tr>
<td>Georges Bank</td>
<td>GLC</td>
<td>0.2 - 1.9</td>
<td>Boehm et al. 1979</td>
</tr>
<tr>
<td>Grand Banks</td>
<td>F</td>
<td>20.3 - 41.3</td>
<td>Levy 1983</td>
</tr>
<tr>
<td>Hibernia Region</td>
<td>F</td>
<td>0.19 - 0.014</td>
<td>Levy 1983</td>
</tr>
<tr>
<td>Ekofisk blowout (North Sea)</td>
<td>F</td>
<td>0.8 - 15.2 (initial)</td>
<td>Mackie et al. 1978</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.8 - 15.2 (final)</td>
<td></td>
</tr>
<tr>
<td>Scottish coastal waters</td>
<td>GLC</td>
<td>0.2 - 3.1</td>
<td>Mackie et al. 1978</td>
</tr>
<tr>
<td>United Kingdom waters</td>
<td>F</td>
<td>1.1 - 1.7</td>
<td>Law 1981</td>
</tr>
</tbody>
</table>

F = Fluorescence spectroscopy
IR = Infrared spectroscopy
GLC = Gas liquid chromatography

Other Contaminants

Contaminants of particular environmental concern include the polycyclic aromatic hydrocarbons (PAHs) and their chemical analogues, the heterocyclic aromatic compounds (HACs) (Kieley et al. 1988). These chemicals are highly potent carcinogens and their bioaccumulation by marine biota has been well documented (Kieley et al. 1988). Shortly after the sinking of the "Argo Merchant" off Cape Cod, Boehm et al. (1979) detected trace levels of PAHs in the waters and sediments off Georges Bank. No data are available for the study area, but it is reasonable to assume that levels in the water column would be barely detectable due to the general lack of industrial development in the area. Elevated levels have been detected in industrialized wharf areas (Dunn and Stitch 1976) and harbours (Kieley et al. 1988).

8.3.4.2 Sediments

Nutrients

Between 1982 and 1988, four cruises were undertaken on the Scotian Shelf to determine the carbon and nitrogen components of surficial and core sediment samples (Saunders et al. 1989). Sediment samples from basins on the shelf and slope contained material with a higher organic content than those collected from exposed locations on the banks of the same area. The lower organic content in sediment samples from exposed locations on the slope is a reflection of the predominantly sandy soil, as noted by Amos and Nadeau (1988). There have been limited studies on both the Scotian Shelf and worldwide describing nutrient and organic compounds of sedimentary material (R. Pocklington, Marine Chemistry Division, Bedford Institute of Oceanography, pers. comm.).
Trace Metals

Many physical, chemical, and biological factors influence both the chemical form and quantities of metal deposition in sediments. Physical factors such as pH, temperature, salinity, and light may all interact to influence the kinetics of potentially toxic compounds and their bioavailability to marine organisms (Woods 1975). Metals are generally introduced into the marine environment in solution and in association with fine-grained solid and colloidal inorganic and organic particles from natural and anthropogenic sources (Loring 1977). The chemistry and grain size of the sediments themselves also affect the adsorption and adherence of trace metals. For example, sediments with high amounts of carbonate tend to accumulate higher levels of aluminum and magnesium than other sediment types (Turekian and Wedepohl 1961). Deposition of metals into the sediments is also affected by the amount and form of SPM in the overlying water column (Loring 1977). Studies of trace metals in the water column and sediments describe the "reactive" component as opposed to total metal concentrations, because it is the former which is of greater importance for availability to biota (Loring 1977).

Worldwide values of trace metals in sediments are presented in Table 8.3-7. Within the past decade, geochemical studies have examined the dynamics of organic matter oxidation in relation to chemical changes in trace metals in deep sea sediments as opposed to only examination of surficial sediments (Buckley 1990 in press). Results of geochemical and sedimentological analysis of cores from the Emerald Basin on the Scotian Shelf suggest that the anoxic reduction of sulfate in this area of organically-rich sediments will result in the precipitation of metal sulfides at relatively shallow depth in fine-grained sediments. The implications of this study are that sediments on the continental shelves may undergo significant geochemical alterations following deposition and accumulation of sedimentary material (Buckley 1990 in press). Hence, SPM containing particles, bound to trace metals in a potentially inert form to marine biota, can become deposited in
<table>
<thead>
<tr>
<th>Element</th>
<th>Location</th>
<th>Concentration (µg g⁻¹)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium</td>
<td>Northeast Scotian Gulf</td>
<td>500</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>310</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Worldwide average coastal sediment</td>
<td>300</td>
<td>Calvert 1976</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>15-690</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Scotian Shelf/Slope</td>
<td>0.01</td>
<td>Hawkins¹</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>0.22</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Southeastern Scotian Shelf</td>
<td>0.06</td>
<td>Bothner et al. 1980</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>0.02-4.3</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Chromium</td>
<td>Northeast Scotian Shelf</td>
<td>130</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Southeastern US Shelf</td>
<td>5-38</td>
<td>Bothner et al. 1980</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>57</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>87</td>
<td>Loring 1978</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>1.48-39.0</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Northeast Scotian Shelf</td>
<td>40</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>12</td>
<td>Loring 1978</td>
</tr>
<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>14</td>
<td>Loring 1978</td>
</tr>
<tr>
<td></td>
<td>Worldwide average coastal sediment</td>
<td>12</td>
<td>Calvert 1976</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>1.3-9.6</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Copper</td>
<td>Northeast Scotian Shelf</td>
<td>52</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Scotian Shelf/Slope</td>
<td>5-10</td>
<td>Hawkins¹</td>
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<td></td>
<td>Bay of Fundy (average)</td>
<td>15</td>
<td>Loring 1982</td>
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<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>25</td>
<td>Loring 1978</td>
</tr>
<tr>
<td></td>
<td>Southeastern US Shelf</td>
<td>2-2</td>
<td>Bothner et al. 1980</td>
</tr>
<tr>
<td></td>
<td>Worldwide average coastal sediment</td>
<td>30</td>
<td>Calvert 1976</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>3-25.6</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Lead</td>
<td>Northeastern Scotian Shelf</td>
<td>85</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Scotian Shelf Slope</td>
<td>5.4-15.2</td>
<td>Hawkins¹</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>20</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>21</td>
<td>Loring 1978</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>0.7-15.3</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Mercury</td>
<td>Scotian Shelf/Slope</td>
<td>0.04-0.07</td>
<td>Hawkins¹</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>0.03</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>0.015</td>
<td>Loring 1975</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>0.01-0.02</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Southeastern US Shelf</td>
<td>1-3</td>
<td>Bothner et al. 1980</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>1.3-6.1</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Nickel</td>
<td>Northeastern Scotian Shelf</td>
<td>80</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>15</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>36</td>
<td>Loring 1978</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>0.1-28.0</td>
<td>MacKnight et al. 1981</td>
</tr>
</tbody>
</table>
### TABLE 8.3-7 (CONTINUED)

**TRACE METALS IN SEDIMENTS**

<table>
<thead>
<tr>
<th>Element</th>
<th>Location</th>
<th>Concentration (µg/g)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanadium</td>
<td>Northeastern Scotian Shelf</td>
<td>85</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>70</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>105</td>
<td>Loring 1978</td>
</tr>
<tr>
<td></td>
<td>Worldwide average coastal sediment</td>
<td>45-146</td>
<td>Calvert 1976</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>10.0-22.8</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Zinc</td>
<td>Northeastern Scotian Shelf</td>
<td>120</td>
<td>Hoffman 1970</td>
</tr>
<tr>
<td></td>
<td>Grand Banks</td>
<td>0.3-3.77</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td></td>
<td>Scotian Gulf Slope</td>
<td>20-41</td>
<td>Hawkins¹</td>
</tr>
<tr>
<td></td>
<td>Bay of Fundy (average)</td>
<td>51</td>
<td>Loring 1982</td>
</tr>
<tr>
<td></td>
<td>Gulf of St. Lawrence (average)</td>
<td>84</td>
<td>Loring 1978</td>
</tr>
</tbody>
</table>

¹ V. Hawkins, Environmental Protection Service, pers. comm. 1982.

organic-rich basins on continental slopes and shelves. Following deposition, geochemical changes may occur which potentially could make these metals (as metal sulfides) into a reactive form which could affect marine biota either in a positive or negative manner.

Studies have shown that the interactions between metals and sediments are affected by a multitude of factors. Levels of trace metals are still highest, however, in estuarine and coastal sediments near direct anthropogenic sources (Loring 1977).

Hydrocarbons

Hydrocarbons in the marine environment may originate from any of the sources summarized in Table 8.3-5. Sediments tend to adsorb higher levels of these compounds than the overlying seawater (Corner 1978). Keizer et al. (1978) analyzed sediments from the Scotian Shelf and around Sable Island and found concentrations of hydrocarbons ranging from <1 to 2.3 μg/g. Their study showed that concentrations were highest in the inshore stations, suggesting terrestrial sources (Keizer et al. 1978). These values are comparable to those determined by Farrington and Tripp (1977) for the offshore North Atlantic (Table 8.3-8) and the Grand Banks (Levy 1983). It is expected that background levels of hydrocarbons in marine sediments are low, except in areas near sources of industrial activity.

Other Contaminants

Various other chemicals from anthropogenic sources may also accumulate in bottom sediments. Low concentrations of polychlorinated biphenyls (PCBs) and DDT have been reported from inlets along the coast of Nova Scotia (Leonard 1977). There have been no studies on the Scotian Shelf which describe concentrations of various compounds (such as PCBs, PAHs, etc.). However, a few studies have documented levels from highly industrialized locations. Ernst et al. (1982) documented high levels of PCBs from sediments in Petit-de-Grat Harbour, Nova Scotia, but
TABLE 8.3-8
TYPICAL CONCENTRATIONS OF SATURATED HYDROCARBONS IN MARINE SEDIMENTS

<table>
<thead>
<tr>
<th>Location</th>
<th>Concentration (µg/g)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Banks</td>
<td>0 - 4.7</td>
<td>MacKnight et al. 1981</td>
</tr>
<tr>
<td>Grand Banks</td>
<td>0 - 7.3</td>
<td>Levy 1983</td>
</tr>
<tr>
<td>Scotian Shelf</td>
<td>0.01 - 2.3</td>
<td>Keizer et al. 1978</td>
</tr>
<tr>
<td>Offshore North Atlantic</td>
<td>1.0 - 5.9</td>
<td>Farrington and Tripp 1977</td>
</tr>
<tr>
<td>North Sea</td>
<td>1.0 - 26.0</td>
<td>Ward et al. 1980</td>
</tr>
<tr>
<td>Coastal Newfoundland</td>
<td>1.0 - 25.0</td>
<td>Keizer 1971</td>
</tr>
</tbody>
</table>

Source: Mobil, 1985.
these were due to localized sources of contamination, i.e., effluent from the local fish plant. It would be expected that levels of chemical contaminants on the Sable Island Banks and Scotian Shelf areas would be very low as there are no localized sources of industrial contamination, and the predominantly sand and low organic content of the sediments would preclude excessive accumulation.

8.3.4.3 Marine Organisms

Trace Metals

Many studies have documented the effects of metal contamination and bioaccumulation on commercially important finfish and shellfish. However, the majority of these are from areas with known areas of elevated levels of pollutants, e.g., elevated levels of cadmium from a coastal lead smelter, Belledune Harbour, New Brunswick (Uthe et al. 1987). In a survey of harbours in the southern United States, Neff et al. (1978) determined that the benthic fauna contained levels of metals in far greater concentrations than those in the overlying water column. However, further generalizations may not be made as the bioaccumulation of trace metals varies between and within species, depending on mode of feeding, substrate type, maturation, and detoxification abilities. Based on the chemical form of the trace metal, the site of accumulation within each organism may also vary. Scallops near a Sable Island drill site had trace metals accumulated in the viscera rather than in the edible muscle tissue (Carter et al. 1983). However, a study by Neff (1982) determined that bioaccumulation had occurred in the edible tissue of finfish. Various benthic fauna were collected from areas within 500 m of the wellsites at Hibernia, on the Grand Banks of Newfoundland (Barchard and Mahon 1986). Despite elevated concentrations of metals in the sediments, the only detectable impact on fauna in the area was the accumulation of barium by sand dollar (Echinarchnium parma) and scallops (Placopecten magellanicus). Other studies have shown that metal uptake appears to vary between species. On Georges Bank, levels of trace metals were not
elevated in either ocean quahog (*Arctica islandica*) or fourspot flounder (*Paralichthys oblongus*) exposed to drilling fluids in water near exploratory drilling rigs (Payne et al. 1982 in: Barchard and Mahon 1986).

No baseline data have been collected which describe the concentrations of trace metals in marine organisms from pristine areas on the Scotian Shelf.

**Hydrocarbons**

Hydrocarbons are present naturally in most marine organisms due to endogenous biosynthesis and dietary exposure (National Research Council 1985). Studies on organisms from known areas of hydrocarbon exposure have shown that petroleum has been detected in numerous taxa. However, other work has illustrated that marine organisms in many parts of the world oceans are free of petroleum at detectable levels (National Research Council 1985). Hydrocarbon data for the biota of Nova Scotian waters deal mainly with post-spill monitoring programs such as programs associated with the "Arrow" spill in Chedabucto Bay (Scarratt and Zitko 1972) or the sinking of the "Argo Merchant" off Georges Bank (Boehm and Hirtzer, 1982). There are no baseline data on the concentration of petroleum hydrocarbons in organisms in the Scotian Shelf-Sable Island region.

**Other Contaminants**

Compounds such as PCBs and PAHs are known to be absorbed and concentrated in shellfish and finfish (Zitko 1971). Both chemicals are of environmental concern and have been associated with diseases in marine biota, particularly bottom dwelling fish (Kieley et al. 1988). There have been few baseline surveys for these contaminants in offshore Scotian waters. Zitko (1981) noted a trend of decreasing PCB levels in cod livers northeasterly from Browns Bank south of Nova
Scotia toward Davis Strait, and high levels could be related to input sources to the marine environment.

A background level of 1.0 µg/g of PCBs was reported for various ocean fish, and a level of 0.010 µg/g for muscle tissue of pollock from the Atlantic coast (Ernst et al. 1982). Ernst et al. (1982) also noted that higher levels of PCBs were generally found in industrial areas where accidental leakage had occurred. In a study of the ocean quahaug (Arctica islandica) which is common on the Scotian Shelf, Steimle et al. (1986) found low levels of PCBs and PAHs in sample organisms from offshore sites, but generally higher values in those from coastal areas. As there is no major industrialized development presently on the Scotian Shelf, it is unlikely that PCBs or PAHs are high in organisms in that area.

8.3.5  BIOLOGICAL MARINE ENVIRONMENT

8.3.5.1  Marine Phytoplankton

Phytoplankton are tiny floating or weakly-swimming plants, which require light, carbon and nutrients for photosynthesis. Their growth, referred to as primary productivity, is influenced by processes affecting the availability of these requirements. Energy for all other levels of the marine food web is supplied by phytoplankton biomass. Though present year-round, phytoplankton concentrations are greatest in early April, during the spring bloom. A smaller bloom occurs in fall (October/November). In general, phytoplankton are typical of most temperate continental shelves, although large eddies from the Gulf Stream occasionally bring subtropical species to Nova Scotian offshore waters. For a list of the species found in the study area, readers are referred to Brunel (1970), Gran and Braarud (1935), and Wright (1907). The following sections discuss the seasonal distribution of marine phytoplankton and annual primary production.
Winter

Chlorophyll levels are low during this period (less than 1 mg/m³) and nutrient levels are higher (nitrate at greater than 11 mg/m³ as NO₃-N; Mobil 1983a). Both chlorophyll and nitrate are uniformly distributed. Throughout most of the study area, the water column is uniformly mixed across the shelf to depths exceeding 75 m. The only area of active phytoplankton growth can be seen at the shelf water/slope water front, as reported by Fournier et al. (1979). At the front, the depth of the wind-mixed layer is decreased, allowing for increased phytoplankton standing crop and levels of productivity. The boundary between these two water masses migrates, making precise location of this front difficult.

Spring

The annual phytoplankton bloom occurs during early April throughout the Scotian Shelf. Sable Island Bank and vicinity may experience an earlier bloom, due to the shallow water and proximity to the front, but that has not been confirmed (Mobil 1983a).

Summer

Concentrations of chlorophyll and nutrients in the surface waters of the Scotian Shelf are low during the summer months, but elevated at subsurface depths over much of the Scotian Shelf/Slope region. The position of the maxima (that is, higher chlorophyll concentrations, phytoplankton biomass and numbers) within the water column depends on light penetration and nutrient variation (Mobil 1983a). There also appears to be a horizontal variation in chlorophyll concentrations in the subsurface over a range of 1 to 10 km. The reason for this is not clear.
Autumn

The autumn phytoplankton bloom is indicated by a chlorophyll peak, occurring uniformly over the Scotian Shelf in the study area. It is triggered by nutrient-rich deep water, mixing with the surface water following cooling surface temperatures and autumn storms. Hargreaves (1982) reported that the subsurface chlorophyll maximum can still be present. This bloom will be of shorter duration than the spring bloom due to decreased daylight hours, lower zenith angle of the sun, and the increasing depth of the wind-mixed water layer (Mobil 1983a).

Chlorophyll and nitrate levels in the vicinity of Sable Island and over the shelf water/slope water front were similar to levels found elsewhere over the Shelf.

Annual Primary Production

Annual primary production on the Scotian Shelf has been calculated to be between 4,855 and 6,060 kJm\(^{-2}\)y\(^{-1}\) (Mobil 1983a). Much of this production is consumed in the water column by filter-feeding organisms such as copepods, euphausiids, or menhaden. Phytoplankton production not thus consumed sinks to the seafloor and becomes food for benthos or becomes part of the sediment layers.

8.3.5.2 Microbiota

Microbiota include bacteria and protozoa (for species list see Muckins-Phillips and Stewart 1974, and Johansen 1976). Their role in the food web is to recycle carbon, energy and nutrients to higher trophic levels. Bacterial productivity is equal to approximately 25 percent of the phytoplankton productivity and is greater than zooplankton productivity. Bacterial biomass is at least equal to that of the zooplankton. Both productivity and biomass decrease with depth and distance from shore. Protozoan biomass is greatest at mid-depth, in summer, in coastal and slope waters. Water column bacteria derive
nutrients necessary for growth from the phytoplankton; their
distribution correlates with phytoplankton. Hydrocarbon-degrading
bacteria are called oleoclasts. They are present in all marine
environments, although concentrations are higher where hydrocarbons
persist.

Few studies have been done on the distribution and activity of
microbiota within the study area (Mobil 1983a). Bacterial abundance
and biomass are generally greater in the chlorophyll maximum than
elsewhere in the water column.

8.3.5.3  Marine Zooplankton

Zooplankton are floating animal life, which transfer organic carbon
from the phytoplankton up the food chain to large animals and to
benthic and planktonic bacterial communities. Major ocean species are
often related to specific water masses (Table 8.3-9). Species
composition (a mixture of arctic, boreal and subtropical species) and
abundance are fairly uniform in the study area, although there is a
strong seasonal component to both factors. In general, the zooplankton
population is greatest in spring and early summer.

Almost 150 species of zooplankton can be found on the Scotian Shelf
(Sameoto 1982). Of these, seven species of copepods, as well as
amphipods, chaetognaths, euphausiids and medusae are considered most
important. Studies to date indicate that Calanus finmarchicus
(including C. glacialis and C. hyperboreus) are the most abundant in
the study area (Mobil 1983a). Estimates of Calanus spp. population
range from more than 500 animals/m³ in the spring to a low of 30 per
m³ in winter. It is particularly abundant in the shelf waters north
of the shelf water/slope water front and overwinters in deep basin
water.
TABLE 8.3-9
ZOOPIANKTON SPECIES CHARACTERISTIC OF VARIOUS WATER TYPES
WHICH CONTRIBUTE TO SHELF AND SLOPE WATER IN THE STUDY AREA

<table>
<thead>
<tr>
<th>Origin of Water Type</th>
<th>Contributes to Shelf (A) or Slope (B)</th>
<th>Dominance of</th>
<th>Paucity of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labrador Current</td>
<td>A</td>
<td>Calanus glacialis, C. hyperboreus, Sagitta maxima</td>
<td>Gulf Stream species, Podon sp., Evadne sp.</td>
</tr>
<tr>
<td>Gulf of St. Lawrence</td>
<td>A</td>
<td>Calanus finmarchicus, Temora longicornis, Podon/Evadne (summer), Thysanoessa sp., Meganyctiphanes longicaudata</td>
<td>Thysanoessa longicaudata, Centropages typicus</td>
</tr>
<tr>
<td>North Atlantic</td>
<td>A, B</td>
<td>Calanus finmarchicus, Thysanoessa longicaudata</td>
<td>C. glacialis, C. hyperboreus</td>
</tr>
<tr>
<td>Gulf Stream</td>
<td>B</td>
<td>Calocalanus sp., Clausocalanus sp., Ecalanus sp., Iucicutia sp., Nannocalanus minor</td>
<td>Labrador Current species</td>
</tr>
</tbody>
</table>

1 This table states the input of various water types to the shelf/slope region as indicated by characteristic organisms present on the shelf/slope. Water types from Smith et al. 1978.
Pseudocalanus sp. also dominates the copepod community in spring and early summer. This species can be found in all water masses within the study area, but is uncommon near the edge of the shelf and the extreme western section (Mobil 1983a).

Centropages typicus is the most abundant copepod in autumn. It can reach levels of 500 animals/m³, especially over the shallow banks.

Metridia lucens is the most abundant copepod in the spring and can be found in the slope waters and western section of the study area.

Amphipods, such as Hyperiidae, are present throughout the area all year, but are most common in the autumn. Vertical diurnal migrations up to 200 m by adults have been noted for these animals. Spawning occurs between February and October.

Chaetognaths are important planktonic predators, being most common in autumn. Sagitta elegans and Eukrohnia hamata are the most abundant (Mobil 1983a), depending on the associate water mass.

Euphausiids are more numerous in spring than other times in the year, and prefer slope water to the shelf itself. Examples of euphausiids include Thysanoessa longicaudata and Meganyctiphanes norvegica.

Annual mean production has been estimated at 282–423 kJm⁻²yr⁻¹ for the Scotian Shelf but may range as high as 705 kJm⁻²yr⁻¹ (Mobil 1983a).

8.3.5.4 Marine Benthos

Benthos refers collectively to the organisms living on, in or attached to the bottom of the oceans. Infauna are those which live within the bottom sediments and epifauna are those which live on or attached to the bottom.
Distribution of benthic fauna within the study area is related to sediment size, water mass characteristics, water depth and levels of primary productivity within the overlying water column (Mobil 1983a). The benthic communities are important to the Scotian Shelf ecosystem as they transfer energy from plankton and bacteria to demersal fish populations (Mobil 1983a).

Benthic organisms have high potential for replacement, resulting in relatively rapid recolonization of suitable substrates.

**West Sable Island Bank**

**Habitat Type.** The area west of Sable Island is characterized by well-sorted, fine to coarse sand, with periodic disturbances brought on by storms. Mega-ripples are common (D. Peer, pers. comm.).

**Species Composition and Distribution.** The predominant epifaunal organisms on Western and Middle Banks are the sand dollar (*Echinarchnus parma*), brittlestar (*Ophiura sp.*) ocean quahaug (*Arctica islandica*), and surf clam (*Spisula polynyma*) (Figure 8.3-3 and Table 8.3-10). Recent surveys on Western and Middle Banks also indicate high populations of polychaetes, amphipods and mollusks (D. Perr, unpublished data). Polychaetes such as *Euchone incolor*, Paraonidae spp. and *Prionospio steenstrupi* were found to exist in large numbers across the banks. These species do not inhabit burrows as the frequent disturbances of the sandy bottom necessitate quick reestablishment. Amphipod species are believed to include *Unciol airoratata*, *Leptocheirus pinguis*, and *Priscella* spp. (D. Peer, unpublished data).

**Seasonal Cycles.** Little is known about the seasonality of benthos in the Western Bank and Middle Bank areas. Species composition changes very little over the year, except immediately after a storm (D. Peer, pers. comm.). Species diversity is fairly constant. Amphipod spawning
Benthic Communities in the Study Area


FIGURE 8.3-3
## TABLE 8.3-10

**BENTHIC ORGANISMS OCCURRING ON THE SABLE ISLAND BANK**

<table>
<thead>
<tr>
<th>Organism</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sponges</strong></td>
<td></td>
</tr>
<tr>
<td><em>Clathria delicata</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Suberites ficus</em></td>
<td>0</td>
</tr>
<tr>
<td>Unidentified sponges</td>
<td>0</td>
</tr>
<tr>
<td><strong>Cnidarians</strong></td>
<td></td>
</tr>
<tr>
<td><em>Hydractinia echinata</em></td>
<td>0</td>
</tr>
<tr>
<td><em>Epizoanthus americanus</em></td>
<td>0</td>
</tr>
<tr>
<td>Cerianthus sp. (?) (in patches)</td>
<td>C</td>
</tr>
<tr>
<td><strong>Polychaetes</strong></td>
<td></td>
</tr>
<tr>
<td><em>Eteone lactea</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Euchone incolor</em></td>
<td></td>
</tr>
<tr>
<td>Paracnidae spp.</td>
<td></td>
</tr>
<tr>
<td><em>Prionospio steenstrupi</em></td>
<td></td>
</tr>
<tr>
<td><em>Spirobranchus spirrilum</em></td>
<td>0</td>
</tr>
<tr>
<td><strong>Crustaceans</strong></td>
<td></td>
</tr>
<tr>
<td>Balanus sp.</td>
<td>0</td>
</tr>
<tr>
<td>Cancer sp.</td>
<td>I</td>
</tr>
<tr>
<td><em>Crangon septemspinus</em></td>
<td>0</td>
</tr>
<tr>
<td>Pagurus arcuatus and sp.</td>
<td>C</td>
</tr>
<tr>
<td><strong>Gastropods</strong></td>
<td></td>
</tr>
<tr>
<td><em>Aporrhais occidentalis</em></td>
<td>0</td>
</tr>
<tr>
<td><em>Buccinum undatum</em></td>
<td>0</td>
</tr>
<tr>
<td><em>Liunatia heros</em></td>
<td>0</td>
</tr>
<tr>
<td><em>Neptunea lyrata decemcostata</em></td>
<td>0</td>
</tr>
<tr>
<td><strong>Amphipods</strong></td>
<td></td>
</tr>
<tr>
<td><em>Leptochierus pinguis</em></td>
<td></td>
</tr>
<tr>
<td>Priscella sp.</td>
<td></td>
</tr>
<tr>
<td>Unciola irrorata</td>
<td></td>
</tr>
</tbody>
</table>

MARCH 7, 1990
## TABLE 8.3-10 (CONTINUED)

**BENIHIC ORGANISMS OCCURRING ON THE SABLE ISLAND BANK**

<table>
<thead>
<tr>
<th>Organism</th>
<th>Abundance$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bivalves</strong></td>
<td></td>
</tr>
<tr>
<td><em>Anomia aculeata</em></td>
<td>O</td>
</tr>
<tr>
<td><em>Arctica islandica</em></td>
<td>O-C</td>
</tr>
<tr>
<td><em>Astarte undata</em></td>
<td>O</td>
</tr>
<tr>
<td><em>Cyrtodaria siliqua</em></td>
<td>O-C</td>
</tr>
<tr>
<td><em>Ensis directus</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Hiatella arctica</em></td>
<td>O</td>
</tr>
<tr>
<td><em>Modiolus modiolus</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Mytilus edulis</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Placopecten magellanicus</em></td>
<td>O</td>
</tr>
<tr>
<td><em>Serripes groenlandicus</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Spisula polynyma</em></td>
<td>I-O</td>
</tr>
<tr>
<td><em>Tellina sp.</em></td>
<td></td>
</tr>
<tr>
<td><strong>Echinoderms</strong></td>
<td></td>
</tr>
<tr>
<td><em>Asterias vulgaris</em></td>
<td>O-C</td>
</tr>
<tr>
<td><em>Henricia sanguinolenta</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Ophiopholis aculeata</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Ophiura sarsi</em></td>
<td>I</td>
</tr>
<tr>
<td><em>Echinarachnius parma</em></td>
<td>C-A</td>
</tr>
<tr>
<td><em>Cucumaria frondosa</em></td>
<td>O-C</td>
</tr>
<tr>
<td><em>Gorganocephalus arcticus</em></td>
<td></td>
</tr>
<tr>
<td><em>Strongylocentrotus droebachiensis</em></td>
<td>I</td>
</tr>
</tbody>
</table>

$^1$ I = infrequent; O = occasional; C = common; A = abundant

(Stanley and James 1971; Davis 1976; Geomarine Associates 1980; 1981a,b,c,d; Martec Limited 1982b; D. Heffler, Fisheries and Oceans Canada, pers. comm 1982; D. Peer, unpublished data.)
occurs during spring, summer and winter, depending on the species. The ocean quahog spawns during late summer/fall (Mobil 1983a).

Feeding Types and Trophic Relationships. The benthic fauna on the banks are dominated by filter-feeders and detritus feeders. Filter-feeders such as the ocean quahog are more efficient feeders as there is probably little accumulation of organic detritus in the shifting sands over the banks. Benthic organisms are in turn consumed by both benthic and demersal fish predators. Examples of benthic predators include starfish (Henricia sanguinolenta) and moon snails (Lunatia heros). Fish predators include cod, haddock, sculpins and skates.

Production. Annual benthic production for Western and Middle Banks is estimated to fall somewhere between the figures derived for Emerald Bank and Grand Bank given below. No actual measurements have been made for Sable Island Bank area. Mills and Fournier (1979) estimated annual production for the area west of Sable Island Bank (Emerald Bank) as 132 kJm²yr⁻¹ for primarily polychaetes and crustaceans. Hutcheson et al. (1981) estimated production for the Grand Banks at 536 kJm²yr⁻¹.

East Sable Island Bank

Habitat Type. The area east of Sable Island is characterized by heavily rippled sand, with sand waves of 2 to 6 m in height, becoming less mobile with increasing depth. Sediment movement is moderate to high and silt accumulation is low (Mobil 1983a).

Species Composition and Distribution. The predominant organisms found in this area is the common sand dollar (Echinarchnus parma). Other common epifauna include hermit crabs (Pagurus sp.), ocean quahog (Arctica islandica), starfish (Asterias vulgaris), and sea cucumbers (Cucumaria frondosa) (Mobil 1983a).
Infauonal species have been less studied in the eastern Sable Island Bank area, but probably include amphipods such as *Uncia lar irrorata* and *Leptochirus pinguis* and many species of polychaetes (Mobil 1983a).

This region is devoid of macrophytes due primarily to the constantly shifting sands (Mobil 1983a).

**Seasonal Cycles.** As with the western portion of Sable Island Bank, there is little change in species composition over the seasons. Benthic density is also relatively constant, except after storms (D. Peer, pers. comm.). It is believed that recolonization is rapid after such disturbances.

Major spawning of invertebrates occurs in late winter/early spring. Most larvae are planktonic and may remain in the water column for several months (Mobil 1983a).

**Feeding Types and Trophic Relationships.** Feeding types in this area are predominantly filter-feeding and deposit-feeding detritivores. Examples of the former type include ocean quahog and the latter include sand dollars. Benthic predators also contribute to production and include moon snails (*Lunatia heros*), starfish (*Asterias vulgaris*), and rock crabs (*Cancer sp.*). Several species of demersal fish also consume benthic organisms, in particular, echinoderms, mollusks, and crustaceans.

**Production.** Annual benthic production in this area is given as an estimate for the whole Scotian Shelf as further studies are needed. It is presumed to fall within the range of 132-536 kJm⁻²yr⁻¹ (Mobil 1983a).

8.3.5.5 **Marine Fish**

Due to the relative importance of demersal species in the fishery of the study area, the following discussion focuses on these species.
Pelagic fish, although present, are not heavily exploited by the commercial offshore fishery.

Reproduction and Early Life History

Analysis of SSIP (Scotian Shelf Icthyoplankton Program) (O'Boyle et al. 1984) data indicates that spawning of Atlantic cod begins in the fall on Sable Island Bank and Banquereau (Figure 8.3-4). Eggs and larvae were still present on these banks during January and February cruises. Spawning activity shifts south to Emerald and Western Banks in the spring, and egg production ceases by May (Figure 8.3-5 and 8.3-6) (O'Boyle et al. 1984).

From preliminary investigations, it appears that cod (Gadus morhua) larvae are retained in the same general area as the eggs, at least until metamorphosis (O'Boyle et al. 1984). This larval retention is probably a factor of circulation patterns over the banks.

SSIP data show haddock (Melanogrammus aeglefinus) eggs and larvae concentrated on Emerald and Western Banks in April, and more widespread by May. Haddock have a short, well-defined spawning period, exhibiting similar larval retention to cod.

Scott (1983) did not find evidence of haddock spawning on Sable Island Bank, but found a small breeding stock on the eastern shallows of Banquereau. This group may represent a separate spawning stock from the Emerald Bank haddock. Scott (1983) also noted significant spawning on Emerald Bank in March, extending into April and May.

Pollock (Pollachius virens) spawning begins around the same time as cod, but ends earlier (O'Boyle et al. 1984). Spawning is concentrated on Emerald and Western Banks, but also occurs to the northeast (Figure 8.3-6). Larval distribution is similar to that of eggs.
### Spawning Periods and Areas of Concentration of Major Fish Species in the Study Area

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Area*</th>
<th>Spawning Period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>American Sand Lance</strong></td>
<td>All Banks</td>
<td></td>
</tr>
<tr>
<td><strong>Atlantic Argentinine</strong></td>
<td>Shelf Edge, Emerald Bank</td>
<td></td>
</tr>
<tr>
<td><strong>Atlantic Herring</strong></td>
<td>Chedabucto Bay, Eastern Shore</td>
<td></td>
</tr>
<tr>
<td><strong>Longhorn Sculpin</strong></td>
<td>Edge of All Banks</td>
<td></td>
</tr>
<tr>
<td><strong>Atlantic Cod</strong></td>
<td>Sable-Banquereau, Emerald Western</td>
<td></td>
</tr>
<tr>
<td><strong>Cusk</strong></td>
<td>Shelf Edge</td>
<td></td>
</tr>
<tr>
<td><strong>Haddock</strong></td>
<td>Emerald-Western</td>
<td></td>
</tr>
<tr>
<td><strong>Pollock</strong></td>
<td>Emerald-Western</td>
<td></td>
</tr>
<tr>
<td><strong>Silver Hake</strong></td>
<td>Western-Sable</td>
<td></td>
</tr>
<tr>
<td><strong>Red Hake</strong></td>
<td>Emerald Basin, Shelf Edge</td>
<td></td>
</tr>
<tr>
<td><strong>White Hake</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>American Plaice</strong></td>
<td>Around Emerald, North Banquereau</td>
<td></td>
</tr>
<tr>
<td><strong>Winter Flounder</strong></td>
<td>Sable</td>
<td></td>
</tr>
<tr>
<td><strong>Witch Flounder</strong></td>
<td>Around Emerald, North Banquereau</td>
<td></td>
</tr>
<tr>
<td><strong>Yellowtail Flounder</strong></td>
<td>Sable-Western</td>
<td></td>
</tr>
<tr>
<td><strong>Redfish</strong></td>
<td>Shelf Edge Basins</td>
<td></td>
</tr>
<tr>
<td><strong>Squid</strong></td>
<td>Gulf Stream</td>
<td></td>
</tr>
</tbody>
</table>

* N.B. All areas are banks unless otherwise noted.

Source: Emery and McCraken 1966; Leim and Scott 1966; O'Boyle et al. 1982; Oldham 1972; Sameoto 1971; Sameoto and Jaroszynski 1972; Sameoto and Lewis 1979; Scott 1983; Scott and Scott 1988

**FIGURE 8.3-4**
Autumn and Spring Distribution of the Early Life History Stages of the Major Species in the Study Area

Source: Koeller 1981; McCracken 1965; R. O'Boyle, Fisheries and Oceans Canada, pers. comm. 1982; O'Boyle et al. 1984; Sameoto and Jaroszynski 1972; Scott 1982 b1983; J. Scott, Fisheries and Oceans Canada pers. comm. 1982; Scott and Scott 1988

FIGURE 8.3-5
Summer Distribution of the Early Life History Stages of Major Fish Species in the Study Area

* NOTE: 0+ = 0 to less than 1 year of age
    1+ = 1 to less than 2 years of age
    2+ = 2 to less than 3 years of age

Source: Koeller 1981; McCracken 1985; R. O'Boyle, Fisheries and Oceans Canada, pers. comm. 1982; O'Boyle et al. 1984; Soseto and Jareczynski 1972; Scott 1982 b1983; J. Scott, Fisheries and Oceans Canada pers. comm. 1982; Scott and Scott 1988

FIGURE 8.3-6
Ripe silver hake (*Merluccius bilinearis*) were found along the edge of the shelf from Browns Bank to Banquereau during late summer (Scott 1983). Eggs are found in four major areas in August and September on Browns, Emerald, Western Banks, and Banquereau. By September, egg and larval distribution is restricted to Emerald and Western Banks (O'Boyle et al. 1984). Scott (1983) also recorded spawning fish from Sable Island Bank. Silver hake exhibit a spawning migration from the edge of the Scotian Shelf to the central shelf area in late spring/early summer (Scott and Scott 1988).

American plaice (*Hippoglossoides platessoides*) can be found widely distributed over the Scotian Shelf during spawning from April to July. High concentrations occur on Sable Island Bank in May (Figure 8.3-6), becoming more scattered during the summer (O'Boyle et al. 1984).

Witch flounder (*Glyptocephalus cynoglossus*) spawn from March to July, primarily over the northeast part of the shelf, including Banquereau (Scott 1983).

Yellowtail flounder (*Limanda ferruginea*) appear to spawn in summer and are concentrated on top of the banks (Scott 1983). Major spawning concentrations are found on Western Bank and south Sable Island Bank (Figure 8.3-5).

Red hake (*Urophysis chuss*) spawns in summer, peaking in July. Ripening white hake (*U. tenuis*) have been found in small, widely-distributed numbers. Ripe red hake are found over the central part of the Scotian Shelf (Scott and Scott 1988), while white hake are found in deep water along the shelf edge, and particularly in the Laurentian Channel (Scott 1983).

Sand lance (*Ammodytes americanus*) begin to spawn in late November, peaking in December. Spawning occurs in shallow water areas on major fishing banks (Scott and Scott 1988). Eggs are demersal.
Seasonal Distributions

Fisheries and Oceans Canada have conducted annual groundfish cruises since 1970, using a bottom trawl and covering the shelf area from the 200 fathom contour to the 50 fathom contour. Sampling from 1970-79 was limited to the summer months, while spring and fall cruises were added after 1980. Research data from 1975-79 and 1980-84 have been summarized in Scott and Scott (1988), and serve as the basis for updating the seasonal distribution figures (Figures 8.3-7 to 8.3-10), along with Scott and Scott (1988). A list of common fish species found in the study area is presented in Table 8.3-11.

Winter. During the winter months, water temperature appears to be the prime factor affecting the distribution of fish species within the study area. Most groundfish species move off the tops of the banks to deeper warmer waters along the bank edges and adjoining basins (Figure 8.3-7) (Scott and Scott 1988).

Atlantic cod are generally concentrated at a depth of 100 m. Haddock can be found as deep as 145 m in 2.5°-3.5°C water. Other species such as yellowtail flounder, sand lance and winter flounder (Pseudopleuronectes americanus) are more tolerant of cooler water temperatures and remain on the banks over the winter. Juvenile Atlantic mackerel (Scummer scombrus), monkfish (Lophius americanus), wolffish (Anarhichas lupus), redfish (Sebastes sp.), Atlantic argentine (Argentina silus) and silver hake are found along the shelf edge. Monkfish, wolffish and redfish are also found in deeper waters of the Gully (Figure 8.3-7). Highly migratory species, such as tuna (Thunnus thynnus), squid (Illex illecebrus), and dogfish shark (Squalus acanthia) are not found in the area in winter.

Spring. Data from spring cruises indicate an extensive distribution of cod and haddock, particularly on the outer edge of Sable Island Bank and southwest Banquereau (Figure 8.3-8). The major (commercial) concentrations of cod occur on the northern edges of Sable Island and
Winter Distribution of Major Species of Adult Fish in the Study Area

Source: Holliday 1973; Hare 1977; Kohler 1968; Kulka and Stobo 1981; Lein and Scott 1966; Pinhorn and Holliday 1975; K. Zwenenburg, Fisheries and Oceans Canada pers. comm. 1982

FIGURE 8.3-7
Spring Distribution and Migration Patterns of Major Species of Adult Fish in the Study Area


FIGURE 8.3-8
Summer Distribution of Major Species of Adult Fish in the Study Area


FIGURE 8.3-9
Autumn Distribution and Migration Patterns of Major Species of Adult Fish in the Study Area


Figure 8.3-10
### Table 8.3-11

**Common Species of Marine Fish Found in the Study Area**

<table>
<thead>
<tr>
<th>Marine Fish</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Plaice</td>
<td><em>Hippoglossoides platessoides</em></td>
</tr>
<tr>
<td>American Sandlance</td>
<td><em>Ammodeto dubius</em></td>
</tr>
<tr>
<td>Atlantic Argentine</td>
<td><em>Argentina silus</em></td>
</tr>
<tr>
<td>Atlantic Cod</td>
<td><em>Gadus morhua</em></td>
</tr>
<tr>
<td>Atlantic Halibut</td>
<td><em>Hippoglossus hippoglossus</em></td>
</tr>
<tr>
<td>Atlantic Herring</td>
<td><em>Clupea harengus</em></td>
</tr>
<tr>
<td>Atlantic Mackerel</td>
<td><em>Scomber scombrus</em></td>
</tr>
<tr>
<td>Atlantic Wolfish</td>
<td><em>Anarchias lupus</em></td>
</tr>
<tr>
<td>Bluefin Tuna</td>
<td><em>Thunnus thynnus</em></td>
</tr>
<tr>
<td>Cusk</td>
<td><em>Brosme brosme</em></td>
</tr>
<tr>
<td>Dogfish</td>
<td><em>Squalus acanthias</em></td>
</tr>
<tr>
<td>Haddock</td>
<td><em>Melanogrammus aeglefinus</em></td>
</tr>
<tr>
<td>Monkfish</td>
<td><em>Lophias americanus</em></td>
</tr>
<tr>
<td>Pollock</td>
<td><em>Pollachius virens</em></td>
</tr>
<tr>
<td>Porbeagle Shark</td>
<td><em>Lamnna nasus</em></td>
</tr>
<tr>
<td>Red Hake</td>
<td><em>Urophysis chuss</em></td>
</tr>
<tr>
<td>Redfish</td>
<td><em>Sebastes spp.</em></td>
</tr>
<tr>
<td>Sculpins</td>
<td><em>Myoxocephalus spp.</em></td>
</tr>
<tr>
<td>Skates</td>
<td><em>Raja spp.</em></td>
</tr>
<tr>
<td>Silver Hake</td>
<td><em>Merluccius bilinearis</em></td>
</tr>
<tr>
<td>Swordfish</td>
<td><em>Xiphias gladius</em></td>
</tr>
<tr>
<td>White Hake</td>
<td><em>Urophysis tenuis</em></td>
</tr>
<tr>
<td>Winter Flounder</td>
<td><em>Pseudopleuronectes americanus</em></td>
</tr>
<tr>
<td>Witch Flounder</td>
<td><em>Glyptocephalus cynoglossus</em></td>
</tr>
<tr>
<td>Yellowtail Flounder</td>
<td><em>Limanda ferruginea</em></td>
</tr>
</tbody>
</table>

**March 7, 1990**
Middle Banks, and may represent a different stock from those found to the northeast (Laurentian Channel). Since the mid-1980s, the haddock fishery has extended to Banquereau, where an increased number of fish have been observed, but it is not known whether this is a separate group from that on Western Bank.

Distribution of red hake is widespread over the central and western Scotian Shelf, with concentrations in the deeper water (73-126 m) and the Gully. White hake are found at 200-1,000 m water depth over muddy bottoms (Scott and Scott 1988).

Pollock begin a seasonal migration from the deep water overwintering grounds along the shelf edge to the warmer waters of Emerald and Western Banks and Banquereau.

Flatfish, including American plaice, halibut (*Hippoglossus hippoglossus*), yellowtail and witch flounder, can be found moving from deeper water to the tops of Sable Island, Western, Middle Banks and Banquereau. Flounders prefer cooler water. Yellowtail flounder and American plaice have similar preferences for sandy bottoms (Scott and Scott 1988). Two stocks of yellowtail flounder may exist, with the Gully serving as a barrier between the Banquereau and Sable Island Bank groups (Scott 1983).

Many pelagic species migrate over the Scotian Shelf on the way to summer feeding or spawning grounds (herring (*Clupea harengus*), mackerel, tuna, and swordfish (*Xiphias gladius*)) (Figure 8.3-8). In June dogfish migrate from winter breeding grounds to the banks and inshore areas (Scott and Scott 1988).

Summer. Atlantic cod have moved from the deeper water to the tops of the banks in 4-8°C water. Major concentrations can be found along the northern edges of Sable Island and Middle Banks.
Haddock distribution in the summer is dependent more on food availability than temperature or depth (Scott and Scott 1988). They are concentrated on the Western Bank and Banquereau (Figure 8.3-9).

Pollock are found in small numbers on the western portion of Banquereau, although distribution of pollock occurs mainly to the west of Sable Island Bank. Preferred depths range between 110-181 m for mature fish (Scott and Scott 1988).

Witch and yellowtail flounders are found widely spread over the banks in 2-6°C water, while concentrations of American plaice occur inside the 100 fathom (91-183 m) contour on Banquereau (Figure 8.3-9) (Scott 1983). Spawning witch flounder can be found along slopes and in deep water channels up to 500 m (Scott and Scott 1988). A small number of halibut can also be found on the southern tip of Banquereau.

Wolffish distributions are concentrated on the edges of the banks and in the deeper waters of the Gully (Scott 1983). Seasonal changes in distribution appear to be minimal.

The abundance of seasonal and pelagic species increases during the summer months. Porbeagle (Lamna nasus) and dogfish sharks are found along the shelf edge (Mobil 1983a). "Giant" bluefin tuna arrive in the area as early as June, while smaller tuna move into the area in late August (Scott and Scott 1988). Squid are widely distributed along the shelf edge, and are found concentrated along the edges of Sable and Western Banks. Abundances of squid vary from year to year (Mobil 1983a).

Fall. Concentrations of cod and yellowtail flounder can be found on Middle Bank and Banquereau. Yellowtail flounder show minor seasonal movements. A large spawning population of cod can be found on Middle Bank. Haddock distribution ranges from Middle Bank to Western and Sable Island Banks. Summer and fall distributions are similar (Figure 8.3-10).
A population of winter flounder, presumably discrete from inshore populations, exists in the shallow areas of Sable Island and Western Banks. No seasonal migrations are believed to take place (Scott and Scott 1988).

American plaice and witch flounders are spread out over the banks, and in the case of witch flounder, along bank edges and gullies. Halibut can be found in the cool waters on southwest Banquereau (Scott 1983). Autumn distribution of this species is similar to summer distribution (Scott 1983).

Many pelagic species are found moving out of the area during autumn (Figure 8.3-10). Atlantic mackerel migrate through the area to wintering areas along the shelf off Sable Island Bank and southward (Scott and Scott 1988). Tuna and swordfish start moving off the Scotian Shelf in October/November. Squid also move offshore at about this time (Mobil 1983a).

8.3.5.6 Marine Wildlife

Marine Turtles

Three species of sea turtle, the leatherback (*Dermochelys coriacea*), Atlantic loggerhead (*Caretta caretta*) and Kemp's Ridley (*Lepidochelys kempi*), may be present in the waters over the Scotian Shelf from May to October. All three species are considered vulnerable or endangered. Major breeding grounds are in warmer waters well to the southwest of the study area, and individuals recorded are summer migrants.

Marine-Related Birds

The distribution of seabirds over the Scotian Shelf is dependent on availability and distribution of preferred prey and the breeding status of the bird. In offshore waters prey distribution is generally of prime importance. In the study area the waters are also used by
breeding birds from Sable Island. Over 25 species of marine birds may be observed in the waters over the Scotian Shelf (Table 8.3-12). Data on the pelagic distribution of seabirds is based on studies by the Canadian Wildlife Service (Brown 1986; Canadian Wildlife Service unpub. data).

Winter. Data on the distribution of seabirds during the winter is restricted to surveys of the western side of the study area. Relative abundance of seabirds for the winter period is presented in Figure 8.3-11. Gulls are the dominant species over the Scotian Shelf in winter. Significant numbers of Northern Fulmars (Fulmarus glacialis) and lesser numbers of Black-legged Kittiwakes (Rissa tridactyla) are present. Dvekies (Alle alle) and murres are also present.

Spring. Seabird densities and diversity increase during this period (Figure 8.3-12). Gulls predominate and are common along the shelf break, with lesser numbers over the top of the banks. Small numbers of Northern Fulmars may still be observed. Shearwaters move into the region to feed along the shelf edge, along with storm petrels. Murres and dovekies are seen feeding as they move northeast through the study area to breeding areas further north.

Summer. During this period gulls and shearwaters predominate except over Emerald Bank where storm petrels dominate (Figure 8.3-13). Seabirds tend to spread over the study area during this period. Near Sable Island, terns may be seen feeding with concentrations of shearwaters, petrels and gulls over the ends of the spits. Maximum densities of seabirds are observed during this season.

Fall. Shearwaters and gulls are most abundant, though densities drop from those seen in summer. Wintering birds, including Northern Fulmars, Black-legged Kittiwakes, and alcids begin to appear in the study area (Figure 8.3-14).
<table>
<thead>
<tr>
<th>Category</th>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEABIRDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gulls</td>
<td>Herring gull</td>
<td><em>Larus argentatus</em></td>
</tr>
<tr>
<td></td>
<td>Great black-backed gull</td>
<td><em>L. marinus</em></td>
</tr>
<tr>
<td></td>
<td>Laughing gull</td>
<td><em>L. atricilla</em></td>
</tr>
<tr>
<td></td>
<td>Iceland gull</td>
<td><em>L. hyperboreus</em></td>
</tr>
<tr>
<td></td>
<td>Glaucous gull</td>
<td><em>L. glaucoides</em></td>
</tr>
<tr>
<td></td>
<td>Black-legged kittiwake</td>
<td><em>Rissa tridactyla</em></td>
</tr>
<tr>
<td>Shearwaters</td>
<td>Greater shearwater</td>
<td><em>Puffinus gravis</em></td>
</tr>
<tr>
<td></td>
<td>Sooty shearwater</td>
<td><em>P. griseus</em></td>
</tr>
<tr>
<td></td>
<td>Manx shearwater</td>
<td><em>P. pufinus</em></td>
</tr>
<tr>
<td></td>
<td>Audubon's shearwater</td>
<td><em>P. l'herminieri</em></td>
</tr>
<tr>
<td></td>
<td>Cory's shearwater</td>
<td><em>Calonecrtis diomedea</em></td>
</tr>
<tr>
<td>Terns</td>
<td>Arctic tern</td>
<td><em>Sternula paradisaea</em></td>
</tr>
<tr>
<td></td>
<td>Common tern</td>
<td><em>S. hirundo</em></td>
</tr>
<tr>
<td></td>
<td>Roseate tern</td>
<td><em>S. dougallii</em></td>
</tr>
<tr>
<td>Alcids</td>
<td>Common murre</td>
<td><em>Uria aalge</em></td>
</tr>
<tr>
<td></td>
<td>Thick-billed murre</td>
<td><em>U. lomvia</em></td>
</tr>
<tr>
<td></td>
<td>Dovekie</td>
<td><em>Alle alle</em></td>
</tr>
<tr>
<td></td>
<td>Atlantic puffin</td>
<td><em>Fratercula arctica</em></td>
</tr>
<tr>
<td></td>
<td>Black guillemot</td>
<td><em>Cepphus grylle</em></td>
</tr>
<tr>
<td></td>
<td>Razorbill</td>
<td><em>Aica torda</em></td>
</tr>
<tr>
<td>Other Seabirds</td>
<td>Northern fulmar</td>
<td><em>Fulmaris glacialis</em></td>
</tr>
<tr>
<td></td>
<td>Leach's storm-petrel</td>
<td><em>Oceanodroma leucorhoa</em></td>
</tr>
<tr>
<td></td>
<td>Wilson's storm-petrel</td>
<td><em>Oceanicus</em></td>
</tr>
<tr>
<td></td>
<td>Northern gannet</td>
<td><em>Sula bassanus</em></td>
</tr>
<tr>
<td></td>
<td>Double-crested cormorant</td>
<td><em>Phalacrocorax auritus</em></td>
</tr>
<tr>
<td></td>
<td>Great cormorant</td>
<td><em>P. carbo</em></td>
</tr>
<tr>
<td>SHOREBIRDS</td>
<td>Piping plover</td>
<td><em>Charadrius melodus</em></td>
</tr>
<tr>
<td></td>
<td>Semipalnated plover</td>
<td><em>C. semipalmatus</em></td>
</tr>
<tr>
<td></td>
<td>Spotted sandpiper</td>
<td><em>Actitus macularia</em></td>
</tr>
<tr>
<td></td>
<td>Least sandpiper</td>
<td><em>Calidris minitilla</em></td>
</tr>
<tr>
<td></td>
<td>Sanderling</td>
<td><em>C. alba</em></td>
</tr>
<tr>
<td></td>
<td>Red-necked phalarope</td>
<td><em>Phalaropus lobatus</em></td>
</tr>
<tr>
<td></td>
<td>Red phalarope</td>
<td><em>P. fulicaria</em></td>
</tr>
</tbody>
</table>

**TABLE 8.3-12**

**MARINE-RELATED BIRDS ASSOCIATED WITH THE STUDY AREA**

MARCH 7, 1990
Winter Seabird Abundance in the Study Area

Abundance - Average number of seabirds per kilometer

- More than 50
- 10.00 to 49.99
- 1.00 to 9.99
- .01 to .99

Species Codes
- Shearwaters
- Gulls/Jaegers
- Alcids
- Other

N.D. - No Data

Source: R. Brown, Canadian Wildlife Service, unpublished data; Brown, 1988

FIGURE 8.3-11
Spring Seabird Abundance
In the Study Area

Abundance - Average number of seabirds per kilometer

- More than 50
- 10.00 to 49.99
- 1.00 to 9.99
- .01 to .99

Species Codes
- Alcids
- Gulls/Jaegers
- Shearwaters
- Other
- N.D. - No Data

Source: R. Brown, Canadian Wildlife Service, unpublished data; Brown, 1986

FIGURE 8.3-12
Summer Seabird Abundance in the Study Area

Abundance - Average number of seabirds per kilometer

Source: R. Brown, Canadian Wildlife Service, unpublished data; Brown, 1986

FIGURE 8.3-13
Autumn Seabird Abundance in the Study Area

Abundance - Average number of seabirds per kilometer

More than 50
10.00 to 49.99
1.00 to 9.99
.01 to .99

Species Codes
- Alcidae
- Gulls/Jaegers
- Shearwaters
- N.D. - No Data of species codes

Source: R. Brown, Canadian Wildlife Service, unpublished data; Brown, 1986

FIGURE 8.3-14
Marine Mammals

Seventeen species of whales, dolphins and porpoise and two species of seal are found in the waters over the Scotian Shelf (Table 8.3-13). Many of the whales are on Canadian and international endangered species lists. Little or no data on the size or status of the stocks are available. In contrast, both species of seal are considered abundant with local stocks increasing yearly (Zwanenburg and Bowen 1990; W. Stobo, DFO, pers. comm.).

Little new data is available on the biology and distribution of whales, dolphins and porpoises over the Scotian Shelf. Estimates on the population size of right whales (Eubalaena glacialis) have increased to over 200 animals, though the stock in the region must still be considered endangered (Gaskin 1987, pers. comm.; J. Prescott in Lien et al. 1989). Extensive data are now being collected on seals in the vicinity of Sable Island and on the use of the Gully east of Sable Island by whales. The populations of harbour (Phoca vitulina) and grey seals (Halichoerus grypus) are both increasing, with present estimates at over 600 harbour and 9,700 grey seal pups born on Sable Island in 1989 (W. Stobo, pers. comm.; Zwanenburg and Bowen 1990).

The seasonal distribution of marine mammals over the Scotian Shelf is dependent on several factors, including availability of preferred prey species, water temperature and, in the case of seals, suitable land for whelping, moulting, and resting. The following sections describing the seasonal distribution of marine mammals are based on Leatherwood et al. 1976; Mobil 1983a; Sutcliffe and Brodie 1977; H. Whitehead, pers. comm.; and J. Parsons, pers. comm.

Winter. During the winter months the diversity and relative abundance of marine mammals is low, with one exception, the grey seal. Grey seals are present in large numbers on and about Sable Island. Wintering populations of pilot (Globicephala melaena), fin (Balaenoptera physalus) and northern bottlenose whales (Hyperoodon
### TABLE 8.3-13
MARINE MAMMALS OF THE STUDY AREA

**CETACEA: Whales, Porpoises, Dolphins**

<table>
<thead>
<tr>
<th>Baleen Whales</th>
<th>Toothed Whales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue whale</td>
<td>Sperm whale</td>
</tr>
<tr>
<td>Fin whale</td>
<td>Northern bottlenose whale</td>
</tr>
<tr>
<td>Sei whale</td>
<td>Pilot whale</td>
</tr>
<tr>
<td>Minke whale</td>
<td>Killer whale</td>
</tr>
<tr>
<td>Right whale</td>
<td>Striped dolphin</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>White-beaked dolphin</td>
</tr>
<tr>
<td></td>
<td>Atlantic white-sided dolphin</td>
</tr>
<tr>
<td></td>
<td>Saddleback dolphin</td>
</tr>
<tr>
<td></td>
<td>Risso's dolphin</td>
</tr>
<tr>
<td></td>
<td>Bottlenose dolphin</td>
</tr>
<tr>
<td></td>
<td>Harbour porpoise</td>
</tr>
</tbody>
</table>

**Balaenoptera musculus**

**B. physalus**

**B. borealis**

**B. acuterostrata**

**Balaena glacialis**

**Megaptera novaengliae**

**Physeter macrocephalus**

**Hyperoodon ampullatus**

**Globicephala melaena**

**Orcinus orca**

**Stenella coeruleodala**

**Lagenorhynchus albinosiris**

**L. Acutus**

**Delphinus delphis**

**Grampus griseus**

**Tursiops truncatus**

**Phocoena phocoena**

**PINNIPEDIA**

<table>
<thead>
<tr>
<th>Seals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour seal</td>
</tr>
<tr>
<td>Grey seal</td>
</tr>
</tbody>
</table>

**Phoca vitulina**

**Halichoerus grypus**

Source: Mobil 1983a.
ampullatus), some species of dolphins, and harbour and grey seals occur over the Scotian Shelf during the winter. Blue (B. musculus) and humpback (Megaptera novaeangliae) whales may also be observed. The edges of the banks appear to be the preferred wintering area for whales, presumably because of the availability of prey. Grey seals are present on Sable Island in January during whelping, and breeding also occurs on the Island late in the month. After breeding, the seals disperse to feed at sea. In March the beginning of the spring migrations may be observed, with blue and killer (Orcinus Orca) whales and white-beaked dolphins (Lagenorhynchus albinos) first to appear in Scotian Shelf waters (Figure 8.3-15).

Spring. In the spring, species diversity and relative abundance of most marine mammals increases over the study area. These increases represent the arrival of species which have overwintered farther south, and are now migrating northwards to the rich feeding areas of Nova Scotia, or farther north. The distribution of whales will reflect the distribution of preferred prey. Sperm whales (Physeter macrocephalus) are present along the shelf break and over the banks feeding on squid. Pilot, fin and minke (B. acutostrata) whales will be observed closer inshore or over the banks feeding on spawning herring or other species of fish. Sei (B. borealis) and right whales occur over Emerald Bank and westward outside the study area, while blue and fin whales occur over Western and Emerald Banks. Northern bottlenose, sperm, humpback, fin and pilot whales, and striped (Stenella coeruleodalba), saddleback (Delphinus delphis), and white-sided dolphins (L. acutus) are present over the Gully east of Sable Island. Harbour and grey seals are present on and around Sable Island. The harbour seals are whelping on the beaches of Sable Island in May followed by breeding in the waters around the Island in June. Large numbers of grey seals (10,000+) haul out on Sable Island in May to moult (Figure 8.3-15).
Winter and Spring Distribution of Marine Mammals in the Study Area

- **Winter and Spring Distribution**
- **Marine Mammals in the Study Area**

**SCALE**

Kilometres 50  0  50  100  200 Kilometres

- Water Depths in metres
- PARKER B
- COHASSET

- **HARBOUR SEAL** (Whelping, Mid-May - Early June)
- **GREY SEALS** (Mating, May)
- **GREY SEALS** (Mating, January)
- **RIGHT WHALES, BLUE WHALES, FIN WHALES, HUMPBACK WHALES**
- **NORTHERN BOTTLENOSE WHALES** (Spring)
- **Sperm Whales** (June)

Source: Mobil 1983

FIGURE 8.3-15
Summer. Whales are most abundant during the summer months, feeding actively on concentrations of plankton and fishes. As during the spring, fin and pilot whales are found over the banks feeding on schooling fishes. Sperm whales are along the shelf edge and over the banks. Northern bottlenose, sperm, humpback, fin whales plus striped and saddleback and white-sided dolphins are feeding over the Gully. During the early summer sei whales are believed to migrate eastward along the shelf edge, returning southwards over the body of the Scotian Shelf in September. The southward migration of summer migrants begins in September. Harbour and grey seals are present around Sable Island throughout the summer though the numbers of seals seen on the Island decreases in September (Figure 8.3-16).

Fall. The numbers and diversity of whales decreases as summer migrants continue south to overwinter. Wintering populations of baleen and toothed whales are present by late fall. During the fall harbour seals appear to disperse from Sable Island. Grey seals also disperse in the early fall but their numbers increase in December as the breeding population returns (Figure 8.3-16).

8.3.5.7 Sable Island

Sable Island is a remnant of a much larger land mass which extended along the outer edge of the Scotian Shelf. The Island has changed shape over recorded history, but can presently be described as a crescent shaped sandbar roughly 43 km long with a maximum width of 1.4 km.

The Island is partially vegetated (39 percent), and contains a number of small freshwater and brackish ponds (Freedman et al. 1982). A fairly diverse plant community common to dune type systems is supported and includes several species of plants endemic to Sable Island (Table 8.3-14).
Summer and Autumn Distribution of Marine Mammals in the Study Area

Source: Mobil 1983a
<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bartonia paniculata (Michx.) Muhl. var. sabulonensis Fern.</td>
<td>Screw-stem</td>
<td></td>
</tr>
<tr>
<td>Epilobium nesophilum (Fern.) var. sabulonense Fern.</td>
<td>Willow-herb</td>
<td>This species was not recorded by either Keddy (1975) or Freedman et al. (1982), and it may now be extinct.</td>
</tr>
<tr>
<td>Juncus pellocarpus E. Mayer var. sabulonensis St. John.</td>
<td>Rush</td>
<td></td>
</tr>
<tr>
<td>Oenothera cruciata Nutt. var. sabulonensis Fern.</td>
<td>Evening-primrose</td>
<td></td>
</tr>
<tr>
<td>Polygonum hydropiperoides Michx. var. psilostachium St. John.</td>
<td>Knotweed</td>
<td></td>
</tr>
</tbody>
</table>
The Island serves as home to breeding colonies of seabirds including two species of gulls, Herring (*Larus argentatus*) and Great Black-backed (*Larus marinus*); three species of terns Arctic (*Sterna paradisaea*), Common (*Sterna hirundo*) and Roseate (*Sterna dougallii*); Semipalmated Plovers (*Charadrius semipalmatus*); several pairs of Common Crow (*Corvus brachyrhynchos*); and the Ipswich Sparrow (*Passerculus sandwichenis princeps*), a subspecies of the Savannah sparrow which is endemic to Sable Island (McLaren 1981).

The harbour and grey seals also use the island as an important breeding, whelping and moulting area. The Sable Island horse (*Equus caballus*) is the only terrestrial mammal on the Island. The Sable Island horse is not a distinct species but is considered endemic to the Island and listed as endangered in Nova Scotia (Isnor 1981).

Five species of fish have been identified in the freshwater ponds (Table 8.3-15) and two species in Lake Wallace, the four-spined stickleback (*Apeltes quadracus*) and a flounder (*Pleuronectides* sp.).

**TABLE 8.3-15**
FISH OF SABLE ISLAND FRESHWATER PONDS

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mummichog</td>
<td><em>Fundulus heteroclitus</em></td>
</tr>
<tr>
<td>Blackspotted stickleback</td>
<td><em>Gasterosteus wheatlandi</em> (Putnam)</td>
</tr>
<tr>
<td>Four-spined stickleback</td>
<td><em>Apeltes quadracus</em> (Mitchell)</td>
</tr>
<tr>
<td>Nine-spined stickleback</td>
<td><em>Pungitius pungitius</em> L.</td>
</tr>
<tr>
<td>American eel</td>
<td><em>Anquilla rostrata</em> (Lasuer)</td>
</tr>
</tbody>
</table>

Source: Garside 1969; Gilhen 1974; and Howden et al. 1970.
8.3.6  FISHERY

8.3.6.1  Shellfish

Stimpson's surf clam (*Spisula polynyma*) is a cold water, slow-growing species present on Sable Island and Western Banks, but abundant on Banquereau (Figure 8.3-3). Total allowable catch for 1989 was 30,000 tonnes on Banquereau and 20,000 tonnes for the rest of the Scotian Shelf (D. Roddick, pers. comm.), up from 1987 figures of 15,000 tonnes for Banquereau and 5,000 tonnes for Scotian Shelf. Commercial landings of surf clams for 1989 were 7,700 tonnes (round weight), over twice the 1988 landings (3,200 tonnes) (D. Roddick, pers. comm.).

The ocean quahaug (*Arctica islandica*) is abundant on Sable Island and Western Banks, and present in low numbers on Banquereau (Figure 8.3-3). Total allowable catch for 1987 was 10,000 tonnes; for 1989, it was 13,200 tonnes (Scotian Shelf). Total allowable catch levels for Banquereau were limited to bycatch of 10 percent levels. There was no commercial offshore quahaug fishery in 1989; landings resulted as bycatches of the surf clam fishery.

Harvesting of these mollusks is done by hydraulic dredge, which creates a jet spray in front of the scoop to loosen sand and expose the clams (Rowell and Chaisson 1983).

Offshore scallop (*Placopecten magellanicus*) fishing has historically been opportunistic on the Scotian Shelf. In recent years, more effort has been made to fish scallops on the Scotian Shelf and St. Pierre Bank, although this fishery still accounts for only 15 percent of the offshore landings, most coming from St. Pierre Bank. Areas fished within the study area are shown in Figure 8.3-3. Commercial quantities exist on Middle Bank where 6.7 tonnes were landed in 1987 and less than 1 tonne was landed in 1988 (Robert et al. 1989). High abundances of scallops can also be found along the edge of the Continental Shelf on Western and Sable Island Banks (Figure 8.3-3). Landings from these
banks amounted to 100.4 tonnes in 1989, down from 415.8 tonnes the previous year (Robert et al. 1989).

8.3.6.2 Marine Fish

Information on domestic and foreign fishing locations is taken from Fisheries and Oceans International Observer Program (IOP) and FFIS (Foreign Fisheries Information System) data sources. The IOP data cover 100 percent of the foreign fleet and 50-80 percent of the domestic boats. The most recent data is for 1988. The FFIS data comes from sightings made by Fisheries and Oceans surveillance personnel and covers the period from January to November, 1989. Seasonal patterns in fishing effort by the domestic fleet is illustrated in Figure 8.3-17. The following sections describe the seasonal distribution of fishing effort.

Winter

In winter, domestic fishing effort is concentrated in the Gully and on Middle and Western Banks (Figure 8.3-18). Some boats were found along the shelf off Emerald Bank. Foreign vessels were not active in the area until late March/early April in 1988.

Domestic catches of cod landed within the study area were greatest in March, while haddock catches were high both in February and March.

Spring

Figure 8.3-19 shows domestic and foreign fishing distribution in spring. Fishing activity by both domestic and foreign boats has increased. Canadian effort was concentrated on top of the banks from Sable Island Bank across to Middle Bank and on top of Banquereau. The number of foreign boats increases along the shelf edge. Domestic catches of cod and haddock in the study area continue to increase.
Fisheries Statistical Divisions of the Scotian Shelf and Cumulative Vessel Days for the Domestic Fishing Fleet

NEW BRUNSWICK

Gulf of St. Lawrence

4T

4Vn

St. Pierre Bank

SUBAREA 3

SCOTIA

NOVA

SUBAREAS

4Vn

4X

BONAVISTA BAY

BRENNER BANK

GEORGES BANK

SUBAREA 5

SCOTIAN GULF

CONIFER

BANK SABLE ISLAND

PARKER

Kilometres 50 100 150 200 250 300 350

SCALE

Source: Fisheries and Oceans Canada 1989 Data (Data for December not available)

FIGURE 8.3-17
Winter Distribution of Fishing Vessel Activity in the Study Area, 1988/89

WHITEHEAD HOLE CLOSURE—FISHING PROHIBITED WITH OTTER TRAWL INCLUDING DANISH AND SCOTTISH SEINES (FISHING VESSELS >19.8m LOA)

SCALE
Kilometres 50 100 200
Water Depths in metres

Source: Fisheries and Oceans, Fisheries Observer Program, 1988; Fisheries and Oceans, Foreign Fisheries Information System, 1989

FIGURE 8.3-18
Spring Distribution of Fishing Vessel Activity
in the Study Area, 1988/89

WHITEHEAD HOLE CLOSURE—FISHING PROHIBITED WITH OTTER TRAWL INCLUDING DANISH AND SCOTTISH SEINES (FISHING VESSELS >19.8m LOA)

Source: Fisheries and Oceans, Fisheries Observer Program, 1988;
Fisheries and Oceans, Foreign Fisheries Information System, 1989

FIGURE 8.3-19
during spring, while landings of redfish and winter flounder peak in May. Foreign fishing is directed towards silver hake.

**Summer**

In summer, domestic fishing activity continues over all banks and scattered in the deeper waters of the Gully and north of Emerald Bank. A small experimental domestic silver hake fishery took place in 1988/89 to ascertain commercial viability. In addition, a domestic experimental fishery for tuna occurs over the slope. Foreign vessels can be found along the edge of Sable Island Bank and on Banquereau (Figure 8.3-20). In 1988, foreign fishing was primarily for silver hake by Soviet and Cuban boats. American vessels chartered by Canada fished for Stimpson's surf clams on Banquereau.

Landings of American plaice continue to be high, especially from Banquereau. Yellowtail flounder catches peaked during the summer. Cusk landings occur throughout the area and are highest during the summer months.

**Fall**

During the fall, domestic activity is greatly reduced and is scattered over Sable Bank, Western Bank and Banquereau, with a few boats fishing in the deeper water of the Gully (Figure 8.3-21). A fall cod fishery dominates in November; the pollock fishery peaks in October. Canadian offshore fishing for surf clams took place on Banquereau in vessels chartered from USA. The principal foreign fishery is the Japanese longline fishery for tuna and swordfish. Foreign vessels had left the area by November in 1988 and by late September in 1989.
Summer Distribution of Fishing Vessel Activity in the Study Area, 1988/89

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WHITEHEAD HOLE CLOSURE — FISHING PROHIBITED WITH OTTER TRAWL INCLUDING DANISH AND SCOTTISH SEINES (FISHING VESSELS >19.8 m LOA)

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* * * SMALL MESH GEAR LINE

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Source: Fisheries and Oceans, Fisheries Observer Program, 1988;
Fisheries and Oceans, Foreign Fisheries Information System, 1989

FIGURE 8.3-20
Autumn Distribution of Fishing Vessel Activity in the Study Area, 1988/89

Source: Fisheries and Oceans, Fisheries Observer Program, 1988; Fisheries and Oceans, Foreign Fisheries Information System, 1989

FIGURE 8.3-21
8.3.7 OTHER RESOURCE USERS

General Marine Shipping

Oil tanker routes along the coast of Nova Scotia are illustrated in Figure 8.3-22. Other commercial and merchant shipping follow similar routes (A. Milne, CCG, pers. comm. 1990).

There are two forms of notification to shipping: through the mail and by radio. The mail service includes the "Notice to Mariners" publication, of which there are annual and weekly editions. Within this publication, non-approach areas are indicated to vessels, foreign vessels are instructed on procedures in Canadian waters, and specific to this project, the position of oil rigs are defined. Every three months there is an update to the "Notice to Mariners" regarding oil rig positions.

The Canadian Coast Guard radio service notices, "Note-Ship", operates on certain marine frequencies at certain times. Other notices to shipping may also be broadcast along with the traffic lists at specified times.

Military Use

There is confirmation from the Department of National Defence - Sea Operations of routine military use within the vicinity of the Cohasset/Panuke Site (Lt. Robertson, Maritime Command, pers. comm.). Any information concerning specific details of operations requires a formal address to the Chief of Staff - Operations. This specific area is not designated on hydrographic/nautical charts as a target-firing range, which is required for vessel traffic. Areas used for firing practices, submarine exercises or other operations are posted in Note-Ships to notify vessels (Cpt. D. Hay, CCG, pers. comm.).
OIL TANKER ROUTES

LEGEND

1) FROM NORTH SEA
2) FROM GIBRALTAR
3) FROM WEST AFRICA
4) FROM CAPE OF GOOD HOPE
5) FROM CARIBBEAN
6) INTERCOASTAL FROM PLACENTIA BAY

FIGURE 8.3-22
Ocean Mining

At present there is no active ocean mining or leased areas for offshore aggregates resources on the Scotian Shelf off Nova Scotia. Locations of potential sand and gravel resources are shown in Figure 8.3-23.

Cables

There is one trans-Atlantic telecommunications cable which lies to the west of the Panuke welljacket location, the Cantat II Cable, which is the property of Teleglobe Canada Inc. (Figure 8.3-24). The landfall site in Nova Scotia is Beaver Harbour. The cable lies to the southwest of Sable Island across the Scotian Shelf and once off the Scotian Slope it runs northeast to England.

The cable was installed in a ploughed trench across the Shelf in 1973. Since then, there have been some experiences with breakages from fishing activities, in particular on-bottom fishing gear (Jacques/McClelland Geosciences 1987).

8.4

ENVIRONMENTAL ISSUES

8.4.1 DEFINITION

Environmental issues are defined as potentially significant project-environment interactions. In this section, environmental issues or concerns relevant to the Cohasset/Panuke Development are presented and evaluated through a review of similar hydrocarbon development projects. Environmental issues for these similar projects have been identified during environmental screening processes and environmental impact assessments which invariably include input from government and academic sources. In addition, three representatives from the fishing industry were contacted to provide input on the proposed Cohasset/Panuke Development.
OFFSHORE PLACER AND AGGREGATE RESOURCES, NOVA SCOTIA

SOURCE: MILLER AND FOWLER, 1987

FIGURE 8.3-23
LOCATION OF SUBMARINE CABLE

SOURCE: JACQUES/McCLELLAND

FIGURE 8.3-24
Environmental concerns for the Cohasset/Panuke Development are expected to be similar to those identified for the Venture Development Project (Mobil 1983a) which has a similar development scenario and is in close proximity to the Cohasset and Panuke fields. Other relevant projects reviewed were the Hibernia Development; and hydrocarbon production activity in the North Sea, Beaufort Sea, and offshore United States.

8.4.2 SUMMARY OF RELEVANT STUDIES

8.4.2.1 Venture Development Project

In 1983, Mobil Oil Canada, Ltd. submitted an Environmental Impact Statement (EIS) to the Federal and Provincial governments as part of its proposal to develop the natural gas reserves discovered in the Venture gas field near Sable Island (Mobil 1983a). Mobil filed two addenda (Mobil 1983b, 1983c) which addressed specific items judged by the regulators to not have been fully addressed in the EIS itself. Together, these documents provide a comprehensive assessment of the various environmental issues and concerns associated with the development of offshore hydrocarbon resources on the Scotian Shelf. In addition, Mobil had established a very large regional study area and identified the features and resources within the area that potentially could have been affected by the project. Mobil's regional study area encompassed the location and predicted area of influence (Ross 1989) of the Cohasset/Panuke Development and therefore provides an excellent source of background information for the assessment of possible environmental and resource-use impacts associated with this development.

The Venture EIS was subject to a full environmental review process, including two sets of public sessions, by the Sable Island Environmental Assessment Panel. The Panel concluded that the project could proceed subject to meeting a series of recommendations outlined in its report (FEARO 1983). It should be
noted that many of the comments contained in the Panel Report pertained to the offshore pipeline and impacts in the nearshore and mainland-based sections of the project, and are therefore not relevant to the proposed Cohasset/Panuke Development.

The numerous documents associated with the Venture Project offer an extensive list of issues and concerns relevant to the Cohasset/Panuke Development. These are discussed below under the subheadings construction and development drilling, production and operations, abandonment and accidental events. The text focuses on those interactions where some level of impact was predicted. For most of the interactions, the impacts were judged to have a negligible effect on the environment.

**Construction and Development Drilling**

The discharge of oil-based drilling muds during construction and development drilling at Venture was judged to have a minor impact on the lower trophic levels such as planktonic and benthic invertebrates, and fish eggs and larvae. In the case of the Cohasset/Panuke Development, it is expected that the impact from drilling muds would be negligible because water-based muds, rather than oil-based muds, are proposed for the drilling program. The remainder of the project-environment interactions during construction and development drilling at Venture was judged to have a negligible effect on the biota either because the effects would be extremely localized or there would not be any discernable consequence. However, the accidental disposal of debris could have some impact on the fishery if lost materials resulted in damage to fishing gear or otherwise interfered with fishing activity in the vicinity of the platforms.
Production and Operations

Only one pertinent routine event during production and operations activities at Venture was rated as having an impact greater than negligible. Debris from materials lost during routine activities was identified as having a minor impact on fisheries. Disposal of produced water and well workover fluids during routine operations were seen as having only a negligible effect.

Abandonment

A review of the potential concerns associated with the abandonment of the Venture development pertinent to the Cohasset/Panuke Development indicate that with the exception of the possible impact of debris on future fishing activity in the area, there were no detrimental effects associated with the project abandonment. In fact, several environmental benefits were seen as arising from removing the facilities, particularly for the fishery which would no longer be restricted from entry to the Safety Zones.

Accidental Events

The most serious environmental concern identified for the offshore components of the Venture Development Project was the potential impact of a gas and gas condensate blowout. The magnitude would be dependent on the timing and duration of the blowout. Direct impacts on plankton, and fish eggs and larvae as a result of direct exposure and resulting toxicity were judged as minor because effects would be relatively localized and transient. Mortality among fish eggs and larvae was expected to be within the range of natural variation in the population. Tainting of commercial fish species was also seen as a possible risk, although the area is remote from locations of major fishing activity such as the Gully or the shelf edge. Seabirds were also considered at risk in the
event of a significant release of condensate during a blowout, particularly during the winter when alcids are present in the area.

The effect of high noise levels on birds and mammals in the vicinity of a blowout was also identified a concern. In the Venture EIS, the effect was expected to be greatest on bird species resident on Sable Island. In fact, the greatest expected impact of accidental events in the offshore components of the Venture Project was the impact of noise on the birds on Sable Island and thus was rated as moderate. Noise from a blowout at the Cohasset/Panuke fields would not be heard on Sable Island.

A batch spill from a pipeline break would also have minor consequences to invertebrate populations, as well as fish eggs and larvae. Any impacts would depend on the timing and size of the release. Seabirds would be vulnerable in the event of a spill.

The greatest concern to the commercial fishery was the possibility of inducing a taint in commercial species. The Panel concluded that tainting probably represented a greater threat to the fishery than mortality.

8.4.2.2 Hibernia Development Project

Hibernia EIS issues were ranked by importance based upon the Hibernia Panel hearings and associated submissions. The two major concerns were related to impacts on marine birds and the commercial fisheries. The latter took precedence because of its economic importance.

Displacement of fishing fleets from an offshore exclusion zone and displacement from areas of oil pollution due to spills or blowouts were judged as major concerns. Also of concern were the potential tainting of commercial fish by petroleum hydrocarbons and potential oil-fouling of fishing gear.
Both acute and chronic biological effects of oil pollution were seen as a major source of concern in relation to marine birds. Chronic effects were an identified source of concern, particularly with regard to direct biological effects related to reproduction (e.g., petroleum-coated eggs), direct ingestion of oil (e.g., feather preening), and loss of insulation effects.

However, the major concern involved the risk to large coastal seabird colonies from a major oil well blowout or tanker spill.

Also identified as areas of major concern were the biological impacts of project-related effluents and general disposal practices. These concerns included the impacts of drilling mud and cuttings on benthos, and the impacts of waste discharges and produced water on marine organisms in general.

8.4.2.3 Beaufort Sea Experience

The following review of environmental concerns associated with limited offshore oil and gas production in the Beaufort Sea is based on EPS (1984).

Production Water

The primary concern related to the effects of produced water on benthic organisms is the residual hydrocarbon loading to the benthic environment and the persistence of aromatics in the sediment. This results in a potential for the accumulation of trace metals and petroleum hydrocarbons in benthic organisms. The degree of concern associated with effects of produced water on benthic biota is increased by shallow water depths, which is pertinent to the shallow waters (30-40 m) found on the Cohasset and Panuke fields.
Drilling Muds and Cuttings

In the case of water-based muds, environmental concerns for benthic organisms include effects of burial (localized) and metal uptake from drilling mud disposal. While levels of accumulation are unlikely to pose a health hazard to humans consuming fish, the long-term effects on benthic organisms are unknown.

There are serious concerns associated with the use of diesel-based drilling muds because of the presence of toxic aromatic hydrocarbons and their potential accumulation and persistence in sediments in the vicinity of production fields.

Marine Mammals and Seabirds

A major concern in the Beaufort Sea was the possible effect of vessel activity (including underwater noise) on marine mammals. Pinniped species spend much of their time in the water column, and in shoreline or ice-covered areas during the mating, pupping and moulting periods (Harwood 1986 cited in EPS 1986). Though there is little evidence of mortality of cetaceans in cold marine waters, Geraci and St. Aubin (1982 cited in EPS 1986) suggest that whales trapped in oil-contaminated areas such as leads in ice or enclosed bays may be killed by oil, and animals already stressed could be susceptible to oil.

Marine seabirds are the most vulnerable of marine organisms to the effects of oil spills. This situation is more pronounced in cold environments where the sensitivity and vulnerability of marine birds to oil is high due to the combined effects of low temperatures and the presence of ice.
Exotic Chemicals

The introduction of exotic (man-made) chemicals to the marine environment is a concern because of the high toxicity of some chemicals such as biocides, and the persistence and bioaccumulation of halogenated organic compounds in the marine environment.

8.4.2.4

North Sea Experience

Petroleum development began in the North Sea in 1965. The North Sea hydrocarbon developments therefore represent the only long-term case study in the North Atlantic in terms of environmental concerns and realized impacts associated with offshore hydrocarbon development.

The following review of environmental concerns associated with North Sea hydrocarbon development is derived mainly from Hartley and Clark (1987).

Drilling Muds and Cuttings

The primary environmental concerns related to drilling muds and cuttings in the North Sea have been the potential effects on benthic marine organisms. Release of oil-based drilling muds into the North Sea has risen to 20 million tonnes per year. Prior to 1982, when low-toxicity oils were phased in, diesel was the primary oil component of the muds. Oil, discharged with drilling cuttings, constitutes nearly 90 percent of the input of oil to the North Sea from offshore operations (Anon. 1987 in Bakke et al. 1989).

The effects related to drill cuttings discharges have been reported to be minor and relatively localized, with detectable changes in benthic community structure restricted to within about a 500-m radius of the drilling platforms (Kingston 1987). The impacts of drill cuttings on the benthic fauna relate to whether they are
diesel-, oil-, or water-based. To date, it has been concluded that the offshore waters and sediments of the North Sea remain little affected by offshore oil and gas developments (Bedborough et al. 1987). This conclusion is based on long-term project experience and the results of field and laboratory studies on benthic community structure (Kingston 1987; Leaver et al. 1987; Moore et al. 1987). However, recent experimental research has shown macrofaunal recolonization to be very slow (greater than 4 years) on substrates of diesel and oil-based mud cuttings. In contrast, water-based cuttings gave no apparent affect on recolonization although redox conditions were below normal (Bakke et al. 1989).

Produced Water

A concern which has been difficult to quantify in terms of effect is that associated with produced water. The North Sea is an aging oil field; as hydrocarbon reserves are depleted, the output of produced water and associated oils increases. Bedborough et al. (1987) present a graph which shows a dramatic increase in produced water from approximately 2 million tonnes in 1979 to a projected peak of 90 million tonnes in 1990.

Debris

Debris is defined as material lost or thrown overboard from rigs, production platforms and supply vessels. This can include metal frames, oil cans, fuel drums, piping, tires, wire and cable and portions of drilling pipe left above the sea floor. In the UK the definition extends to rock or clay heaps left by anchors and pipeline trenching operations. Debris has been seen to cause major conflict between fishing and petroleum interests by the experience of the North Sea. The main effects on fishing operations are damage to equipment, reduction of fishing effort and loss of access (Gordon 1988; Barchard and Mastandrea 1986).
Physical damage or loss of fishing gear and/or catch and less frequently damage to vessels will cause a loss in revenue and could be significant if it occurs during intensive fishing activities within restricted seasonal periods. Fishing effort can be lost while removing debris from nets, repairing gear and fouled propellers and carrying debris to shore. Indirectly debris can cause a loss of access attributed to avoidance of areas known or perceived to contain debris until cleaning operations have occurred (Barchard and Mastandrea 1986).

The rapid increase in petroleum activity in the North Sea caused a considerable area of the sea to become unusable by the trawler fleet by 1977 due to potential damage to fishing gear from petroleum related debris (Barchard and Mastandrea 1986). Debris damage claims averaged about two per week with the majority of collisions clustered around drilling sites along pipelines and in the sea lanes of supply vessels (Heyerdahl 1977). By 1980 the Norwegian government has spent $3.3 million Canadian for damage not centered around well sites and $793,000 on cleanup operations. Oil companies contributed $27.5 million (Barchard and Mastandrea 1986).

Seabirds

Prior to the development of the North Sea oil fields, a major environmental concern was the potential effect on seabirds. This was due to a history of large, well-publicized oil spills, as well as small, unattributed oil slicks at sea. In particular, there were concerns that the operation of oil fields would result in serious mortality and declines in the large populations of seabirds breeding and wintering in and around the North Sea. The results of long-term monitoring programs have shown little or no effect on seabirds. However, the risk associated with a well blowout remains.
Experience in the Offshore United States

The three offshore regions in the United States where petroleum hydrocarbon production presently occurs are the Gulf of Mexico, the California coast, and Cook Inlet, Alaska. The following section presents results of American research in the major areas of environmental concern related to offshore hydrocarbon development.

Produced Water and Deck Drainage

Much of the existing information relating to the effects of produced water on the marine environment comes from studies conducted in the Gulf of Mexico (Gallaway 1980; Southwest Research Institute 1981). The Central Gulf of Mexico Platform Study and the Buccaneer Oil and Gas Field Study are two of the most comprehensive field investigations into the cumulative effects of chronic low-level discharge of hydrocarbons in produced water. The relevant environmental concerns related to hydrocarbon development which have been identified during the course of this research are:

- Several studies have shown a positive correlation between levels of petroleum hydrocarbons in fish and invertebrate tissues and the incidence of histopathological conditions and abnormal enzyme activity in fish.

- Limited data collected to date suggests that juvenile and larval stages of shrimp and fish may be more sensitive than adults to the effects of produced water.

Drilling Wastes

The primary environmental concerns associated with offshore drilling wastes are the possibility of toxic or sublethal effects to marine organisms from whole muds or components, and the potential for metal accumulation by marine organisms. Each type of
drilling mud (diesel-, oil-, and water-based) has its own inherent list of concerns. A major concern about the routine discharge of drilling muds, including non-toxic water-based muds, is the potential for accumulation of metals to concentrations that are harmful to marine organisms.

Several large-scale monitoring programs have been conducted adjacent to offshore drilling waste disposal locations in United States waters and these have provided information on the fate and effects of drilling fluids and cuttings. Conclusions as to the effects of water-based muds and cuttings, based on research conducted in the United States, are:

- Biocides are moderately toxic, but are present in low concentrations in the whole mud. Overall, whole muds are less toxic than the individual components. Toxicity of the mud aqueous fraction appears to result from volatile organic components.

- Laboratory experiments have shown that lobsters and winter flounder will accumulate small amounts of barium from exposure to water-based muds and cuttings. Chronic exposure to drilling mud resulted in moderate stress (increased mortality) to lobsters compared to control animals (Neff et al. 1989).

- Benthic fauna, primarily infauna, are affected by drilling waste disposal although impacts are restricted to an area within a radius of 300 to 500 m of the production platform. Other concerns relate to burial of sessile fauna, reduced abundances and alteration of benthic community structure, as well as attraction of marine organisms (e.g., fish) to drill cuttings piles.
Well Completion and Workover Fluids

Completion and workover fluids usually contain hydrocarbons. Completion fluids may contain solutions of zinc bromide, calcium bromide, calcium chloride, and a range of additives and acids. Environmental concerns related to these fluids are associated with elevated levels of dissolved zinc and organobromides. Of less concern is the potential toxicity of associated additives due to their low concentrations.

There has been limited investigation into the acute lethal and sublethal effects of zinc, bromide ion, and organobromide in completion and workover fluids associated with offshore oil production. However, it is suspected that effects would be local and short-term (EPS 1984).

OVERVIEW OF ENVIRONMENTAL CONCERNS RELATED TO HYDROCARBON DEVELOPMENT

The following section is a synthesis of environmental concerns in relation to petroleum hydrocarbon developments. It draws upon existing, extensive project experience, monitoring programs, and experimental studies in the North Sea and United States, and upon environmental impact studies conducted in the Beaufort Sea, Grand Banks of Newfoundland (Mobil-Hibernia), and Sable Island Bank (Mobil-Venture). In addition, three representatives from the fishing industry were contacted to provide input on the proposed Cohasset/Panuke Development.

Overall, the greatest environmental concern is the potential for a major accidental event such as a well blowout, and its associated effects on the marine ecosystem. Considering routine events only, a concern that is common to all development projects is the overall fate of oily discharges from production platforms and their effect on the marine environment. Oily discharges of prime concern are
produced water and, in particular, drilling muds and cuttings. Based on the amount of research conducted in recent years, the environmental effects of disposed drilling cuttings and muds are seen as a continuing and cumulative concern, particularly in the case of the North Sea where hydrocarbon production has been ongoing for 25 years and where there are a large number of production platforms.

Associated with the concern over the effects of oily discharges is the potential for accumulation of trace metals in the tissues of benthic organisms and sediments. Although representing a significant input to the environment, oil-contaminated produced water is generally regarded as a relatively minor concern.

Due to the nature and behaviour of oil slicks, a concern for seabird populations is a common theme. Concerns are in relation to acute effects (mass mortality) from oil spills and small, chronic spillages, as well as long-term effects on breeding populations and overall distribution patterns.

Other concerns such as effects of hydrocarbon production on commercial fishing activity tend to be project-specific. For instance, the northeastern Grand Banks of Newfoundland (location of Terra Nova and Hibernia development projects) represent an important fishing area for American plaice, whereas the Venture and Cohasset/Panuke Development areas are not prime finfish fishery areas, although more effort has been expended in recent years on sea scallop fisheries on Sable Island Bank. The introduction of pollutants into the environment by offshore petroleum development and production can potentially reduce stocks available to a fishery in three ways:

- by direct mortality of adult stocks
- by direct mortality of juveniles and larvae decreasing recruitment to future stocks

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8.122
- by indirectly disrupting the biological community that the stock relies upon (for food).

Pollutants produced by petroleum operations can be divided into two groups, accidental spills and operational discharges of drilling fluids (Barchard and Mahon 1986). Both groups contain soluble and toxic compounds, and drilling muds can smother benthos.

The effects of project-originated seafloor debris on commercial fishing activity is a potential concern.

Tainting is another concern for the fishery, in particular marketability. Most hydrocarbons are only sparingly soluble in water. However, the more toxic components of oil belong to the water soluble fraction which can be absorbed by marine organisms directly through the skin on contact with oil or on fouled fishing gear, by respiration via the gills or by digestion of contaminated food. Sub-lethal concentrations of the water soluble fraction in fish flesh can cause tainting. The working definition of tainting used by the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) is: "The development of a flavour or odour in the organism when caught or harvested which is not typical of the organisms themselves" (S. Fudge and Associates Limited 1989). Confirmed or even suspected tainting of fish stocks may have severe marketing consequences and fishing strategies would have to be altered accordingly.

The levels of hydrocarbons in water and flesh reported necessary to produce detectable off flavours or odours vary considerably although most investigations required concentrations of 5 ppm in the flesh before notable tainting had occurred (Tidmarsh et al. 1984).

During the interviews with the representatives from the fishing industry, the following concerns were raised:
- The heavy offshore scallop drags could damage the pipeline connecting the Cohasset and Panuke well sites. An exclusion zone may not prevent scallop vessels from tracking through the area.

- A spill may exclude fishermen or threaten the haddock nursery area and longline fishery on Western and Emerald Banks.

There are two concerns which deal with socio-economic related concerns namely, loss of access and labour migration. The loss of access occurs in two forms, legal and effective. Legal loss of access is specified in law as exclusion zones around production platforms, temporary installations such as exploration rigs and some suspended well heads within which fishing vessels are prohibited. Effective loss of access covers areas around exclusion zones due to fishing activities being curtailed before the 500 m limit, and petroleum related structures without exclusion zones, such as suspended well heads and pipelines, but which are avoided by fishermen fearing damage to gear.

The direct effect of loss of access would be to reduce available stock and therefore revenue to the fishery. Indirect effects include altering fishing operations and displacing vessels causing a "knock on" effect in other areas. The impact on the fishery is difficult to estimate due to the resolution of catch statistics. An oil and gas installation will take up only a small proportion of a statistical area or division.

Apart from the permanent loss of access associated with legal and effective areas, the fishing industry will suffer a temporary loss of access to areas effected by accidental oil spills. The extent and persistence of the loss of area will depend upon the size and type of hydrocarbon release. The timing of a spill is an important factor. A spill occurring during the off season may have a negligible impact on the fishery. However, the same spill occurring during peak season could have a substantial impact.
The recent spill of oil from the Exxon Valdez prompted a closure of the local herring fishery, this translating to a loss of revenue to fishermen of $11.7 million US (Hodgson 1990).

A worst case temporary loss of access caused by an accidental tanker spill from the Cohasset/Panuke Development would cover a surface area of 1,120 km² (S.L. Ross Ltd. 1989). Based on catch statistics presented in Gardner Pinfold Ltd. (1989) and assuming that the excluded area would equal the area of the spill and would persist over the total fishing season, this would represent a loss of catch of only 177.4 tonnes of groundfish and 4.4 tonnes of shellfish. The impact of such a scenario on the fishery would be minimal due to the location of the proposed sites within NAFO unit area 4Wf. The loss would equal only 0.2 percent of the groundfish and 0.1 percent of the 1982-1988 average annual shellfish harvest of 4VsW.

Labour migration out of an established, often traditional, renewable resource industry into a non-renewable highly industrialized oil sector may lead to cultural and socio-economic changes with implications for the family and community (Nordco 1984). The potential effects of offshore petroleum activities on the fishing industry labour force can be seen in three ways:

- The possibility of both inshore and offshore fishermen moving to the oil sector
- Onshore construction activity attracting general workers from the processing sector
- Skilled employees from harvesting or processing operations could provide support and maintenance services for the petroleum industry
In Newfoundland and Nova Scotia, corporate interests are most concerned about the loss of key manpower such as trawler maintenance crews, offshore fishermen and ships personnel as well as skilled tradesmen and supervisory staff from processing plants. The migration of general processing workers or independent inshore fishermen draws less attention (Nordco 1983).

8.5

VALUED ECOSYSTEM COMPONENTS

8.5.1

FRAMEWORK

Beanlands and Duinker (1983) note that an essential stage of any environmental assessment process is the identification of the valued ecosystem components (VECs). VECs are environmental attributes or components for which there is public or professional concern, or both, and to which the assessment should primarily be addressed.

The first step in the selection of VECs for the Cohasset/Panuke Development was the review of the Venture Development Project EIS documents. These documents included the EIS itself and the recommendations of the Venture Environmental Assessment Panel. Because of the similarities between the proposed Cohasset/Panuke and Venture Developments and the fact that the proposed Venture Development underwent full public hearings and Panel review, these documents were helpful in identifying potential VECs for this project.

8.5.2

SELECTION CRITERIA

The VECs for the Cohasset/Panuke Development were chosen on the basis of four criteria (Figure 8.5-1):

(1) Draft environmental impact assessment guidelines established by the Canada-Nova Scotia Offshore Petroleum Board
### CRITERIA FOR THE SELECTION OF VALUED ECOSYSTEM COMPONENTS

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<th>EIA Guidelines</th>
<th>Professional Concern</th>
<th>Economic Importance</th>
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**FIGURE 8.5-1**
(2) Professional concern with respect to abundance and status of species in the area

(3) Economic importance of species to the people of Nova Scotia

(4) Comparison with Venture environmental components

The VECs selected on the basis of these criteria are species of marine fish, birds, and mammals, except the ecosystem of Sable Island, and offshore fisheries. In some cases, related species were grouped at a more general level reflecting similarities in economic importance or social value, habitat requirements, or probable response to project components. For example, winter flounder (Pseudopleuronectes americanus) and yellowtail flounder (Limanda ferruginea) are collectively referred to as flounder because they share a common benthic food source and habitat. While northern sand lance (Ammodytes dubius) has no economic importance, this species has been included as a VEC since it plays an important role as forage for groundfish.

8.5.3
COHASSET/PANUKE VALUED ECOSYSTEM COMPONENTS

8.5.3.1
Fish

Demersal Species

The groundfish species on the Scotian Shelf are a major commercial resource (Scott and Scott 1988). The fish in this category feed and dwell near the bottom and are therefore potentially affected by certain offshore oil and gas production activities (Mobil 1983a). The species considered VECs are juvenile cod and haddock, silver hake, and flounder. Sand lance is also considered a valued ecosystem component as it is an important food source for many commercially-important groundfish species and found in abundant
distribution on Sable Island Bank (Scott and Scott 1988; Auster and Stewart 1986).

Juvenile Cod and Haddock. The juvenile life stage of cod and haddock is of particular concern as the Sable Island Bank provides a significant nursery area for these species (Fanning et al. 1987; Fanning and MacEachern 1989; Koeller et al. 1986). Upon reaching a length of approximately 3 to 9 cm, most groundfish species take on a demersal existence. The major adult fish stocks are located on the periphery of Sable Island Bank and elsewhere on the Scotian Shelf (Mobil 1983a).

Much of the feeding of the juvenile fish occurs close to the bottom on benthic and hyper-benthic organisms. Thus, they are susceptible to development and production drilling wastes or accidental events such as spills or blowouts.

Silver Hake. Silver hake are one of the most abundant species on the Scotian Shelf (G. Hurley, pers. comm. 1989). They are of major commercial value to the foreign fishery only, although their domestic importance may increase as a result of the reduced stocks of cod and haddock (Mobil 1983a).

Sable Island Bank is a major spawning ground for silver hake. The major nursery area is to the west in Emerald Basin (Mobil 1983a).

Flounder. Yellowtail and winter flounder are two commercially important species of flatfish which are abundant on Sable Island Bank (Mobil 1983a). Both species use the Bank for resident and spawning habitat. Winter flounder are found here year-round while yellowtail occupy the area mainly in the summer. Both species use the area for spawning. Thus, all life history stages could be affected by project wastes.
Northern Sand Lance. Sand lance have no commercial value, but they are an important prey item for many species of groundfish (Auster and Stewart 1986; Scott and Scott 1988). Adult sand lance account for up to 50 percent of prey for Atlantic cod per year. They are also a significant component of the diets of certain marine mammals and seabirds. These fish are widely distributed on the Scotian Shelf, on substrates composed of sand or fine gravel. Sand lance occur throughout the water column and burrow into bottom sediments to avoid predators (Auster and Stewart 1986).

Fish Eggs and Larvae

Most species spawning in the study area are demersal fish, hence the pelagic component to be considered in this impact assessment will include fish eggs and larvae, which will potentially interact with effluents and discharges from this Development. Eggs of demersal groundfish are slightly buoyant and float in surface waters. After hatching, the larvae of all fish species become pelagic. It is at this stage that eggs and larvae are vulnerable to hydrocarbon concentrations which are greatest at the surface following spills. Also, eggs and larvae are more sensitive than adult stages to oil (EPS 1986). The developmental time spent at the pelagic stage depends upon species, temperature, and food availability.

Benthos

Two commercially valuable (or potentially valuable) shellfish species, the sea scallop (Placopecten magellanicus) and ocean quahog (Arctica islandica), are identified as VECs for this environmental evaluation. These species, which are fished on Sable Island Bank, are part of the benthic community.

Scallop beds on the Scotian Shelf are exploited alternatives to the main fishing grounds of Georges Bank. The deep-sea fleet, in
exploring new grounds, shift effort from year to year on Sable Island and Western Banks, and Banquereau (Robert et al. 1989). In some years, the fishing effort has included areas in close proximity to the Development site.

The fishery for the ocean quahog on Sable Island Bank is experimental. However, these shellfish inhabit areas in close proximity to the site.

8.5.3.2 Seabirds

One of the most important seabird populations near the study area is on Sable Island; gulls and terns being the most common breeding seabirds in the summer (Mobil 1983a). During the winter months, alcids are very abundant in these waters. In the summer, shearwaters and Wilson's Storm-Petrels spend their austral winter on the open sea.

Seabirds rely on the fine structure of their plumage for insulation, water repellency, and for giving their bodies the aerodynamic shape for flight. Petroleum oils disrupt the arrangement of the barbules and barbicelles of the feathers, resulting in the feathers becoming matted and water-logged. Seabirds will drown if water-logged, expend excess energy to fly if oiled, die of hypothermia from loss of insulation, and ingest oil while preening oiled plumage (Leighton et al. 1985; NRC 1985). Other impacts include evidence of reproductive impairment and embryotoxicity, as shown through experiments with Prudhoe Bay Crude (Leighton et al. 1985).

The most susceptible birds are those that spend most of their time in the water and dive rather than fly when disturbed.
Alcids

Alcids feed primarily on fish, squid, and crustaceans which are captured by pursuit diving. These species spend most of their time on the surface and are, therefore, highly vulnerable to oil pollution, and are thus included as VEC.

Alcids found in the study area include Common Murre (Uria aalge), Thick-billed Murre (Uria lomvia), Dovekie (Alle alle), Atlantic Puffin (Fratercula arctica), and Razorbill (Alca torda). These species are transients and occur most commonly during the winter months following dispersal from their breeding colonies. Dovekie, thick-billed murre, and common murre are the most abundant alcids wintering in the study area.

Shearwaters

Shearwaters feed primarily upon sand lance, cephalopods, and crustaceans which are captured while pursuit diving. The large numbers of shearwaters present in the study area, combined with their susceptibility to hydrocarbon contamination, warrants their inclusion as a VEC.

Shearwaters are abundant in the study area during the summer months spending most of their time on the water. Five species of shearwater that are found in the area include Greater (Puffinus gravis), Sooty (P. griseus), Maux (P. puffinus), Audubon's (P. lherminieri), and Cory's (Calonectris diomedea) Shearwater.

Terns and Gulls

Larids (terns and gulls) are the most abundant seabirds in the study area and thus warrant inclusion as a VEC. Commonly occurring species include Herring Gull (Larus argentatus), Great Black-backed Gull (L. marinus), Iceland Gull (L. glaucoides), Glaucous
Gull (L. hyperboreus), Black-legged Kittiwake (Rissa tridactyla), Common Tern (Sterna hirundo), and Arctic Tern (S. paradisaea). Roseate Tern (S. dougallii) (which breed on Sable Island) can also be considered as an important larid, since it is a rare species in Nova Scotia and is declining throughout its range.

During the summer, gulls tend to be concentrated near Sable Island with herring gulls and great black-backed gulls breeding there. Iceland and glaucous gulls are present during winter. Black-legged kittiwakes are common from late fall to early spring. Arctic and common terns are common on Sable Island during spring and summer when they form breeding colonies.

Gulls are opportunistic feeders on a variety of items such as fish, offal, and detritus. These food items are captured using a variety of techniques including seizing from the surface while flying or swimming, plunging into the water while flying, and scavenging shorelines. Terns feed primarily on small fish and crustaceans which they capture by plunging into the water or by seizing the item from the surface while in flight. Both species groups are susceptible to the potential effects of hydrocarbon.

8.5.3.3 Marine Mammals

Both seals and whales are present in the project area and due to their sensitivity and endangered or threatened status (for several species), they are included as VECs.

There are very few studies involving the effects of oil in water on marine mammals. St. Aubin et al. (1985) studied the reaction of dolphins to oil films. Marine mammals are at risk when surfacing to breathe (Englehardt 1987). Low molecular weight hydrocarbons at the air-water interface are known to cause nervous system effects when inhaled, and skin and eye lesions may result from contact (Englehardt 1987). Exposure may result from inhalation, coating,
direct ingestion, and through ingestion of contaminated food organisms.

Seals

Both grey (Halichoerus grypus) and harbour (Phoca vitulina concolor) seals inhabit the study area year-round, where they whelp and haul-out on Sable Island.

Grey seals whelp in the winter months (December to February) on the Island. By mid-February, the adults have left to feed at sea. The young are left to fend for themselves and usually depart to sea by March. Harbour seals are pelagic during winter and haul out on Sable Island in spring to whelp. It is during their time at sea where interactions with the Development Project could occur.

Cetaceans

Seventeen species of cetaceans (whales, dolphins, and porpoises) inhabit the study area at some point in their life cycles. Fin whales (Balaenoptera physalus), harbour porpoises (Phocoena phocoena), and pilot whales (Globicephala melaena) are present in the study area year-round. Distribution patterns are controlled by location of prey species and migration routes.

Baleen whales feed by collecting large volumes of water and straining the food. Toothed whales feed on larger organisms such as pelagic fish.

Concern is heightened by the lack of knowledge of the impacts of oil on this group of marine mammals. Some species such as the fin and sei whales (Balaenoptera borealis) are considered endangered because of low reproductive potentials and past over-exploitation.
8.5.3.4 Offshore Fisheries

The development lies within NAFO subdivision 4Wf, a part of divisions 4VsW, which are grouped together for analysis of catch data. Historically, 4Wf has contributed only a very small portion to the total 4VsW catch. Between 1982 and 1988, 4Wf contributed 1.46 percent of the groundfish and 9.19 percent of the shellfish harvested from 4VsW (Gardner Pinfold 1989).

Trawling and longlining for groundfish is not extensive near the Cohasset and Panuke fields. Groundfish are harvested west of the proposed well sites and longliners fish extensively on Western Bank and Emerald Bank. Pollock is fished along working underwater cables, including Cantat II which bisects the Panuke field. Halibut are fished along the edge of the Sable Island Bank and fishing of a new silver hake fishery in deep water off the Bank has recently commenced. Canadian vessels are beginning to undertake a nascent silver hake fishery in deep water off the Sable Island Bank.

Scallop fishing in the area is variable, with scallop draggers being common in the vicinity of the fields in some years.

The development area is also in a transit area for offshore trawlers travelling to other fishing locations.

Overall, despite the relatively small importance of the fishery in the area, the fishery is extremely important from a socio-economic perspective and is included as a VEC in this study.

8.5.3.5 Sable Island

Although there are no project-related facilities on Sable Island, it is considered a VEC for the Cohasset/Panuke Development because of its unique and dynamic ecosystem and proximity to the proposed development. The Island's isolation and geographical history have
supported a unique biological system. A number of plants and insects are endemic. Although introduced, the Sable Island horses are also considered endemic. Birds found on the Island such as the Roseate Tern and Ipswich Sparrow are listed as threatened and rare, respectively (COSEWIC 1988).

Sable Island may be used during accidental events associated with the Project. At present there is an emergency facility established for such use which is regulated through Transport Canada. During construction and installation, navigation and positioning personnel will be present on the Island from time to time.

8.6 STUDY BOUNDARIES

An important aspect of the environmental assessment process is the determination of the study boundaries. Beanlands and Duinker (1983) recognized four types of temporal and spatial boundaries that should be considered in developing a study design and carrying out an environmental impact assessment:

- Project boundaries
- Administrative boundaries
- Ecological boundaries
- Technical boundaries

Each of these types is discussed below in light of the Cohasset/Panuke Development.

8.6.1 PROJECT BOUNDARIES

Project boundaries refer to the time and space scales over which the project extends. Temporally, the construction, installation, production, and abandonment phases of the Project will take place over a seven-year period (1990 to 1997).
Spatially, the project area encompasses the following:

- the area enclosed within the Cohasset and Panuke well jackets, extending from the atmosphere, through the seawater, to the depth of the producing formations

- the area between the wellhead jackets and the development wells, in the subsurface, along the directionally drilled wells

- the flowline corridor between the two well jackets, extending from the atmosphere, through the seawater, to the seafloor

- the area overlain by the jack-up rig, the floating storage vessel, and offloading system, from the atmosphere through to the seawater

Figure 8.6-1 is a schematic of the project boundaries.

8.6.2 ADMINISTRATIVE BOUNDARIES

Administrative boundaries are time and space limitations imposed on the assessment for political, social, or economic reasons. The only administrative limitation placed on the Cohasset/Panuke Development environmental evaluation is the time frame within which it has to be completed (fall of 1989 through to the winter of 1990). This restriction, due to the proponent's schedule, and the small scale of the project necessitated the reliance on existing information, primarily from the Venture Development Project Environmental Impact Statement (Mobil 1983a,b,c), updated through a review of recent literature and discussions with discipline experts.
**ECOLOGICAL BOUNDARIES**

Ecological boundaries refer to the time and space scales over which natural systems function. Ecological time boundaries can be established on the basis of a variety of temporal characteristics of natural systems. Such factors include:

- The seasonality of chemical, biological, and physical characteristics of a population or ecological system

- The ecological sensitivity of an ecological system

- The time required for a population or ecological system to recover from a perturbation to its pre-impact state

The time scales that need to be considered in assessing impact vary widely between marine organisms. For example, the levels of temporal resolution may involve days or weeks when considering the possible impact of project activities during marine wildlife breeding periods or fish spawning. Other processes may be of seasonal or longer duration. Because of the time scales associated with fish stock recruitment, impacts on the fisheries may extend over many years.

The degree of impact of a perturbation on a particular species also depends on other ecological characteristics including the proportion of the year that the species remains in the proposed development area, the timing of sensitive life history periods in relation to the schedule of proposed activities, and whether the annual activity cycle of the species includes a period of dormancy. For example, many of the pelagic fish species in the study area are migratory and may move away from potential sources of impact. In dealing with time boundaries for impact assessment, there is a need to consider intervals that are biologically meaningful with respect to the life cycles of the species being considered.
Spatial ecological boundaries influence the likelihood that impacts on ecological systems could extend beyond the boundaries of the project area. Migratory bird and demersal and pelagic fish populations are frequently considered vulnerable because deterioration or loss of breeding and spawning habitats could influence population levels and resource use over extensive areas.

It is also necessary to know the physical transport mechanisms which could affect ecological systems adjacent to the proposed development area. Knowledge of the movement of currents, water mass and nutrients, physical characteristics, and light levels which vary seasonally in the euphotic zone of the water column, is necessary to conduct an environmental evaluation of the proposed development. These will affect primary and secondary biological production in the upper water layers, and subsequently, benthic production in and on the bottom sediments. Depending on these factors, dispersal of condensate in accidental spill, and blowout circumstances may, in certain instances, extend beyond the boundaries of the development area.

The susceptibility of a species to impacts is also governed by the size and distribution of the species relative to the area of impact. Conover et al. (1985) distinguished between three types of populations. Type 1 populations are considered most susceptible because they may have a large proportion of their population confined at any time within a given zone of influence. Type 2 populations include species which exist as a number of semi-isolated groups, or stocks, and have only a limited proportion of their population confined at any time to a given zone of influence. Therefore, although the entire species is not likely to be threatened by a particular source of impact, a particular group or stock could be vulnerable. By comparison, Type 3 populations have a widespread distribution and would have only a very small proportion of their population confined at any time to a particular zone of influence. A summary of the criteria used in the selection
of VECs (Section 8.5) and the definition of ecological boundaries is provided in Figure 8.6-2. The selection criteria (Section 8.5) and ecological boundaries for each VEC are summarized in Figure 8.6-3.

8.6.4 TECHNICAL BOUNDARIES

Technical limitations on the ability to predict and monitor project impacts must be considered at the outset of an EIA. These technical limitations define the technical boundaries of the EIA study. Most often, technical limitations in an environmental impact assessment can be placed in one of the following categories:

(1) Insufficient quantitative data on the resources to be monitored or treated in an impact assessment in terms of distribution and abundance and natural variation in population dynamics

(2) Inability to predict future potential impacts of the project due to altered patterns of utilization

Technical limitations with respect to impact assessment, Sable Island Bank resources and monitoring for the IASMO development are discussed in the following sections.

8.6.4.1 Impact Assessment

Overall, a lack of information on the distribution, abundance, and natural variation in populations of marine mammals, seabirds, and fish makes it difficult to accurately predict the impacts of an accidental event, such as a well blowout, on populations of these marine organisms. Currently, the ability to predict site-specific impacts on the fisheries due to oil spills is based on oil spill-fisheries interaction models which incorporate a large number of assumptions because of poor understanding of the dynamic nature of
CRITERIA FOR THE SELECTION OF VALUED ECOSYSTEM COMPONENTS AND DEFINITION OF ECOLOGICAL BOUNDARIES

**SELECTION CRITERIA**

- **STATUS.** Abundance and distribution of the species throughout the area; its abundance, scarcity or uniqueness to the area.
- **PROFESSIONAL CONCERN.** As expressed through the literature, or by scientists familiar with projects of this type or knowledgeable about the area in proximity to the proposed project area.
- **ECONOMIC IMPORTANCE.** Value to the people of the region in proximity to the proposed project area.

**POPULATION BOUNDARIES**

- **TYPE 1.** Species which may have a large proportion of their population confined at any time within a given zone of influence.
- **TYPE 2.** Species which exist as several semi-isolated groups, or stocks, and have only a limited proportion of their population confined at any time within a given zone of influence.
- **TYPE 3.** Species which have widespread distribution patterns, and have only a very small proportion of their population confined at any time within a given zone of influence.

**VALUED ECOSYSTEM COMPONENTS**

**SPATIAL BOUNDARIES**

- **NATIONAL.** Exists in other parts of Canada.
- **REGIONAL.** Exists only in the region surrounding the proposed project area.
- **LOCAL.** Exists only within the proposed project area.
- **CONTINENTAL MIGRATION.** Exhibits regular movements outside the region surrounding the proposed project area.
- **REGIONAL MIGRATION.** Exhibits regular movements in and out of the project area but remains in the general region surrounding the proposed project area.
- **GEOGRAPHIC.** Exists in the region surrounding the proposed project area but is limited to particular habitats by altitude, latitude, climate and/or habitat.

**TEMPORAL BOUNDARIES**

- **ANNUAL.** Found in the study region throughout the year.
- **SEASONAL.** Found in the study region during certain seasons.
- **OCCASIONAL.** Has occurred or may potentially occur in the study region.
- **DORMANCY.** Exists in the study region but is in a state of inactivity or dormancy at certain times of the year.
- **CYCLICAL.** Passes through regular periods of high and low population levels over several years.

*FIGURE 8.6-2*
### VALUED ECOSYSTEM COMPONENTS AND BOUNDARIES

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*Figure 8.6–3*
marine ecosystems. However, a large amount of empirical data from the monitoring of exploration, production and transportation of offshore hydrocarbons from other areas of the world, i.e., the North Sea and the Gulf of Mexico, and the experience with exploratory drilling in the Sable area can be used to make predictions of the type and potential magnitude of impacts from this project.

8.6.4.2 Sable Island Bank Resources

There is a potential for changes in the species fished for on the Scotian Shelf. Because of shifted fishing boundaries on Georges Bank, increased experimental shellfish fisheries on the Scotian Shelf, including Sable Island Bank, have appeared in recent years. There are indications that the scallop fishery, and possibly fisheries for surf clams and ocean quahogs could become important in the future in the study area. If such fisheries are established, they could potentially conflict with LASMO's development activity. At present, however, the magnitude of these potential conflicts cannot be identified.

8.6.4.3 Monitoring

Because of the generally poor data base which exists for most marine ecosystems in terms of baseline levels of water and sediment chemistry parameters, the ability to detect environmental change is impeded. This is compounded by the existence of other non-project related pollution sources or impacts related to such activities as fishing and shipping within the development area. These extraneous sources of potential pollution or impacts will render monitoring of some project-specific impacts extremely difficult, if not impossible.
8.7 IMPACT ANALYSIS

The potential impacts of the Cohasset/Panuke Development Project on the biophysical environment of the study area are assessed in this section, using the information presented in the preceding sections. This section will serve as a basis for IASMO's project planning, implementation, and development of mitigation measures. Following a description of the basis for the biophysical impact assessment, an evaluation of impact significance is presented through comparison of the project attributes with the VECs. This is followed by a discussion of potential routine, accidental, and cumulative impacts of the project.

8.7.1 BASIS FOR BIOPHYSICAL IMPACT ASSESSMENT

The biophysical impact assessment focuses on the evaluation of potential interactions between the project components and activities described in Section 8.2 and the VECs described in Section 8.5. In addition to describing the nature of the impact, the evaluation employs a numerical rating system to indicate the magnitude, duration, geographical extent, and probable frequency of occurrence of expected interactions.

Potential impacts on VECs are assessed on the basis of a review of relevant literature, consultation with experts, and professional judgment. In some instances, the current state of knowledge or understanding of the sensitivity of certain VECs is limited, making it necessary to rely primarily on professional judgment. As well, professional judgment is used in instances where required data on the abundance and distribution of VECs is lacking. Ratings are therefore provided to indicate the level of confidence with each impact prediction.

The impact predictions presented in this section are those that would be expected to occur following the incorporation of
mitigative measures that are inherent to the project design (Section 8.2). Residual impacts, or those impacts that are expected to remain following the adoption of all practical mitigative measures, are identified in Section 8.8.

The biophysical impact assessment is organized by type of event (routine or accidental) and project activity, as set out in Section 8.2. Summary matrices are presented for each project activity indicating the impact ratings for each VEC. The discussion of impact begins with the identification of potential interactions between project components and VECs followed by an assessment of potential impacts associated with each project activity.

8.7.2 EVALUATION OF IMPACT SIGNIFICANCE

Biophysical impacts on VECs were ranked using population-based criteria, following the methodology described by Conover et al. (1985). These criteria were expanded to allow ranking of impacts on the fisheries. Impact definitions are as follows:

(1) A major impact is defined as one affecting a whole stock or population of a species in sufficient magnitude to cause a decline in abundance and/or change in distribution beyond which natural recruitment (reproduction and immigration from unaffected areas) would not return that population, or any populations or species dependent upon it, to its former level within several generations. A major impact to fisheries is defined as either one of long duration (lasting several generations) or one affecting an entire definable group of people in significant magnitude to cause a significant change in economic, physical, or psychosocial well-being or in long-established activity patterns that would not return to pre-project levels or patterns within several generations.
(2) A moderate impact is defined as one affecting a portion of a population that results in a change in abundance and/or distribution over one or more generations of that portion of the population or any population dependent upon it, but does not change the integrity of any population as a whole; it may be localized. A moderate impact to fisheries is defined as one which is of medium-term duration (one which affects one or two generations and/or the portion of the population dependent upon it) or one which affects a moderate portion of the population without affecting the integrity of the population as a whole.

(3) A minor impact is defined as one affecting a specific group of individuals in a population at a localized area and/or over a short period (one generation or less), but not affecting other trophic levels or the integrity of the population itself. A minor impact to fisheries is defined as either one of short-term duration or affecting a specific group of people in a localized area but not necessarily affecting the integrity of the entire group itself.

(4) A negligible impact is one affecting the population or a specific group of individuals at a localized area and/or over a short period in such a way as to be similar in effect to small random changes in the population due to environmental irregularities, but having no measurable effect on the population as a whole. A negligible impact to fisheries is defined as one of either very short duration or one which affects a small group of people or which occurs in a localized area in a manner similar to small random changes due to extraneous irregularities, but having no measurable effect on the population as a whole.

The system used to rate impacts is illustrated in Figure 8.7-1. The impact of each interaction between a project component or activity
Key to Impact Ratings

Impact Ratings

- No Impact

O Negligible Impact

○ Minor Impact

● Moderate Impact

● Major Impact

N.A. Not Applicable

+ Positive Impact (no symbol = negative)

Distance from Fixed Facilities

1 <= 100 m radius
2 101 - 1000 m
3 1001 - 5000 m
4 > 5000 m

Duration of Interaction

1 < 1 month
2 1 - 12 months
3 > 12 months

Frequency of Occurrence

1 < 10 Events or Days per Year
2 < 11 - 50 Events or Days per Year
3 > 50 or Continuous

Level of Confidence

1 Low
2 Moderate
3 High

Range of Possible Impact Ratings

0 No Impact
1 Negligible Impact
2 Minor Impact
3 Moderate Impact
4 Major Impact

FIGURE 8.7-1
and a VEC is rated as negligible, minor, moderate, or major using a series of circular symbols. Where it is felt that interactions will not result in impact, the cell of the matrix is marked with a horizontal dash. Where no interaction is expected, the cell is marked NA (not applicable). Where a positive impact is predicted, a "+" sign appears over the impact rating symbol. The absence of a "+" sign indicates that the impact will be negative.

Numerical modifiers that appear in each cell of the matrix provide additional information on the nature of the interaction and the level of confidence associated with the impact ratings. The number in the upper right-hand corner is a rating, on a scale of one to three, of the level of confidence the study team had in the impact prediction. A rating of one would indicate that existing scientific data on the effects of that type of interaction are insufficient to predict confidently the nature and magnitude of impact, whereas a rating of three would indicate that there is a strong basis for the prediction that is made. The range of possible impact ratings is indicated in the lower right-hand corner of the cell.

Numbers in the lower left-hand corner provide information on the duration and frequency of interactions between project activities and VECs. Interactions that are expected to occur for more than 12 months throughout the life of the project are assigned a duration rating of three. Interactions that occur as discrete events (e.g., cement disposal) are categorized by their expected frequency of occurrence within a year. Other interactions are indicated by the number of days per year in which a particular activity will occur. A rating of three is used to indicate interactions that are expected to take place continuously.

The numbers in the upper left-hand corner indicate the total area likely to be affected by the interaction.
8.7.3 POTENTIAL IMPACTS

The potential biophysical impacts of the Cohasset/Panuke Development are discussed in terms of impacts from routine and accidental events for each project phase, and cumulative impacts for the whole project.

8.7.3.1 Potential Impacts from Routine Events

Construction and Installation Activities

(a) Potential Interactions with Valued Ecosystem Components

During routine flowline laying and facility installation, the potential exists for interaction between construction equipment and facilities and all VECs.

Atmospheric Emissions. Routine atmospheric emissions during construction and installation activities will be restricted to generator, engine, and utilities exhausts from construction and installation equipment. Their release will be continuous during on-site activities at an expected rate of $10 \times 10^{-3}$ per day. The exhausts will consist of CO, NOx, unburned hydrocarbons, and particulates. These will occur over the 60 to 90 days required for these activities. Atmospheric emissions will interact with marine bird VECs only.

Liquid and Solid Releases. Routine liquid and solid releases during construction and installation activities will occur from the construction vessels. Hydrostatic test fluid from the flowlines will also be discharged during the period. Table 8.2-3 identifies and describes the liquid and solid effluents expected during this phase of the project.
Hydrostatic test fluids contain oxygen scavengers (typically 50 to 100 mg/L), biocides (typically 50 to 200 mg/L), and corrosion inhibitors (typically 100 to 500 mg/L). The oxygen scavenger will be sodium or ammonium bisulphite. Biocides, added to prevent sulphur reducing bacterial activity, are usually aldehydes (glutaraldehyde) and/or quaternary amines. Corrosion inhibitors will be of the film-forming type, typically amines or imidazolines. After hydrostatic testing, the test water, containing residual chemicals, will be discharged to the sea under controlled conditions. The expected volume of discharge is low (300 m³).

Noise, Lights, and Human Presence. Routine noise from construction and installation vessels and rigs in the offshore will be principally from the power generating facilities and deck operations and could produce noise in the order of 80 to 100 dB. This noise will be intermittent and will reach ambient background levels within 1 km of the site (Institute of Offshore Engineering 1984). Construction and installation vessels will have warning lights which together with routine noise will interact with all VECs except Sable Island.

Turl (1982) reviewed sources of underwater noise associated with offshore oil and gas activities, and suggested typical source levels between 130 and 180 dB in a frequency range of 10 Hz to 10 kHz. Specific examples included 160 dB for a semi-submersible drilling rig and 170 dB for logistic support vessels.

During the course of the construction and installation phase, it is likely that project personnel will visit Sable Island to inspect emergency-response facilities and set up navigation and positioning systems.
Physical Disturbance and Presence. Construction and installation equipment will be on site intermittently over approximately 12 months (April 1991 to April 1992). On-site construction activities will involve the laying of flowlines between the two wellheads, hydrostatic testing of the lines, installation of the wellhead jackets and loading buoy. Construction of wellhead jackets and modification of the jack-up unit, mooring and offloading system, and floating storage vessel will be carried out onshore or nearshore. Installation time on site will be in the order of 60 days.

The wellhead jackets will each cover an area 17 m by 21 m and will be secured with piles into the seafloor. The subsea flowline between the wellheads will be 9 km long in a 10 m wide corridor. Neither pile installation nor pipe laying will involve the removal of sediment. However, sediment around the piles will be displaced 1 to 2 m during pile installation.

The initiation of the project will result in the establishment of a minimum 500-m radius fishing exclusion zone around project facilities.

(b) Potential Impacts

Figure 8.7-2 shows the environmental impact ratings of construction and installation activities on VECs prior to mitigation.

Atmospheric Emissions. All atmospheric emissions will meet regulatory standards. Impacts of atmospheric emissions on the marine bird VECs are rated negligible because of the low volumes and short duration of the emissions and the expected limited interaction between the emissions and the birds. There are no other potential impacts of atmospheric emissions during this phase.
### ENVIRONMENTAL IMPACT RATINGS

CONSTRUCTION AND INSTALLATION ACTIVITIES

<table>
<thead>
<tr>
<th>VALUED ECOSYSTEM COMPONENTS</th>
<th>ROUTINE EVENTS</th>
<th>ATMOSPHERIC EMISSIONS</th>
<th>LIQUID AND SOLID RELEASES</th>
<th>NOISE, LIGHTS, AND HUMAN PRESENCE</th>
<th>PHYSICAL DISTURBANCE AND PRESENCE</th>
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FIGURE 8.7-2
Liquid and Solid Releases. Liquid and solid releases during the construction and installation phase are rated as having negligible impacts on all VECs except offshore fisheries where no impact is predicted, and Sable Island where no interaction is identified. The disposal of all liquid and solid wastes will conform to regulatory standards. The component of liquid and solid releases with potentially the greatest impact during this phase is the disposal of hydrostatic test fluids. The expected volume of fluid discharged is low, however, and it will be rapidly diluted.

Debris will not interfere with fishing operations since regulations control the production of debris, the proposed development is not extensive, and debris will be limited to the exclusion zone area.

Noise, Lights, and Human Presence. Noise, lights, and human presence during the construction and installation phase are rated as having negligible impacts on all VECs with the exception of Sable Island. The impact on the fisheries is potentially positive because the lights on the construction and installation vessels will serve as a locator beacon, and the first aid facilities on the vessels could be used in a medevac situation.

Physical Disturbance and Presence. Physical disturbance to the seabed will occur during pile installation and the laying of the flowlines. This disturbance could result in loss of seabed habitat and mortality of marine organisms in the affected area, thereby affecting all VECs except fish eggs and larvae, and Sable Island for which no impacts are expected.

The impacts of physical disturbance to the seabed during installation of piles and laying of the flowlines are rated as negligible. As discussed in Mobil (1983a), installation of
piles could generate local, short-term turbidity in the water column (Martec 1980a; Mellor 1981) and some turbidity could result from increased current velocities scouring the seabottom around the piles. Mobile benthic organisms, however, would avoid these turbid areas, and the small number of sessile forms (e.g., sand lance eggs) that might be affected by the placing of piles would be insignificant in the context of the populations inhabiting Sable Island Bank. Flowline laying may result in the loss of some infauna and sessile epifauna. However, comparable benthic communities are common on the Scotian Shelf, rendering such losses negligible. The impact of seabed disturbance on fish species in the project area will be negligible. Although demersal fish inhabit the Scotian Shelf seabottom, Mobil (1983a) state that there was no evidence that laying the Venture pipeline, which was to be trenched, would unduly affect those species. The flowlines for the Cohasset/Panuke Project will be laid on the seafloor without trenching, offering even a lesser potential for seabed disturbance.

The presence of the construction and installation vessels will have a negligible impact on the offshore fisheries. The commencement of construction activity will result in the establishment of the fishing exclusion zone around the site which will persist throughout all phases of the project. The exclusion zone encompasses only 1700 hectares and fishing effort is not substantial near the Cohasset and Panuke fields.

With regard to competition for labour, labour requirements for the proposed development are small compared to the pool of labour available in the fishing industry. The industry is presently undergoing a slowdown, resulting in substantial layoffs. Employment opportunities in oil and gas development will not therefore cause labour shortages in the fishing industry.
Drilling and Completion Activities

(a) Potential Interactions with Valued Ecosystem Components

During routine drilling and completion activities, potential interactions with all VECs have been identified.

Atmospheric Emissions. Routine atmospheric emissions during drilling and completions will consist of particulate matter, gases, and unburned hydrocarbons from flaring operations during well testing and completion, and exhausts from generators, engines, and utilities as shown in Table 8.2-3. The flaring operations will take place intermittently at rates dependent on the characteristics of the reservoir fluids but may be as high as $5 \times 10^3$ m$^3$/d. Atmospheric emissions will interact with all VECs except Sable Island.

Liquid and Solid Releases. Routine liquid and solid releases during drilling and completion activities will consist of drilling mud and cuttings, deck drainage, sanitary wastes, cooling water, desalinization brine, and domestic garbage. Expected volumes are shown in Table 8.2-3.

Drilling mud and cuttings will be the major volume of the liquid and solid releases. Drilling mud contains water, clay, and chemical additives including corrosion inhibitors and bacteriociides. Cuttings are made up of the overburden or bedrock materials that are removed from the wellbore during the drilling process.

Present plans call for the use of water-based drilling fluids:

- A seawater gel mud, composed of seawater and bentonite to 1000 m
- A seawater based potassium chloride/polymer mud to total depth

- Saturated brine for workover fluids

The compositions of typical seawater gel and potassium chloride/polymer drilling muds used for offshore drilling are shown in Table 8.2-1.

During the course of drilling, it occasionally becomes necessary for operational reasons to discharge quantities of water-based drilling muds. These releases occur when dilution of the mud is required and whole mud is released overboard; when the mud is changed from one section of the hole to another and at the end of the hole. Due to the drilling conditions of the present project, bulk mud dumps are expected to be rare or non existent (ASA Consulting 1989). Should low toxicity mineral oil-based muds be used, no bulk mud discharges will occur. Liquid and solid releases during drilling and completion activities will interact with all VECs except Sable Island.

**Noise, Lights, and Human Presence.** Routine noise from drilling and completion activities will be in the order of 80 to 100 dB. This noise will be restricted to the immediate vicinity of the activity and will potentially interact with all the VECs except Sable Island. The jack-up rig and the well jackets will have warning lights which will interact with all VECs except Sable Island. During the drilling and completion activities, it is likely that project personnel will visit Sable Island to inspect emergency-response facilities.
Physical Disturbance and Presence. Drilling and completion activities will interact with all VECs except Sable Island through disturbance to the seafloor or through the presence of project facilities. Seafloor disturbance results from drilling and the discharge of cuttings and drilling mud. The expected volumes are presented in Table 8.2-1. Well jackets and flowlines will be present on site throughout the drilling and completion phase. The jack-up drilling and production unit will remain on location, continuously, during the production phase.

(b) Potential Impacts

Figure 8.7-3 shows the environmental impact ratings of drilling and completion activities on project VECs prior to mitigation.

Atmospheric Emissions. Atmospheric emissions during drilling and completion activities will have no impact on VECs, with the exception of marine birds, where the potential for a negligible impact is recognized. All atmospheric emissions will meet regulatory standards. Mobil (1983a) recognized that routine emissions from development drilling at Venture would have very limited implications for biota. Residues which are carried out of the atmosphere into the sea and sediments may be degraded by microbiota. Refractory components will make a negligible contribution to the background chemical environment. A small number of birds might come in direct contact with the flare.

The Cohasset and Panuke condensate has a very low sulphur content. As a result, virtually no sulphur compounds will be emitted from the flare. Although hydrocarbon vapours could enter the atmosphere during fuel transfer operations, and dust from drilling muds and dry cement could be blown into the
### ENVIRONMENTAL IMPACT RATINGS

DRILLING AND COMPLETION ACTIVITIES

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FIGURE 8.7-3
atmosphere, the quantities of such emissions will be insufficient to cause a measurable impact.

**Liquid and Solid Releases.** Liquid and solid releases during drilling and completion activities are rated as negligible impacts for all VECs except offshore fisheries and Sable Island, where there is no interaction. The disposal of all liquid and solid wastes will conform to regulatory standards.

Documented impacts of the disposal of drilling fluids and cuttings include burial of sessile fauna, reduced abundance or changes in the species composition of benthic fauna, and the accumulation of barium, chromium, lead, and mercury in the tissues of faunal species (Thomas et al. 1986). Thomas et al. (1986) also found that the heavy metals were depurated relatively quickly when the organisms were no longer exposed to drilling fluids and that impacts were restricted to an area within 300 to 500 m of the discharge area. Neff et al. (1986) exposed winter flounder, soft shell clams, sand worms, and grass shrimps to natural marine sediments containing approximately 100,000 mg/kg of either a relatively poor grade of barite or an impure barite. After 1, 3, and 13 weeks of exposure, tissues were analyzed for arsenic, cadmium, copper, lead, and mercury. The authors concluded that metals associated with drilling mud barite are virtually non bioavailable to marine organisms that might come in contact with discharged drilling fluids solids. The results supported the hypothesis that much of the metals apparently accumulated from barite contaminated sediments in tissues of marine mammals were actually in the gut or gills as unassimilated barite particles.

Neff (1981) found no evidence that chemical toxicity of water-based drilling muds occurs in drilling field environments, although bioaccumulation of certain heavy metals (chromium,
Barium, mercury) was recorded in marine organisms collected in the immediate vicinity of drilling platforms. He concluded that benthic animals exposed to environmentally realistic concentrations of used drilling muds in the sediments are unlikely to accumulate sufficient mud-associated metals to represent a toxicity hazard to themselves or to predators, including man.

Mobil (1983a) rated the impacts of disposing of cuttings and drilling fluids as negligible.

Using computer modelling, ASA Consulting (1989) investigated the extent and duration of contamination from a bulk 770 m³ discharge of drilling fluids at Panuke and Cohasset. They found that maximum mound thickness below the release point ranges from 1.6 m (Panuke) to 2.8 m (Cohasset), while 60 m from the release point, the thickness ranges from 0.04 m to 0.07 m.

ASA Consulting (1989) found that mound dispersion from sediment transport took place in approximately one month under typical summer wave and current conditions. Since this is the order of the release period, extensive mixing and dilution of the cuttings into the sediments would be expected even as the drilling is in progress.

Other liquid and solid releases include deck drainage, engine cooling water, domestic wastes, and solid wastes and debris. Mobil (1983a) assessed all of these as having a negligible impact for the Venture Development, citing studies from the North Sea where no measurable impacts from deck washings or domestic wastes were found (Ward et al. 1980; Massie et al. 1981).
Noise, Lights, and Human Presence. The impacts of noise, lights, and human presence during drilling and completion activities are rated as negligible for all VECs, except Sable Island, where there is no interaction. The impact on the fisheries is potentially positive because the lights on the facilities will serve as a locator beacon and the helicopter decks on the facilities could be used in a medivac situation.

Mobil (1983a) assessed impacts of noise, lights, and beacons from development drilling at Venture as negligible, except for impacts on birds on Sable Island, which were rated as moderate. The Venture Project facilities were to be located 16 km off Sable Island, while the Cohasset/Panuke facilities are approximately 40 km away from the Island, reducing impacts on birds on Sable Island to nil.

Physical Disturbance and Presence. Impacts of physical disturbance and presence of drilling and completion facilities are rated as negligible for all VECs with the exception of Sable Island.

Production Activities

(a) Potential Interactions with Valued Ecosystem Components

Production will take place seasonally from April through October each year. Production from the Panuke field will be transported to the separation facilities at Cohasset via the subsea flowline. During production, the floating storage vessel will be on-site and a shuttle tanker will transport the produced condensate to markets. Over the remaining months, the equipment will be maintained and the production wells will be worked over as necessary.
Many potential interactions between the project and the VECs during the production phase will be similar to those identified for the construction and drilling stages.

Atmospheric Emissions. Atmospheric emissions will consist of engine and heater exhausts; vented and flared by-product; natural gas on the production platform; and engine exhaust from the tankers, standby, and resupply vessels.

Energy for all the project and support activities will be supplied by liquid fossil fuels transported to the site. Combustion of these fuels will produce water, CO₂, NOₓ, and some particulates. Combustion gases will be directed to exhaust systems and vented directly to the atmosphere. Natural gas produced with the condensate will be flared. Flaring will produce CO₂ and water.

Natural gas will be produced from the Cohasset and Panuke fields as part of the condensate recovery process. Anticipated gas production rates will be up to 85 X 10³ m³/day. For technical reasons, it may not be possible to use produced gas as fuel to operate the production facilities or to re-inject into the formations. Volumes are also too small to transport to markets. Therefore, produced gas will be flared.

Atmospheric emissions will potentially interact with all VECs.

Liquid and Solid Releases. The types and volumes of liquid and solid wastes produced during the production phase are listed in Table 8.2-4. Liquid wastes will consist primarily of water produced from the formations containing the condensate as well as injected water used to maintain reservoir pressure. Collectively, they are termed produced water. Other sources include sanitary wastes, deck drainage, and cooling water released from both the production facilities and the vessels,
as well as bilge and ballast water from the vessels. Solids include sand produced from formations during production, garbage, and process sludges. Liquids and solids released during production will interact with all VECs. The floating storage and shuttle tankers will take on and discharge seawater as required to maintain vessel stability. These vessels will be fitted with segregated ballast and storage tanks so that the condensate and the seawater will not come into contact. This removes any potential for contamination of the seawater.

Formation and injection water will be produced as a byproduct of condensate recovery. As the reservoirs are depleted, the ratio of produced water to condensate will increase. During the first year of production, little or no produced water is expected but it will increase during subsequent years. For the purposes of this review, it is estimated that as much as 6360 m$^3$/day could be produced. Present plans for the Cohasset/Panuke fields indicate that produced water will not be reinjected into the formations to maintain reservoir pressure, but rather, will be discharged into the sea through a pipe located 10 m below the sea surface.

Produced sand consists of formation sand and clay solids (EPS 1984) brought to the surface with the formation liquids. These solids will be removed in the stage 1 separation process and either recovered for disposal at a shore based landfill or disposed of on location. In most fields, the volumes produced are generally small (less than 10 m$^3$/day) particularly during the initial stages of production (EPS 1984). With on-site disposal, produced sands are discharged through a caisson immediately after separation and treatment. Depending upon the composition of the material and the degree of hydrocarbon contamination, they may be washed with straight or treated seawater before release. Oily water is sent to the oily water
separator for removal of hydrocarbon before discharge in the produced water stream. Johnson (1981) reports that the hydrocarbon content of produced sand in North Sea production is in the order of 15-25 ppm. Limits are not specifically recommended in the C OgIA Offshore Waste Treatment Guidelines (1989). Each situation is judged independently.

Periodically over the operational life of the Cohasset/Panuke Development, the production wells will have to be re-entered to maintain or enhance production levels. Fluids used to control the wells during these periods will consist primarily of seawater-based brine plus other specialized additives if required. Some of these fluids are normally lost to the formation during the workover process and are returned to the facilities as produced water. The fluids remaining in the well after the workover is complete will be recovered when production restarts. They will have the same characteristics as produced water. Entrained hydrocarbons will be separated on the platform and the water discharged through the produced water system. The volumes of workover fluids will vary from situation to situation, but the slugs will not exceed the capacity of the treatment system because they will return to the surface as part of the normal production cycle.

Noise, Lights, and Human Presence. Noise from production activities will be in the order of 80 to 100 dB. Underwater noise may affect marine mammals while airborne noise may affect the marine-associated birds present. Lights and beacons will be installed on all facilities located in the project area and will be operated year round for the duration of the project. These will consist of navigation lights for ships and aircraft, lights to illuminate working areas, and light from the operation of the flare used to burn byproduct natural gas. Seabirds and fisheries are the only VECS that will be affected by lights and beacons. Seabirds and marine mammals are the
only VECs affected by the presence of humans in the area for extended periods of time, although Sable Island may experience some additional visits as a result of the project during emergencies.

Physical Disturbance and Presence. The presence of the facilities will potentially interact with all VECs. In the case of Sable Island, project personnel will be present occasionally to conduct inspections.

(b) Potential Impacts

Figure 8.7-4 shows the environmental impact ratings of production activities on project VECs prior to mitigation.

Atmospheric Emissions. Atmospheric emissions from production activities will have a negligible impact on marine-associated birds in the area. None of the other VECs will be affected by these emissions. All atmospheric emissions will meet regulatory standards.

Fuel combustion will produce atmospheric emissions but will meet regulatory standards. The flare will also be used to safely dispose of excess hydrocarbon during system upsets.

There will be no open condensate in the production system. Only vents would be located on the tanker cargo tanks. These vents will be fitted with pressure valves set at about 5 psi above atmospheric pressure.

Liquid and Solid Releases. Impacts of liquid and solid releases during production activities are discussed in terms of those associated with produced water, produced sand, workover fluids, and other discharges. All releases will meet regulatory standards.
ENVIRONMENTAL IMPACT RATINGS

PRODUCTION ACTIVITIES

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<th>VALUED ECOSYSTEM COMPONENTS</th>
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FIGURE 8.7-4
Produced water has been described as an "oily brine" (Boehm 1987) which contains anionic and cationic salts, metal ions, hydrocarbons, trace metals, additives, and suspended solids (Arctic Laboratories 1984). Produced water can have salinities higher than ambient seawater. Recently, it has also been shown that produced waters can contain low levels of radioisotopes of radium and thorium (Middleditch 1984). There are presently no data to indicate the quality of produced water that may be expected from the Cohasset/Panuke Development. The systems used to treat produced water are most effective at removing suspended solids and colloidal oil, but do little to remove dissolved constituents such as aromatics or biocides, nor do they reduce salt or trace metal concentrations (Arctic Laboratories 1984).

Operational discharges from the proposed Cohasset/Panuke site have been estimated to have no impact on the fisheries due to their very localized effects. Significant smothering would not extend beyond 60 m from the discharge, well within exclusion zones around the platforms. Residual hydrocarbon concentrations from produced water would be less than 10 ppb at 1 km from the site (Hurlburt and Isenor 1989).

The disposal of produced water may have an impact on sensitive species resident near the disposal site. Studies in the Gulf of Mexico have shown that elevated levels of hydrocarbon and heavy metals have been encountered in sediments in shallow nearshore areas around outfalls, where suspended sediment levels are high and circulation is restricted (Neff 1987). These have resulted in discernible shifts in the local benthic community in the immediate vicinity of the discharge point. However, from studies around platforms in the open ocean, Middleditch (1984) reports that effects are limited to the mixing zone immediately around the discharge point. The same has been experienced in the North Sea (Johnson 1981).
et al. (1987) noted that rapid removal of metals and hydrocarbons associated with produced water is accomplished by weathering, evaporation of volatile liquid hydrocarbons (VLIHs), advection, and particulate scavenging by suspended sediments. Neff (1987) indicated that the radioisotopes in produced water show little tendency to partition into the sediments around a disposal site, but rather, remain in solution and are dispersed in the water column.

EPS (1984) indicated that produced water is only slightly toxic to non-toxic to marine organisms. Studies have not demonstrated any indication of bioaccumulation of heavy metals or adverse effects of oily water discharges on biota around offshore production facilities. Any toxicity associated with the disposal of produced water is generally attributable to the presence of biocides added to injection water (Middleditch 1984). Other additives such as demulsifiers, scale inhibitors, and foam inhibitors are not toxic in the concentrations found in produced water (Neff 1987). Thus, the impact on sea scallops and ocean quahogs have been rated as minor due to the potential of these effects in the vicinity of the production unit.

The lethal toxicities of produced waters (measured as the 96 hour LC₉₀) measured in the laboratory vary widely from as little as 8,000 ppm to in excess of 400,000 ppm (Menzie 1982). Where biocides have been added, the toxicity is increased to about 1,000 ppm. These concentrations are far in excess of the levels encountered in the environment beyond the immediate mixing zone where Neff (1987) has reported generalized dilutions of about 500 times within 150 m of the discharge point and 1,000 to 3,000 times within 1 km. Laboratory studies have also shown that concentrations of pollutants known to cause sublethal effects in sensitive marine organisms are also confined to the mixing zone (EPS 1984). Beyond the mixing
zone, hydrocarbons rarely exceeds 30 ppb above ambient concentrations while elevated levels of heavy metals are rarely detectible (Neff 1987).

To confirm the expected zone of influence of produced water discharges from the Cohasset/Panuke Development, ASA Consulting (1989) modelled the behaviour of a 6000 m³ discharge from the Cohasset production facility. The conditions used for the analysis are shown in Table 8.7-1. It shows that the plume from the discharge would respond to tidal currents immediately after discharge (Figure 8.7-5) but that the influence of the residual flow would transport the water south and east toward the shelf edge. The plume will not approach the shallows around Sable Island where haddock and cod juveniles are resident during the summer.

### Table 8.7-1

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<th>Conditions Used to Model the Behaviour of Produced Water Plumes Released from the Cohasset/Panuke Development Project</th>
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<td>Duration of Discharge</td>
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<td>Rate of Discharge</td>
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PREDICTED SEAFLOOR CONCENTRATIONS (mg/L) OF WHOLE PRODUCED WATER DUE TO A CONTINUOUS DISCHARGE, SHOWN AT 1/4 TIDE CYCLE INCREMENTS.

The concentration contours shown in Figure 8.7-5 indicate very rapid dilution of the produced water plume. The highest concentration shown is 1,000 ppm immediately after discharge when the tide is flooding over the Bank in a northwesterly direction. During the other phases of the tide, the maximum concentration does not exceed 300 ppm. Although Figure 8.7-5 indicates that the influence of the plume will be apparent over an area of about 200 km², the concentrations of whole produced water will be very low relative to the most conservative 96 hour IC₅₀ (about 7,000 ppm) determined in laboratory studies (Middleditch 1984).

Predicted oil concentrations are shown in Figure 8.7-6. The Offshore Waste Treatment Guidelines (COGLA 1989) recommend a maximum total hydrocarbon concentration of 40 mg/L in produced water discharges. In most cases, the concentrations at the Cohasset and Panuke fields are expected to be in the order of 20 to 30 mg/L. Given the upper limit specified in the regulations, the predicted hydrocarbon concentration at the seafloor will not exceed 12 ppb. The area affected will be less than 0.50 km² intermittently over different stages of the tidal cycle. Although the produced water will be discharged at 68°C, the excess heat is very rapidly dissipated. Temperature increases will be less than 1°C outside the mixing zone and will reach ambient levels within a few hundred metres of the discharge point.

These levels of total hydrocarbon will have a negligible impact on the local benthos. Concentrations are too low to cause any direct mortality and will not result in the induction of tainting in scallops or quahaulgs resident in the area (Carter et al. 1988). Sublethal effects are not expected because organisms will not be continually exposed to these concentrations. In addition, the VLEs (benzene, toluene, xylene) which are the most toxic of the hydrocarbons present, will be
"SNAPSHOT" IN TIME OF PREDICTED SEAFLOOR CONCENTRATIONS (ug/L) OF DISSOLVED HYDROCARBON, DUE TO A CONTINUOUS DISCHARGE OF PRODUCED WATER WITH A HYDROCARBON CONCENTRATION OF 40mg/L.

SOURCE: ADAPTED FROM ASA(1989)
rapidly dispersed and will be subject to secondary evaporation, which will limit their residence time in the area and prevent any accumulation in the water column or sediments. Therefore, impacts on the VECs will be negligible, with the exception of offshore fisheries and Sable Island where no impact is predicted. The biofouling community immediately around the outfall may show minor effects as a result of exposure in the mixing zone (Middleditch 1984).

The other potential contaminants such as heavy metals will also have a negligible impact on the identified VECs. Although concentrations of some metals may exceed normal background levels found in Scotian Shelf seawater, they will be rapidly diluted immediately after release. Menzie (1982) indicated that these elevated levels do not appear to induce stress in exposed organisms. Menzie has also shown that, with the exception of barium from drilling fluid disposal, trace metal concentrations around production facilities are not elevated compared with the background.

EFS (1984) have reported that relatively little work has been done on the environmental effects of produced sand discharge. At the same time, it is recognized as a relatively minor concern because of the small volumes involved and the fact that the material is treated before discharge. Disposal of produced sand is expected to have a negligible impact on the project VECs. Impacts will be confined to an area within 500 m of the discharge point and will be limited to temporary burial of benthic organisms. However, discharged produced sand is not expected to accumulate in the sediments at the site because the oceanographic regime on Sable Island Bank is dynamic, and the sediments are constantly being reworked by wave action and currents. Mobil (1983a) judged the impact of produced sand discharge to be negligible for the Venture Project.
The impact of the discharge of workover fluids on the identified VECs will be negligible. The expected effects will be similar to those anticipated from the discharge of produced water.

The impacts of discharges of deck drainage, cooling water, sanitary wastes, and ballast water on the project VECs will be negligible with the exception of offshore fisheries and Sable Island where no impacts are expected. Deck drainage consists of rainwater and washdown water trapped by curbs and gutters on the platform as well as small amounts of lubricants and other fluids collected in drip pans under the machinery. Drainage will be directed to the produced water treatment system before discharge and will meet the 40 ppm hydrocarbon limit recommended in the Offshore Waste Treatment Guidelines (COGIA 1989).

Approximately 1,000 m³/d of seawater will be used to cool engines and processing equipment on the production platform. This water may be treated with chlorine to prevent biological growth in the heat exchanger although operators report relatively few problems of this type during previous periods of extended operation on Sable Island Bank. The temperature of the cooling water will be between 35 and 40°C but local dispersion is expected to reduce the temperature to within one degree of the ambient seawater temperature within a few hundred metres of the discharge point. Fish eggs and larvae will be entrained in the cooling water intake stream and will probably be killed by turbulence as they pass through the system. This impact will be negligible given the relatively small volumes of water being withdrawn and the fact that fish eggs and larvae are widely distributed over the Scotian Shelf. Impacts on the VECs as a result of these discharges is rated as negligible, with the exception of offshore fisheries and Sable Island, where no impact is predicted.
Sanitary and domestic wastes from the production platform will be treated in compliance with COGIA regulations. It is expected that about 10 m$^3$ of these wastes will be generated daily and will be discharged into the sea. Although these wastes can contribute to local nutrient enrichment of receiving waters, high BOD, and smothering of benthic organisms in confined coastal waters, discharges on Sable Island Bank will be rapidly dispersed by local currents and the impact of these discharges will be negligible, with the exception of offshore fisheries and Sable Island, where no impact is predicted.

The floating storage and shuttle tankers will take on and discharge seawater as required to maintain vessel stability. These vessels will be fitted with segregated ballast and storage tanks so that the condensate and the seawater will not come into contact. This removes any potential for contamination of the seawater and hence, no impacts from ballasting operations are anticipated. Any bilge water from these vessels or the standby/resupply vessels will conform with the discharge regulations specified in the Canada Shipping Act, i.e., no discharge of oil into Canadian waters. Bilge water will be directed through an oil-water separator before being discharged. The volumes will be small except in an emergency situation and impacts on VECs will be negligible, with the exception of offshore fisheries and Sable Island, where no impact is predicted.

Noise, Lights, and Human Presence. Noise and lights associated with routine facility operations at the Cohasset/Panuke Development will have a negligible impact on the seabirds and marine mammals present either seasonally or permanently in the project area. A concern about flares attracting and killing marine-associated birds which was identified in the Venture EIS (Mobil 1983a) has proven not to be as great a concern in the North Sea as originally thought. Dunnet (1987) indicated that flares are having a minimal impact on seabirds resident in the

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vicinity of producing platforms. Lights on vessels and platforms may prove beneficial to offshore fishing interests as they can be used to confirm their position.

Although Sable Island will not be used as a staging or storage base for the project, the presence of the project may lead to increased numbers of visitors. This will be an intermittent activity which is expected to have a negligible impact on the island. The emergency evacuation base on the island maintained by active Scotian Shelf operators will not be manned, but will be inspected periodically by IASMD personnel to ensure that equipment is maintained and systems are operational.

**Physical Disturbance and Presence.** Except for routine inspection and maintenance activities, the operation of the Cohasset/Panuke facilities will not cause any additional physical disturbance to the surrounding environment. Certain species of demersal fish may be attracted to the facilities for refuge or to feed on the biofouling community. Picken (1989) has extensively documented the presence of large numbers of fish around offshore production facilities in the UK sector of the North Sea. His observations do not indicate any negative impacts of operational discharges on these organisms.

The safety zone around the facilities required under the Production regulations will be in place on a year-round basis for the duration of the production activities. This exclusion will not be lifted during the winter months when production has been suspended. Thus, commercial fishing vessels will be excluded from 1700 hectares of the Sable Island Bank. While this area of the Shelf is not considered a prime fishing ground, the area does support populations of sea scallops, quahaugs, and demersal fish species. Organisms within the safety zone will not be subject to fishing pressure and the area may provide a refuge for these species over the life of the project.
The impact of this zone on the commercial fisheries will be negligible. The safety zone represents only 0.12 percent of the area of NAFO Subdivision 4Wf and is remote from the more intensively fished areas of the Scotian Shelf. The commercial fishery will benefit from the presence of the facilities. Support vessels and the production facilities will be in a position to offer assistance for search and rescue activities as well as medical emergencies. Overall, the impacts on the commercial fisheries are judged to be negligible and some benefits may be derived from the presence of the facilities.

Because of the proximity of Sable Island, commercial vessel traffic tends to avoid this region of the Scotian Shelf. The Trans-Atlantic shipping routes are located south and east of the project area, while coastal traffic travels well inshore of the location. Therefore, the presence of the facilities will have little or no impact on commercial vessels and there will be little risk of collision.

Abandonment Activities

(a) Potential Interactions with Valued Ecosystem Components

Upon depletion of the Cohasset and Panuke reservoirs, all production facilities will be removed. This removal will include:

(1) Cementing of all wells and the removal of casings from below the mud line to the seafloor

(2) Flushing of flowlines and their removal, removal of the tanker loading line and tanker mooring system

(3) Removal of the wellhead jackets at Cohasset and Panuke and the cutting of the piles below the seafloor
(4) Removal of the jack-up unit, which will be towed to port.

Atmospheric Emissions. Routine atmospheric emissions during abandonment activities will be similar to those associated with construction and installation activities, i.e., generator, engine, and utilities exhausts from vessels used for abandonment activities. Their release will be continuous during on-site activities at an expected rate of $10 \times 10^3$ per day. The exhausts will consist of CO$_2$, NO$_x$, unburned hydrocarbons, and particulates. Atmospheric emissions will interact with all VECs.

Liquid and Solid Releases. Routine liquid and solid releases during abandonment will occur from the abandonment vessels and be similar to those from the construction and installation vessels (Table 8.2-3).

Noise, Lights, and Human Presence. Routine noise from marine vessels used during abandonment activities will be in the order of 80 to 100 dB. This noise will be intermittent and will be restricted to the immediate vicinity of the activity. The marine vessels will have warning lights which, together with routine noise, will interact with all VECs except Sable Island.

Physical Disturbance and Presence. Removal of the wellhead jackets and pilings will be accomplished using explosives placed inside casings and pilings. Flowlines will be purged of condensate and removed. Abandonment activities are scheduled for the fall of 1997 and are expected to take several weeks.

(b) Potential Impacts

Potential impacts to the project VECs during the abandonment phase are shown in Figure 8.7-7.
**ENVIRONMENTAL IMPACT RATINGS**

**ABANDONMENT ACTIVITIES**

<table>
<thead>
<tr>
<th>VALUED ECOSYSTEM COMPONENTS</th>
<th>ROUTINE EVENTS</th>
<th>ATMOSPHERIC EMISSIONS</th>
<th>LIQUID AND SOLID RELEASES</th>
<th>NOISE, LIGHTS, AND HUMAN PRESENCE</th>
<th>PHYSICAL DISTURBANCE AND PRESENCE</th>
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**FIGURE 8.7-7**
Atmospheric Emissions. The impacts of routine atmospheric emissions during abandonment activities will be similar to those during the construction and installation phase, i.e., the impact on seabird VECs will be negligible. All other VECs will experience no impact.

Liquid and Solid Releases. The impacts of liquid and solid releases during the abandonment phase are rated as negligible for all VECs, with the exception of offshore fisheries and Sable Island where no impact is predicted. Only very small volumes of liquids will be released during abandonment activities and these will be diluted in the water column. Volumes of solids released during this phase are also expected to be very small.

Noise, Lights, and Human Presence. Noise, lights, and human presence will have none-to-negligible impacts on project VECs during the abandonment phase, due to their small area of affect and limited duration. The impact on fisheries is potentially positive because the lights on the vessels will serve as a locator beacon and the first aid facilities on the vessels could be used in a medivac situation.

Physical Disturbance and Presence. Removal of the wellhead jackets and pilings could create seafloor disturbances and possible resuspension of drilling mud and cuttings on the seabed. Facility removal will result in drilling mud and cuttings from the development drilling being redistributed and dispersed. Potential impacts on the VECs are rated as negligible for all VECs except Sable Island where no impact is predicted.

Since the interfield flowlines will not be trenched into the seafloor, it is expected that there will be no significant disturbance of the benthos from removal of the flowlines.
There will be a negligible positive impact upon fishing activity in the field area when all facilities are removed and the exclusion zone is reopened.

8.7.3.2 Potential Impacts from Accidental Events

This section addresses the potential effects of an accident resulting in the release of condensate or other hazardous chemicals into the environment during the installation, drilling and completion, and production phases of the Cohasset/Panuke Development.

Potential Interactions with Valued Ecosystem Components

Unlike the routine activities associated with project development and production, the potential interactions between VECs and accidental events will be much less likely to occur, but would cover a much wider area of the Scotian Shelf. An accident could occur at any time of the year, although the risks are higher during drilling and completion, and production activities. Although the risk of a major accident is low, the possibility of accidents cannot be discounted. Hence, in the assessment, a worst case situation for each type of accident is assumed and the effects assessed.

The potential interactions between accidental events and project VECs are discussed under four categories:

(1) Condensate spills
(2) Hazardous chemical spills
(3) Atmospheric emissions
(4) Noise, lights, and human presence

(a) Condensate Spills

Four types of condensate spills are recognized for the Cohasset/Panuke Development:
(1) Condensate losses from a blowout
(2) Operational spills
(3) Spills from a flowline leak
(4) Spills from a tanker accident

The last three can be grouped together as "batch spills."

IASMO has completed a detailed review of possible scenarios involving a condensate spill from either the Cohasset or Panuke facilities (S.L. Ross Ltd. 1989). Based on an assessment of historical accidents, Ross developed a group of accident scenarios as shown in Table 8.7-2. All project VECs could potentially be affected by an accident although the degree will be dependent on the timing and duration of the event. The largest impacts would likely be experienced with the largest spills. Because the Cohasset/Panuke facilities are located in the open ocean far removed from sensitive coastal areas and are remote from Sable Island, spilled condensate will rapidly disperse in the environment and will not become trapped in sediments or on beaches. The estimated drift from surface slicks associated with various spills is shown in Figure 8.7-8.

Spilled Condensate Behaviour. IASMO has undertaken a detailed evaluation of the behaviour and fate of hydrocarbon accidentally released from the Cohasset/Panuke facilities (S.L. Ross Ltd. 1989). The light oil or condensate to be produced from the Cohasset/Panuke fields is very different from conventional crude oils. The oil, more properly referred to as condensate, is very light (specific gravity of 0.77) and is highly volatile. It has properties similar to refined products such as diesel oil and gasoline (Table 8.7-3). It shows no tendency to form stable emulsions. Because of the characteristics of the condensate, it will readily evaporate and slicks would dissipate in a matter of hours, compared with days or weeks for heavier crude oils.
## TABLE 8.7-2
ACCIDENT SCENARIOS
COHASSET/PANUK DEVELOPMENT PROJECT

<table>
<thead>
<tr>
<th>Type</th>
<th>Status</th>
<th>Volume</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blowout</td>
<td>Average</td>
<td>318 m³/d</td>
<td>5 days</td>
</tr>
<tr>
<td></td>
<td>Worst-case</td>
<td>2,000 m³/d</td>
<td>30 days</td>
</tr>
<tr>
<td>Interfield Flowline</td>
<td>Worst-case</td>
<td>240 m³</td>
<td>1 hour</td>
</tr>
<tr>
<td>Loading Line</td>
<td>Worst-case</td>
<td>1,590 m³</td>
<td>1 hour</td>
</tr>
<tr>
<td>Operational</td>
<td>Valve failure</td>
<td>0.64 m³</td>
<td>Instantaneous</td>
</tr>
<tr>
<td></td>
<td>Fractured separator</td>
<td>24.5 m³</td>
<td>Instantaneous</td>
</tr>
<tr>
<td></td>
<td>Tanker spill</td>
<td>3.2 m³</td>
<td>Instantaneous</td>
</tr>
<tr>
<td>Tanker Spill</td>
<td>Medium</td>
<td>8,000 m³</td>
<td>Instantaneous</td>
</tr>
<tr>
<td></td>
<td>Worst-case</td>
<td>31,800 m³</td>
<td>Instantaneous</td>
</tr>
</tbody>
</table>
ESTIMATED DRIFT OF SURFACE SLICKS ASSOCIATED WITH VARIOUS SPILLS FROM THE COHASSET/PANUKE FACILITIES

<table>
<thead>
<tr>
<th></th>
<th>Cohasset</th>
<th>Panuke</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>48</td>
<td>56</td>
</tr>
<tr>
<td>Density (kg/m³) (15°C)</td>
<td>790</td>
<td>775.7</td>
</tr>
<tr>
<td>Viscosity (CP)</td>
<td>2.06</td>
<td>1.47</td>
</tr>
<tr>
<td>Pour Point</td>
<td>-30</td>
<td>-36</td>
</tr>
</tbody>
</table>

**Viscosity (in mP) Compared With Other Materials @ 20°C**

<table>
<thead>
<tr>
<th>Material</th>
<th>Viscosity (mP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>0.5</td>
</tr>
<tr>
<td>Water</td>
<td>1</td>
</tr>
<tr>
<td>Panuke Condensate</td>
<td>1.47</td>
</tr>
<tr>
<td>Cohasset Condensate</td>
<td>2.06</td>
</tr>
<tr>
<td>Diesel Oil</td>
<td>3</td>
</tr>
<tr>
<td>Bunker C</td>
<td>1000-5000</td>
</tr>
</tbody>
</table>

As much as 80 percent of the condensate loss from the surface slick readily partitions into the water column in either a dissolved or dispersed form. Partitioning into the water column is greater in the winter months than during the summer because mixing energies are higher. However, the estimates of dispersal provided by S.L. Ross Ltd. (1989) do not account for secondary evaporation of VLHs (volatile liquid hydrocarbons) after the condensate has been removed from the surface slick and mixed into the water column. Hence, the predicted concentrations in the water column are in all probability higher than would occur in a spill situation.

Two types of accidents were postulated in the S.L. Ross Ltd. (1989) study, a continuous discharge of condensate from a blowout, and batch spills as a result of equipment or system failures.

S.L. Ross Ltd. (1989) postulated two blowout scenarios, an average and a worst case situation. The average blowout at each
site would be about 320 m$^3$/day for 5 days. The worst case would result from a free flowing well at Cohasset where condensate would flow at a rate of 2,000 m$^3$/day for 30 days. Flows at Panuke would be smaller but would last for the same duration.

The first scenario considered is a subsea blowout where condensate escapes from the wellbore at the seafloor and rises to the sea surface where it forms a thin slick. The second is a surface blowout where the condensate is projected into the air and settles on the sea surface as a slick. The predicted areal coverage and duration of the resulting average and worst case slicks are shown in Table 8.7-4. In winter higher wind speeds and waves will tend to dissipate the slick within one kilometre of the spill site, while during summer the slick may extend as much as four kilometres from the platform.

The distance travelled by the plume of condensate formed after mixing into the water column depends upon the volume, location, and timing of the blowout. Because of the higher currents during winter, the plumes will travel 20 to 25 percent further than during summer, before concentrations are reduced to the 1 ppm hydrocarbon threshold. In an average blowout, the maximum excursion from the site will be in the order of 7 km although the plume will travel almost twice that distance as it moves back and forth across the shelf in response to the semi-diurnal tide (Figure 8.7-9). In a worst case incident, the plume will disperse below the 1 ppm hydrocarbon limit within 20 km of the spill site (Figure 8.7-10).

The predicted behaviour of various postulated batch spills is shown in Table 8.7-5. The spill sizes range from small operational spills of less than 1 m$^3$ to a catastrophic tanker accident causing the loss of the entire cargo of 31,800 m$^3$. 
<table>
<thead>
<tr>
<th>Location</th>
<th>Condition</th>
<th>Season</th>
<th>Slick Area (km²)</th>
<th>Duration (days)</th>
<th>Excursion (km)</th>
<th>Percent Dissipation</th>
<th>Plume Maximum Width (km)</th>
<th>Plume Dissipation (km)</th>
<th>Plume Excursion (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohasset</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>Average</td>
<td>Summer</td>
<td>0.07</td>
<td>5</td>
<td>0.83</td>
<td>61</td>
<td>0.5-1</td>
<td>≤ 7</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>0.07</td>
<td>5</td>
<td>0.49</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Worst-Case</td>
<td>Summer</td>
<td>0.4</td>
<td>30</td>
<td>2.25</td>
<td>54</td>
<td>4-5</td>
<td>≥ 20</td>
<td>45</td>
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<td></td>
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<td>Winter</td>
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<td>30</td>
<td>0.77</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsea</td>
<td>Average</td>
<td>Summer</td>
<td>&lt;0.02</td>
<td>5</td>
<td>0.14</td>
<td>72</td>
<td>1.0</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>&lt;0.02</td>
<td>5</td>
<td>0.07</td>
<td>89</td>
<td>1.0</td>
<td>≤ 7</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Worst-Case</td>
<td>Summer</td>
<td>0.08</td>
<td>30</td>
<td>0.40</td>
<td>55</td>
<td>4-5</td>
<td>≤ 20</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>0.04</td>
<td>30</td>
<td>0.18</td>
<td>84</td>
<td>4-5</td>
<td>≤ 20</td>
<td>65</td>
</tr>
<tr>
<td>Panuke</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>Average</td>
<td>Summer</td>
<td>&lt;0.03</td>
<td>5</td>
<td>0.87</td>
<td>41</td>
<td>0.5-1.0</td>
<td>7</td>
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<td></td>
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<td>Winter</td>
<td>0.025</td>
<td>5</td>
<td>0.49</td>
<td>52</td>
<td>0.5-1.0</td>
<td>9</td>
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<td>Summer</td>
<td>&lt;0.07</td>
<td>30</td>
<td>1.67</td>
<td>33</td>
<td></td>
<td>22</td>
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<td></td>
<td>Winter</td>
<td>&lt;0.05</td>
<td>30</td>
<td>0.92</td>
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<td>Average</td>
<td>Summer</td>
<td>&lt;0.01</td>
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<td>0.18</td>
<td>64</td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>0.012</td>
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<td>0.10</td>
<td>77</td>
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<td>11</td>
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<tr>
<td></td>
<td>Worst-Case</td>
<td>Summer</td>
<td>0.07</td>
<td>30</td>
<td>0.41</td>
<td>62</td>
<td></td>
<td>35</td>
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<td>Winter</td>
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<td>30</td>
<td>0.18</td>
<td>70</td>
<td></td>
<td>40</td>
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</table>
ESTIMATED DRIFT OF DISPERSED OIL PLUME FROM AVERAGE BLOWOUTS FOR THE COHASSET/PANUKE FACILITIES

ESTIMATED DRIFT OF DISPERSED OIL PLUME FROM WORST-CASE BLOWOUTS FOR THE COHASSET/PANUKE FACILITIES

<table>
<thead>
<tr>
<th>Type</th>
<th>Condition</th>
<th>Season</th>
<th>Area (km²)</th>
<th>Duration (days)</th>
<th>Excursion (km)</th>
<th>Percent Dissipation</th>
<th>Maximum Dissipation Width (km)</th>
<th>Plume Dissipation (km)</th>
<th>Excursion (km)</th>
</tr>
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<tbody>
<tr>
<td><strong>Operational Spills</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanker 3.2 m³</td>
<td></td>
<td>Summer</td>
<td>0.01</td>
<td>2</td>
<td>≤3</td>
<td>44-62</td>
<td>0.01</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>0.01</td>
<td>1</td>
<td>≤3</td>
<td>50-76</td>
<td>0.02</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Small 0.64 m³</td>
<td></td>
<td>Summer</td>
<td>&gt;0.001</td>
<td>1</td>
<td>&lt;2</td>
<td>45-64</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Platform</td>
<td></td>
<td>Winter</td>
<td>&gt;0.001</td>
<td>0.5</td>
<td>&lt;2</td>
<td>53-78</td>
<td>&lt;0.01</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Medium 24.5 m³</td>
<td></td>
<td>Summer</td>
<td>0.08</td>
<td>3</td>
<td>≤5</td>
<td>46-65</td>
<td>0.05</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Platform</td>
<td></td>
<td>Winter</td>
<td>0.08</td>
<td>1.5</td>
<td>≤5</td>
<td>55-76</td>
<td>0.07</td>
<td>3</td>
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<tr>
<td><strong>Tanker Accidents</strong></td>
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<td></td>
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<tr>
<td>Cohasset 8000 m³</td>
<td></td>
<td>Summer</td>
<td>6.0</td>
<td>9.9</td>
<td>≤15</td>
<td>65</td>
<td>30</td>
<td>60</td>
<td>≤20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
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<td>6.9</td>
<td>≤15</td>
<td>77</td>
<td>60</td>
<td>90</td>
<td>≤20</td>
</tr>
<tr>
<td></td>
<td>31800 m³</td>
<td>Summer</td>
<td>19</td>
<td>12.6</td>
<td>≤25</td>
<td>65</td>
<td>200</td>
<td>140</td>
<td>≤50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>16</td>
<td>6.9</td>
<td>≤25</td>
<td>77</td>
<td>500</td>
<td>200</td>
<td>≤50</td>
</tr>
<tr>
<td>Panuke 8000 m³</td>
<td></td>
<td>Summer</td>
<td>5.5</td>
<td>10.7</td>
<td>≤15</td>
<td>47</td>
<td>20</td>
<td>50</td>
<td>≤20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>4.5</td>
<td>5.9</td>
<td>≤15</td>
<td>56</td>
<td>40</td>
<td>70</td>
<td>≤20</td>
</tr>
<tr>
<td></td>
<td>31800 m³</td>
<td>Summer</td>
<td>15</td>
<td>13.4</td>
<td>≤25</td>
<td>47</td>
<td>150</td>
<td>120</td>
<td>≤50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>18</td>
<td>7.2</td>
<td>≤25</td>
<td>56</td>
<td>300</td>
<td>270</td>
<td>≤50</td>
</tr>
<tr>
<td>Interfield 1590 m³</td>
<td></td>
<td>Summer</td>
<td>0.1</td>
<td>0.46</td>
<td>&lt;2</td>
<td>63</td>
<td>0.6</td>
<td>6</td>
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</tr>
<tr>
<td>Flowline</td>
<td></td>
<td>Winter</td>
<td>0.04</td>
<td>0.18</td>
<td>&lt;2</td>
<td>68</td>
<td>1.0</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>Loading Line 4800 m³</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohasset</td>
<td></td>
<td>Summer</td>
<td>0.18</td>
<td>1.6</td>
<td>&lt;2</td>
<td>63</td>
<td>1.2</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>0.19</td>
<td>0.75</td>
<td>&lt;2</td>
<td>78</td>
<td>1.3</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Panuke</td>
<td></td>
<td>Summer</td>
<td>0.09</td>
<td>2.0</td>
<td>&lt;2</td>
<td>44</td>
<td>1.0</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter</td>
<td>0.09</td>
<td>0.82</td>
<td>&lt;2</td>
<td>63</td>
<td>1.1</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>
Surface slicks arising from operational spills and accidents involving the flowlines will break up within 1 to 3 hours of release and will travel no more than 2 km from the spill site before disappearing. The higher energy levels during winter will reduce the drift distances by about half before the slick breaks up. More than half of the condensate will disperse into the water column rather than evaporating.

As was the case with the blowouts, the cloud in the water column will travel greater distances than the surface slick before dispersing. The operational spills will disperse within 3 hours of release and will impact an area of less than 0.1 km². Clouds arising from flowline accidents will travel between 6 and 17 km before dispersing.

Tanker accidents will have the greatest influence on the project area environment. S.L. Ross Ltd. (1989) postulated two spill scenarios, a moderate sized event of 8,000 m³ and a catastrophic accident. The moderate event in summer would result in a slick that would break up within 10 hours while a slick from the catastrophic event would take up to 13 hours to dissipate. Similar events in winter would result in a slick life of about half the summer time.

The greatest variation between winter and summer tanker accidents is with the duration of the dispersed oil plume. The analysis has shown that the clouds will remain at hydrocarbon concentrations greater than 1 ppm for a longer period in the winter than the summer. In the summer the plume from the smaller spill would dissipate within 50 to 60 hours of release while the same release in winter would take 70 to 90 hours. For the catastrophic accidents, the cloud would take 120 to 140 hours in summer and 170 to 200 hours in winter to disperse.
For the smaller accident, the plume would cover an area of 60 km$^2$ before dispersing below the 1 ppm hydrocarbon limit. Because of the tidal action, the excursion from the site would be only 20 km (Figure 8.7-11). For the larger incident, the plume would cover an area of 500 km$^2$ although it would be dispersed within 50 km of the spill site (Figure 8.7-12).

In summary, the analysis of the potential spill scenarios indicates that for most of the small operational spills, the surface slicks and subsurface plumes will dissipate within a few kilometres of the spill site. The surface slicks from well blowouts and the two large tanker spills will break up within half a day in any season but the plumes will persist for as much as 8 days before dissipating below the 1 ppm hydrocarbon threshold. Because of the behaviour of the semi-diurnal tides in the area, the excursion from the spill site will be limited and the centroid of the plume will never be further than 50 km from the spill site.

**Condensate Toxicity and Tainting Threshold.** Several investigations of the toxicity of Scotian Shelf condensate have been carried out (EPS 1983; Hutcheson et al. 1983; Mahon et al. 1987; Carter et al. 1989). The data indicate that these materials are toxic in the range of about 1 to 20 ppm condensate, with the median being less than 5 ppm. Bioassays conducted by Harris (unpubl.) report that the 24-hour $LC_{50}$ for Cohasset and Panuke condensates is 3.3 ppm. Sublethal effects from exposure to condensate have not been reported in the literature although they would be expected to be in the 10 to 100 ppb range identified for adult cod (Kuhnhold 1978; Kuhnhold et al. 1978) and the 50 to 60 ppb range for larvae (Solberg et al. 1982; Tilseth et al. 1984).
ESTIMATED DRIFT OF DISPERSED OIL CLOUD FROM AVERAGE TANKER SPILLS FOR THE COHASSET/PANUKE FACILITIES

ESTIMATED DRIFT OF DISPERSED OIL CLOUD FROM WORST-CASE TANKER SPILLS FOR THE COHASSET/PANUKE FACILITIES

FIGURE 8.7-12

Under natural conditions tainting is not likely to occur at the concentrations of hydrocarbons found in the oceans following a blowout or spill in the open ocean unless a major disaster such as the Amoco Cadiz has occurred. No tainting was recorded by taste panels in cod, halibut and haddock caught in the immediate vicinity of the Uniacke blowout off Sable Island (Tidmarsh et al. 1984) and there were no reports of tainting after the Ixtoc blowout in the Gulf of Mexico despite a ban on fishing in oiled areas (S. Fudge and Associates Limited 1989). After the 11 million gallon Exxon Valdez spill in Alaska extensive surveys failed to detect tainting in halibut and salmon nor the pink salmon out migrants which came down the streams at the time of the spill by taste testing and chemical analysis. In coastal areas, however, hydrocarbons do not disperse as quickly and can become trapped in sediments increasing the risk of tainting of fin and shellfish. In 1978 Janvrin Lagoon remained contaminated with oil from the tanker Arrow wrecked in 1970 (Gilfillan and Vandermeulen 1978) despite no reports of lobster tainting from the spill (Anon. 1970). Lobsters were tainted, however, by the Kurdistan spill in the same area in 1979 (Scarratt 1980).

Specific toxicity concentrations for seabirds and mammals are not known. Impacts on seabirds are caused by ingestion of condensate from preening and loss of insulation caused by stripping natural oils from feathers. No adverse impacts have been reported for the types of seals and whales found in the region.

Very little work has been reported on the effects of tainting by condensate spills. The 2200 tons of diesel oil from the British Mallard tainted herring, flounder, sea trout, salmon, haddock and pollock over a two month period (Ernst et al. 1987). Tainting thresholds for sea scallops and cod have been reported in the literature. Ernst et al. (1987) reported that cod exposed to the water soluble fraction of various crude oils exhibited
a taint if concentrations exceeded about 0.5 ppm for as little as 3 hours while Carter et al. (1989) reported that sea scallop were tainted at concentrations greater than 0.8 ppm, regardless of the duration of exposure. In both sets of experiments, depuration occurred within 24 hours for short-term exposures and within 2 weeks for longer-term events. Research by Ernst et al. (1989) on the effects of Scotian Shelf natural gas condensate on sea scallops showed that depuration rates were extended for scallops exposed to lower levels of hydrocarbons for longer periods of time indicating that chronic pollution may cause more stress than batch spills of oil. Carter et al. (1989) identified xylenes and toluenes as the most likely constituents of the water soluble fraction of condensate responsible for tainting. In addition to low hydrocarbon concentrations found after spills and blowouts, Ernst et al. (1987) also noted avoidance reactions by fish to hydrocarbon contamination which, if it occurred in levels below that known to cause tainting, would prevent fish from remaining in areas long enough to become tainted.

The fouling of fishing gear is caused by hydrocarbons attaching to fishing gear. Fouled fishing gear has been recorded in a number of surveys following major oil releases even if catches were not found to be tainted (S. Fudge and Associates Limited 1989).

While contaminated gear can be cleaned, fishery revenues can be affected through:

- The discarding of spoiled catches which become tainted from the fouled gear
- Lost fishing time spent returning to port to clean or replace gear
- The cost of cleaning gear
Contaminated gear can also indirectly affect the fishery. Vessel captains may avoid areas where fishing gear has been contaminated, increasing the effective loss of access. After an oil spill in Santa Barbara, fishing effort was reduced since fishermen were reluctant to foul gear (S. Fudge and Associates Limited 1989). Contaminated gear may become associated with tainting, causing even unaffected catches to become unmarketable.

(b) Hazardous Chemical Spills

The hazardous chemicals that may be used in the development and production of the Cohasset/Panuke fields include fuels, lubricants, hydraulic fluids, drilling fluid and injection water constituents, as well as workover and kill fluid components (Tables 8.2-1 and 8.2-2). Many of these materials will come under the regulations contained in the Transportation of Dangerous Goods Act and the Canadian Environmental Protection Act. These materials will be stored in appropriate containers before use and, if used in drilling or production, will be disposed of only in accordance with the Offshore Waste Management Regulations (COGIA 1989).

(c) Atmospheric Emissions

Well blowouts, large batch spills involving the release of volatile liquids into the environment, or a fire resulting from an accident will result in atmospheric emissions. These will include CO₂, NOₓ, water, and smoke if the emissions are burning or methane, CO₂, and droplets of condensate if a fire does not occur.
(d) Noise, Lights, and Human Presence

An accident will result in a significant increase in the level of human activity in the vicinity of the accident site. This will include personnel, vessels, and aircraft employed to control the incident, in addition to those employed in the appropriate spill countermeasures.

Potential Impacts

Studies on oil spills over the last 20 years (National Academy of Sciences 1985) have suggested that a spill in the open ocean will have a negligible impact on the local ecosystem because the contaminant is rapidly dispersed by winds and waves, and marine populations tend to be more widely dispersed than those in more protected coastal environments.

The potential impacts of accident events on project VECs prior to mitigation are rated in Figure 8.7-13.

(a) Condensate Spills

In this section, the potential impacts of each spill scenario on the project VECs are discussed. Impacts on fisheries have been derived from the analysis of S.L. Ross Ltd. (1989) while other possible impacts have been adopted from the Venture EIS (Mobil 1983a,b,c).

Operational Spills. The surface slicks and subsurface clouds arising from small spills of condensate on the production facilities and the tankers will be confined to an area within 1 km of the site. The impacts on the fish and fisheries, seabirds, and marine mammals are rated as negligible. The slicks and clouds will dissipate within 4 hours and there will not be any residual material remaining to contaminate organisms. Adult
**ENVIRONMENTAL IMPACT RATINGS**

**ACCIDENTAL IMPACTS - ALL ACTIVITIES**

<table>
<thead>
<tr>
<th>VALUED ECOSYSTEM COMPONENTS</th>
<th>ACCIDENTAL EVENTS</th>
<th>CONDENSATE SPILLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OPERATIONAL</td>
<td>PIPELINE</td>
</tr>
<tr>
<td>JUVENILE COD AND HADDOCK</td>
<td>2 1/1 1 1/1 1/1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
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<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>FLOUNDER</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>NORTHERN SAND LANCE</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>FISH EGGS AND LARVAE</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>SEA SCALLOPS</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>OCEAN QUAHOG</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>ALCIDS</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>SHEARWATERS</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>TERNs AND GULLS</td>
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<td>3 2 1/1 1/1 1</td>
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<tr>
<td>SEALS</td>
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</tr>
<tr>
<td>WHALES</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>OFFSHORE FISHERIES</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
<tr>
<td>SABLE ISLAND</td>
<td>2 1/1 1 1/1 1</td>
<td>3 2 1/1 1/1 1</td>
</tr>
</tbody>
</table>

**FIGURE 8.7-13**
## ENVIRONMENTAL IMPACT RATINGS

### ACCIDENTAL IMPACTS - ALL ACTIVITIES

<table>
<thead>
<tr>
<th>VALUED ECOSYSTEM COMPONENTS</th>
<th>ACCIDENTAL EVENTS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HAZARDOUS CHEMICAL SPILLS</td>
<td>ATMOSPHERIC EMISSIONS</td>
<td>ADDITIONAL NOISE, LIGHTS &amp; HUMAN PRESENCE</td>
<td></td>
</tr>
<tr>
<td>JUVENILE COD AND HALDOCK</td>
<td>2</td>
<td>2</td>
<td>0-1</td>
<td>1/1</td>
</tr>
<tr>
<td>SILVER HAKE</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>FLOUNDER</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>NORTHERN SAND LANCE</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>FISH EGGS AND LARVAE</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>0-1</td>
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<tr>
<td>SEA SCALLOPS</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>OCEAN QUAHOG</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>ALCIDS</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>SHEARWATERS</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>TERNs AND GULLS</td>
<td>2</td>
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<td>4</td>
<td>2</td>
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<tr>
<td>SEALS</td>
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<tr>
<td>WHALES</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>OFFSHORE FISHERIES</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>SABLE ISLAND</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

[FIGURE 8.7-13 (CONTINUED)]
fish caught in the plume could take up hydrocarbons to a level where longer-term exposure might elicit a taint, but the short duration of exposure means that these materials will be rapidly depurated and product quality will not be impaired.

Impacts on resident seabirds and marine mammals are rated as negligible because the area affected is small and the duration of the surface slick very short. Despite the fact that a spill may result in fishing vessels being asked to leave the area for safety reasons, the effect of such an action is considered to be negligible because the area currently supports very low levels of fishing activity compared with adjacent areas of the shelf. Operational spills will not have any impact on Sable Island.

**Pipeline Leaks.** Leaks in flowlines (pipelines) may result in the release of 240 m$^3$ of condensate to the sea surface over a one-hour period. Based upon the modelling results, the surface slick could cover an area of 0.8 km$^2$ and would move 1.5 to 2 km from the leak location before dissipating. The subsurface plume could move between 6 and 18 km before dispersing below 1 ppm hydrocarbon concentration. This dispersion should take place in less than one day.

The impacts on the project VECs are rated as negligible with the exception of Sable Island where no impact is predicted. Larval fish and benthic organisms are unlikely to be adversely affected. The modelling data indicate that the plume will not have a measurable effect on the larval populations (S.L. Ross Ltd. 1989). Adult fish caught in the plume may be exposed to concentrations in excess of tainting and lethal concentration thresholds but the duration will be short and the effects at the population level negligible. Similarly, the potential effects on offshore fisheries are rated as negligible given the low level of activity in the region.
Potential effects on the seabird and marine mammal VECs are rated as negligible because the slicks will rapidly disperse and the populations of these organisms are relatively widely scattered on the Scotian Shelf. A pipeline spill will not affect Sable Island.

**Blowouts.** The blowout scenarios indicate that most of the surface slicks will dissipate within 1 km of the blowout location although in a worst case incident in the summer, the slick could remain intact for up to 2.25 km. The subsurface plume from an average blowout would travel between 7 and 14 km before dispersing below the 1 ppm hydrocarbon limit. However, subsurface plumes from the spill could extend for up to 20 km from the spill site in a worst case situation.

The impacts of such a spill on adult fish are rated negligible but effects on juvenile fish, and eggs and larvae could be minor if the worst case blowout were to persist for an extended period (S.L. Ross Ltd. 1989) with as much as 30 percent larval mortality. The percentage of mortality attributable to an oil spill is almost impossible to establish over normal population fluctuations unless at least 100% mortality occurs within a good year class. Impacts on benthic species are rated as negligible (CAFSAC 1981).

Impacts on seabirds are rated as minor because the slick would extend for only several kilometres from the site. Marine mammals will be largely unaffected. While the analysis provided in the appendix (S.L. Ross Ltd. 1989) for the impact of spills on fish is a rigorous mathematical or statistical approach, this depth of analysis for seabirds is not possible. The data base for seabirds is not as extensive or complete as it is for fish. Accordingly the analysis must be limited to a more simple qualitative approach based on the physical properties of the condensate and the observed distribution and life histories of
seabirds. Offshore fisheries will be temporarily displaced and the effect is rated as minor although the impact could increase if the blowout persisted. Sable Island will not be affected by the surface slick or subsurface plume from either a surface or subsurface blowout.

Tanker Spills. The behaviour of condensate from medium-sized (8,000 m³) and catastrophic (31,800 m³) spills are summarized in Table 8.7-5. The analysis shows that the slick from a medium-sized spill will dissipate within 6 to 7 hours in winter and 10 to 11 hours in summer. Each will cover an area of 5 km². A catastrophic spill slick will take 6 to 7 hours in winter and 13 to 14 hours in the summer to break up. However, the large spill will cover an area up to 20 km² before it dissipates.

The subsurface plume resulting from the slick will take longer to disperse, upwards of 90 hours for a medium-sized spill and 200 hours for a catastrophic event. The resulting plumes are shown in Figure 8.7-11. The centroid of the plumes will migrate only 20 and 50 km from the site, respectively although they will cover areas of 60 and 475 km² before they disperse below the 1 ppm hydrocarbon threshold.

The assessment of possible impacts on the fish and offshore fisheries (S.L. Ross Ltd. 1989) suggests that the a medium-sized spill would cause less than 1 percent mortality in the 0+ age class, while a catastrophic event could result in upwards of 2 percent year class mortality. Impacts on fish larvae are rated as negligible for a medium-sized spill and negligible-to-minor for the catastrophic spill. Tanker spills represent the greatest threat to adult and juvenile fish because of the size of the cloud containing condensate concentrations known to be lethal to finfish. The assessment shows that the threat to bottom-living species is lower than for pelagic dwellers because the area of impact is smaller (S.L. Ross Ltd. 1989) and the
exposure times will be shorter. The impacts on older fish are rated as minor because a spill will only affect a small percentage of the population of any given species and exposure will be for a short duration. A significant impact on adult stocks would only be measurable if at least 25 percent mortality occurred within the best case stock (CAFSAC 1981). Due to its location in NAFO unit area 4Wf, accidental spills from the proposed development would have at worst only a minor effect on the fishery as this unit area has only accounted for an average of 1.46 percent of groundfish, 9.19 percent of shellfish harvests in 4Wf and no pelagic catches since 1982-1988 (Gardner Pinfold Ltd. 1989). The indirect effects of hydrocarbon releases and their consequent past, present, or future fish stocks is difficult to estimate.

Although condensate concentrations will be high enough to cause a taint in pelagic as well as some bottom dwellers (northern sand lance, sea scallops, and ocean quahog), the risk is judged to be minor because of the short exposures and the small percentage of the stock exposed. Impacts on offshore fisheries are rated as minor, however, because the area is not a significant fishing area (Gardner Pinfold 1989) and any exclusions will be for a relatively short duration.

A spill may motivate governmental agencies to close large areas to fishing activity. Fishermen may therefore be unable to fish in the immediate areas for the period when the spill is ongoing. Compensation for fishermen is discussed in a following section.

The impacts on seabirds are rated as minor. Although birds in the vicinity of the spill could suffer direct or delayed mortality as a result of oiling, the surface slick will be rapidly dissipated and will be confined to the immediate area around the fields. None of the species that potentially could be affected are limited by range to the project area. The
persistence of the subsurface cloud will not have a direct effect on the seabirds in the area, but marine mammals may temporarily move out until it disperses. Thus, the impact on seals and cetaceans is predicted to be negligible.

Although Sable Island will not be directly affected by a surface slick, the edges of the cloud may impinge on the western end of the island and the west bar. The impacts are rated as negligible because the concentrations would be relatively low and the plume would not persist for more than a few days before dispersing.

Fishing gear is principally fouled by the long-chain hydrocarbons which form the familiar "tar balls" in water. Condensate, not crude oil, will be extracted from the Cohasset/Panuke fields. Since condensate is principally composed of short chain hydrocarbons which evaporate after release, fouling of fishing gear is highly unlikely.

(b) Hazardous Chemical Spills

The impacts of hazardous chemical spills during facility installation, drilling, and production are rated as negligible with the exception of offshore fisheries and Sable Island, where no impact is predicted. If a spill occurred as a result of an accident during transfer to the rig or platform, or a failure of the containment system, the quantities would be very small and the contaminants would be rapidly dispersed by currents and wave action. The effects would be limited to the area immediately around the spill site and the effects on the identified VECs would be negligible. A spill of these chemicals would not have any effect on Sable Island.
(c) Atmospheric Emissions

Depending upon the size of the blowout, between 5,600 m³/d and 35,600 m³/d of gas could escape. The escaping gas and condensate would be projected into the atmosphere and drift downwind, dispersing as it moves. The zone of influence, even under worst-case conditions, is expected to be confined to a few hundred metres around the blowout. The gases released would rapidly disperse and some of the larger droplets would fall to the sea surface to form a slick before evaporating. The deposition rates are unknown at present. After evaporation, some of the heavier hydrocarbons present would photo-oxidize resulting in a transient increase in local ozone concentrations but the impact of this change would be negligible. If the gas was ignited, most of the material would burn. The smoke would disperse in the atmosphere but some particulates would fall back to the sea surface. None of these materials would reach Sable Island.

Because of the very high evaporation rates exhibited by the Cohasset and Panuke condensates, large volumes of vapors would be emitted from surface slicks. Depending on the size of the spill, this evaporation could continue for up to several hours. The rate would depend upon the local wind speed and the wave action at the time of the spill. The greater the wind speed, the more rapid the evaporation. The higher the sea state, the faster the dispersion and the less the amount of condensate available for evaporation. However, there would be a zone around the slick where the cloud could be explosive and it would be essential for the safety of personnel and the facilities that this cloud dissipate before any countermeasures were employed.

The impact of atmospheric emissions resulting from a blowout or a batch spill on project VECs are rated as negligible for fish eggs and larvae, sea birds, and marine mammals. Some bird mortality might be expected if the cloud catches fire but the
numbers are expected to be small relative to the population in the vicinity of Sable Island. Sable Island will not be affected by the atmospheric emissions from a spill. There would be no impact on fish, bottom-dwelling species, offshore species, and Sable Island.

(d) Noise, Lights and Human Presence

The first concern in an accident will be the lives and safety of the workers at risk. Therefore, the first step will be the evacuation of crews to the emergency base on Sable Island. The base is a self-contained unit capable of supporting 300 people for a maximum of 3 days. The facility was put in place for such emergencies and the effect of using it on the environment of Sable Island would be minor. Some birds, in particular Roseate Terns, might be disturbed by the helicopter traffic associated with the evacuation but the adherence to flight rules over the Island, commensurate with human safety, would minimize any impact. Seabirds in the vicinity of the accident might be disturbed by the increased traffic in the area but the impact is expected to be transient and the longer-term effect would be negligible.

The underwater and atmospheric noise associated with a blowout would be significant. Seabirds and marine mammals would be disturbed and may be temporarily displaced. However, the effect would be transient and the long-term impact would be negligible. Underwater noise levels associated with increased vessel traffic may temporarily disturb some marine mammals but the impact would be transient. Increased light levels are not expected to have any discernable impact on the bird populations present in the area.
The potential exclusion zone associated with an accidental event may result in a minor impact on the offshore fishery. All other VECs would experience no impact.

8.7.4 CUMULATIVE IMPACTS

Peterson et al. (1987) defined cumulative effects as occurring:

When at least one of two circumstances prevail:
- persistent addition of a material, a force, or an effect from a single source at a rate greater than can be dissipated; or
- compounding effects as a result of the coming together of two or more materials, forces or effects, which individually may not be cumulative.

Sonntag et al. (1987) noted that cumulative effects can be characterized as impacts on the natural and social environments which:

- Occur so frequently in time or so densely in space that they cannot be "assimilated"

- Combine with effects of other activities in a synergistic manner

The major types of cumulative effects that are of widespread public concern (and relative to this project) are:

- Long-range transport of air pollutants
- Cumulative effects associated with climatic modification
- Habitat alienation
- Increased sediment, chemical and thermal loading of marine habitats
- Declining fish stocks due to resource exploitation
Marine biologists often have a poor understanding of the role of natural processes in the regulation of natural populations in the open ocean system. It is nearly impossible in many cases to accurately evaluate the capacity of a population to adjust to external influences such as resource harvesting.

The ability to assess the cumulative impacts of this project is extremely limited by this lack of understanding. Dayton (1986) described some of the difficulties in understanding pelagic community responses to cumulative impact in that commercial fishing pressures may represent some of the most profound chronic and cumulative effects in the marine realm, and yet, little research is ever done other than on vertebrate species. It is not possible to discern between project-related impacts (which are predicted to be minor or less) and major long term cumulative impacts attributable to such factors as resource exploitation or long term climatic change.

Given the difficulty of impact prediction associated with this project for specific VECs, it is concluded that the prediction of cumulative impacts is not possible. However, it should be noted that the VECs studied in this environmental evaluation are all affected by varying degrees of non-project cumulative impact. Predicted project-related impacts can be assumed only to be contributory to overall cumulative impacts. In this context, it is felt that the degree of impact predicted is minimal (minor or less) for all VECs. Where certain VECs are currently experiencing significant cumulative impacts, i.e., fish stocks, the proportion or contribution of the Cohasset/Panuke Development is felt to be negligible.

8.8 MITIGATION, RESIDUAL IMPACTS, AND COMPENSATION

This section presents the proposed mitigation and compensation programs which IASMO proposes to implement to minimize adverse impacts and maximize project benefits. Where further development is required to prepare mitigation and compensation programs, the
required steps are clearly identified. The responsibilities of parties-at-interest, including IASMO, the Canada-Nova Scotia Offshore Petroleum Board, federal and provincial agencies, and the public, are discussed with regard to the establishment of mechanisms by which impacts and issues can be resolved as they emerge through the construction, operation and abandonment phases of the development.

The residual impacts, those impacts which are predicted to remain following the application of all practical mitigation measures, are also presented.

8.8.1 MITIGATION

The refinement of IASMO's mitigation strategy for the reduction of potential impacts has involved a number of phases. The mitigative measures developed prior to this EIA study are incorporated in the project description (Section 8.2). Further, in designing the control systems and engineering design of the facilities, it has been necessary to meet and consider numerous laws, regulations, and guidelines which in itself result in substantive mitigation of potential impacts.

With the exception of shipping, the offshore petroleum industry is regulated either by federal-provincial boards such as the recently appointed CNSOPB, or directly by COGIA. The shipping component is regulated by the Canadian Coast Guard through the Canada Shipping Act. The regulations under which the industry operates contain significant environmental protection components.

At present, emissions standards for flaring and venting from platforms or other production facilities are not specifically mentioned in either the Drilling Regulations (COGIA 1986) or the draft Development Guidelines. Atmospheric emissions from vessels,
including engine exhaust on the rigs come under the air pollution regulations of the Canada Shipping Act. These regulations are intended to limit smoke emissions in harbours and will therefore have little bearing on vessel operations in the project area.

Liquid effluents are controlled by the same regulatory bodies. The Offshore Waste Treatment Guidelines (COGIA 1989) have been put in place to establish recommended discharge levels of various effluent streams from offshore facilities, as well as recommended sampling and analytical procedures. These limits are shown in Table 8.8-1 and are directed primarily to limiting hydrocarbon discharges in the various waste streams. The Drilling Regulations (COGIA 1986) make specific provisions for the use of oil-based drilling muds in the offshore including a limit for oil retained on cuttings before discharge.

Under the Canada Shipping Act, oil cannot be discharged by vessels operating in Canadian waters. Contaminated bilge water must be treated to contain less than 15 mg/L total hydrocarbons before discharge, except if the vessel is in peril. However, there are no regulations for sewage, gray water, or cooling water discharges. Under the Act, tankers are required to meter all discharges and discharge of hydrocarbons during product transfer operations are prohibited.

Both COGIA and the Coast Guard require that all garbage and other solid wastes be transported back to shore for disposal. Combustible refuse can be incinerated on-site although, in most cases, it is brought to shore. COGIA also requires that any debris resulting from accidental losses be reported and an attempt made to recover the material, particularly if it presents a potential hazard to fishing activity.

CEARC (1988) observed that priority should be given to the application of impact prevention measures in the earliest possible
<table>
<thead>
<tr>
<th>Waste Stream</th>
<th>Parameter</th>
<th>Recommended Level</th>
<th>Detection Method</th>
<th>Sampling Frequency</th>
<th>Data Reporting Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste From Formation Testing</td>
<td>Total hydrocarbon</td>
<td>---determined on a case-by-case basis---</td>
<td>---determined on a case-by-case basis---</td>
<td>---determined on a case-by-case basis---</td>
<td>---determined on a case-by-case basis---</td>
</tr>
<tr>
<td>Produced Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Production</td>
<td>Total hydrocarbon</td>
<td>40 mg/L</td>
<td>Infrared spectrophotometry</td>
<td>Twice per day</td>
<td>Monthly</td>
</tr>
<tr>
<td>Water Production</td>
<td>Total hydrocarbon</td>
<td>40 mg/L</td>
<td>Infrared spectrophotometry</td>
<td>--determined on a case-by-case basis--</td>
<td></td>
</tr>
<tr>
<td>Produced sand</td>
<td>Total hydrocarbon</td>
<td>---determined on a case-by-case basis---</td>
<td>---determined on a case-by-case basis---</td>
<td>---determined on a case-by-case basis---</td>
<td>---determined on a case-by-case basis---</td>
</tr>
<tr>
<td>Storage Displacement Water</td>
<td>Total hydrocarbon</td>
<td>15 mg/L</td>
<td>Infrared spectrophotometry</td>
<td>Once per shift during discharge period</td>
<td>Monthly</td>
</tr>
<tr>
<td>Unsegregated Ballast Water</td>
<td>Total hydrocarbon</td>
<td>15 mg/L</td>
<td>Infrared spectrophotometry</td>
<td>Once prior to discharge</td>
<td>Monthly</td>
</tr>
<tr>
<td>Bilge Water</td>
<td>Total hydrocarbon</td>
<td>15 mg/L</td>
<td>---Adequate operation of oil discharge and control system as recommended by the International Maritime Organization (IMO)</td>
<td>Monthly</td>
<td></td>
</tr>
<tr>
<td>Machinery Drainage</td>
<td>Total hydrocarbon</td>
<td>15 mg/L</td>
<td>---Adequate operation of oil discharge and control system as recommended by IMO</td>
<td>Monthly</td>
<td></td>
</tr>
<tr>
<td>Clorinated Cooling Water</td>
<td>Residual chlorine</td>
<td>0.5 mg/L</td>
<td>---Adequate operation of chlorination system with adjustment of the level of chlorination as a function of the desired residual chlorine level in the discharge</td>
<td>Monthly</td>
<td></td>
</tr>
</tbody>
</table>

stages of the planning process. In this regard, IASMO's development plan and engineering design have incorporated impact prevention measures extensively.

Like many offshore hydrocarbon development projects, the proposed development cannot use avoidance and site selection as a principal means of mitigation. The location of the field provides little or no latitude for the siting of facilities. Opportunities for avoidance of critical resources in the development area are also limited, although the reduction of continuous production in winter months in itself, could be considered as a major measure of avoidance mitigation.

IASMO's mitigative strategy involves a commitment to implement environmentally-responsible construction, operation and training practices that are accepted as the norm, irrespective of regulatory requirements. Such measures are routinely implemented by the offshore oil and gas industry. Other mitigative measures which have been presented in Section 8.2 reflect a commitment to adhere strictly to all applicable laws, regulations and guidelines.

IASMO's mitigation program was developed in accordance with six principles:

(1) IASMO has the responsibility for implementing measures which are required to mitigate predicted adverse impacts and to maximize potential benefits.

(2) All parties potentially affected by the project should have the opportunity to voice their concerns during the planning, construction, operation, and abandonment of the development.

(3) IASMO and responsible jurisdictions will advise potentially affected parties of the measures taken for impact mitigation.
(4) IASMO has and will continue to incorporate mitigative measures early in the planning and design phases of the development.

(5) Impact management and mitigation must be timely and adaptive, changing with the evolution of the project, local conditions, and knowledge of the impacts of project activities.

(6) The success of mitigative measures will depend, in part, on cooperation between IASMO, the public, and other jurisdictions.

This subsection discusses the proposed mitigation program in terms of mitigation framework, environmental protection planning, summary of biophysical mitigation, and mitigation of cumulative impacts.

Subsection 8.8.1.1 outlines the framework for the implementation of mitigative measures proposed in the chapter. The organizational structure is related to the responsibility and approach to impact management. Publicity and education programs are presented. Subsection 8.8.1.2 presents the Environmental Protection Plan which will be used as a tool to coordinate the implementation of many mitigative measures, including contingency planning, and education and orientation. Subsection 8.8.1.3 presents a summary of the mitigation measures proposed for the biophysical impacts which have been predicted to be minor or greater in Section 8.7. Subsection 8.8.1.4 discusses mitigation of cumulative impacts.

8.8.1.1 Mitigation Framework

A comprehensive framework is proposed for the management and mitigation of potential biophysical impacts of the project. This framework provides the structure for implementing the mitigative measures in a coordinated manner for construction, operation and abandonment.
Project Planning and Management for Impact Mitigation

Organizational Structure. Although the organizational structure of the IASMO management team may change through the construction, operation and abandonment phases of the development, a typical organization chart is presented in Figure 8.8-1. This figure outlines the relationship between the General Manager, the Environmental Advisor, the public and Government Affairs Officer, and the Operations Manager.

Responsibility for Impact Management. Although the organizational structure of the project team will change through the phases of the development, the Environmental Advisor will maintain overall responsibility for the coordination of IASMO's environmental affairs, particularly their self-regulatory Environmental Compliance Monitoring activities (Section 8.9). The Environmental Advisor will report directly to the General Manager. Under the scrutiny of the Environmental Advisor, IASMO will assign environmental responsibility to various staff members as required.

The Environmental Advisor will:

- Coordinate the preparation, updating and implementation of the Environmental Protection Plan

- Prepare applications for government permits and approvals on environmental matters

- Coordinate the preparation, updating and implementation of the Contingency Plans

- Coordinate all EEM studies and maintain liaison with the EEM Advisory Committee to ensure that any mitigation refinement which stems from these studies is implemented
TYPICAL ORGANIZATION CHART
LASMO

GENERAL MANAGER
HALIFAX

PUBLIC AND GOVERNMENT AFFAIRS
MEDIA

ENGINEERING MANAGER
ENGINEERING STAFF

OPERATIONS MANAGER

LOSS PREVENTION ADVISOR

LOGISTICS & PROCUREMENT MANAGER
LOGISTICS SUPERVISOR
AIRPORT COORDINATOR
SUPPLY BASE SUPERVISOR
PURCHASING

ADMINISTRATION
ACCOUNTING
ENVIRONMENTAL ADVISOR
ENVIRONMENT STAFF AND CONSULTANTS

MARINE SUPERINTENDENT

TANKER IN TRANSIT

STORAGE TANKER
STANDBY VESSEL
PRODUCTION FACILITIES

DRILLING SUPERINTENDENT

PRODUCTION SUPERINTENDENT

DRILLING SUPERVISOR

JACK-UP DRILLING UNIT

NORMALLY ONSHORE

NOTE: THE ABOVE STRUCTURE MAY CHANGE WITH THE DIFFERENT PHASES OF OPERATIONS.

FIGURE 8.8-1
- Coordinate the environmental education and orientation program

- Maintain liaison with environmental agencies and facilitate regulatory environmental surveillance

**Environmental Planning.** IASMO will prepare an Environmental Protection Plan (Section 8.8.1.2) for the overall management of project-related impacts. This will be a comprehensive document which will consolidate all of the proposed environmental mitigation procedures, including contingency plans, for the construction, operation and abandonment of the development.

**Publicity and Education**

An important element of IASMO's mitigation plans will be to conduct both publicity and education programs. It is IASMO's intention to keep the public apprised of its activities, particularly fishermen and mariners through direct communications, the use of "Notices to Mariners," and the media. Fisheries exclusion zones will be published in the media and fisherman and fishing companies will be advised. Foreign fishermen will be advised through their Canadian agents.

IASMO will also conduct an information program for fishermen and fish companies using the area to inform them of the nature of the operations and any potential effects the project may have on fishing activities. Fisheries exclusion zones and compensation plans will also be reviewed in these sessions.

**Conflict Resolution**

The IASMO Public and Government Affairs Coordinator will, in cooperation with the General Manager and Environmental Advisor, be responsible for the development and implementation of mechanisms and procedures for the resolution of problems which arise as a
result of development activities which are in conflict with other resource and transportation activities in the vicinity of the development area. The Public Affairs Coordinator will attempt to resolve any problems which arise between IASMO and other parties before they become serious conflicts or misunderstandings.

IASMO will develop policies and procedures for the investigation of complaints. IASMO will also develop a program to address fisheries-related compensation issues.

8.8.1.2 Environmental Protection Planning

In the last ten years, several large scale developments in Atlantic Canada have used environmental protection plans (EPPs) and a coordinated Environmental Compliance Monitoring program (Section 8.9) to facilitate the mitigation of predicted environmental impacts. This experience has resulted in a very substantial improvement in the level of compliance for environmentally-sensitive projects.

IASMO will prepare an EPP for the management of project-related impacts. The EPP will provide the practical framework for implementing the environmental requirements and mitigation. The EPP will be the tool for the practical application of much of the mitigation proposed in this chapter. It will outline IASMO's environmental policy, and outline programs for employee orientation and education, environmental inspection, reporting procedures, contingency planning, conflict resolution, and mechanisms for environmental decision-making.

The EPP will be a comprehensive document which will consolidate all of the proposed environmental mitigation procedures for the construction, operation, and abandonment of the Development. The EPP will thus comprise a dynamic "life of project" environmental protection planning and mitigation strategy.
The EPP will be compatible with and comprised of the following key elements:

- IASMO's operating procedures
- The Canada-Nova Scotia Offshore Petroleum Board regulations and guidelines
- IASMO's hazardous materials contingency plan
- IASMO's education and orientation program
- Applicable laws, regulations, guidelines, permits, and approvals

The EPP will include full details of the development including such information as facility locations, seabed morphology, currents, sensitive environmental species or areas, fishing activities, shipping activities, and aviation activities. The EPP will incorporate appropriate elements of IASMO's operating policy and procedures which it uses as a matter of course in its offshore petroleum activities in other locations. To assure the implementation of environmental procedures is effective, the EPP will be written in a language and format which can be incorporated verbatim into policy and procedures manuals, and contract documents.

The EPP will outline procedures to be followed during the construction, operation and abandonment. The intent of the EPP is to facilitate compliance with the applicable laws, regulations, permits, guidelines and policies, and commitments made in the Development Application. The EPP will also provide regulatory authorities and other interested parties a benchmark against which to judge compliance.
The overall objective of the EPP will be to outline the procedures for the protection of the environment through all phases of the project. The main objectives of the EPP are as follows:

- Document environmental concerns and appropriate protection measures

- Provide concise and clear instructions to project personnel regarding procedures for protecting the environment and minimizing environmental impact

- Ensure that LASMO's commitments to minimize environmental impacts will be met

The update and implementation of the EPP will be the overall responsibility of the Environmental Advisor. The development of the EPP will be phased in such that the development of protection measures for the construction phase may precede, at least in part, the development of measures for the operation and abandonment phases. The EPP will by necessity be an evolving document. As new information becomes available from the Monitoring Program (Section 9) and from other sources such as the Canada-Nova Scotia Offshore Petroleum Board, the required additional information will be included. The EPP will be developed in close consultation with the Board, the Province, federal agencies, fishermen, and other special interest groups.

Contingency Planning

As noted by CEARC (1988) a contingency plan cannot prevent or minimize adverse impacts in the same way that mitigation can. Contingency planning is a way of approaching potential impacts which remain after mitigation. For environmental accidents and unforeseen environmental problems, contingency plans will be developed for this project. This contingency plan will be separate
from but complementary to the EPP. The plans will include contingency planning for loss of well control, structural damage, fire or explosion, collision with vessels, overdue or lost aircraft, lost or in-distress vessels, diving emergency, condensate spills on site, hazardous material spills, and personnel injury or death.

There are several valued ecosystem components which could be affected as a result of accidental events. Most of the potential negative impacts related to this project are a result of accidental events which could occur during construction or operation of the development.

In view of the importance of contingency planning in the context of offshore development, IASMO have presented an outline of its proposed contingency plan in Section 12 of the Development Application.

Countermeasures. An important element of contingency planning process will be the identification and implementation of the countermeasures that will be employed in the event of an accident resulting in the release of large volumes of condensate into the environment. S.L. Ross and Associates (1989b) have reviewed the potential countermeasures that could be employed to minimize the potential impacts of a spill but the characteristics of the Cohasset and Panuke condensates limit the options available. The analysis showed that surface slicks will evaporate very quickly and that the condensate will readily disperse into the water column. It is estimated that the surface slick from a 31,800 m³ spill will dissipate within 13 hours which leaves little or no time to implement countermeasures. Once the condensate enters the water column, nothing can be done.

S.L. Ross and Associates (1989b) have identified two components of countermeasures response, tracking and surveillance, and
containment and recovery. For smaller spills, tracking buoys and visual observations from ships and helicopters would be used to monitor slick movement until it dissipates. For larger spills or blowouts, computer trajectory models and aircraft mounted remote sensing equipment would be employed to follow the surface slick until it disappears. This monitoring will assist on-site personnel implement appropriate countermeasures to protect any sensitive environmental features or areas threatened by the slick, and provide information to warn fishermen and other vessels lying in its path.

Because of the speed with which the slick will dissipate and the danger to life and property posed by the vapour cloud over the slick in the immediate area of the source, there are relatively few containment and recovery options available. The analysis has shown that it could be as much as 24 hours before it would be safe to deploy and equipment to recover any contained condensate. The experience during the Uniacke G-72 blowout (Martec 1984) showed that the slicks would disperse relatively harmlessly and there was no environmental justification for implementation of countermeasures. The only countermeasure considered appropriate for the Cohasset/Panuke development is the possible use of dispersants to break up the slick to protect concentrations of seabirds, or avoid remnants of the slick beaching on Sable Island (S.L. Ross and Associates 1989b). The required equipment would be stored at the Sable Island Emergency Base. Any attempt to contain and burn the slick is considered risky with only limited potential success.

The analysis showed that condensate has a strong tendency to dissolve in seawater and partition into the water column. Technology does not exist to control or affect the behaviour of the resulting cloud which may take several days to disperse. The only countermeasure available is monitoring the movement and behaviour of the cloud using a ship borne water quality monitoring system. The system would determine whether the concentrations in the cloud
are lethal to or could cause tainting in exposed organisms. The information would be used to warn fishermen away from areas where they might come in contact with contaminated fish to avoid any repercussions from tainted product reaching market.

Training and Orientation

Training is important in order to achieve a high degree of compliance with environmental mitigative procedures. Training and orientation does not mitigate adverse impacts, although it is necessary to ensure mitigative measures are successfully implemented. Personnel must be aware of the environmental requirements of working in the development area.

All LASMO personnel and its contractors will receive safety training prior to working offshore. LASMO intends to expand this safety training to include some background on the environmental sensitivities of the development area, and to outline the procedures which must be followed to avoid negative interaction with VECs. Briefings will focus on the prevention of accidental events in view of the relative importance of these in relation to the potential impacts of the development. Other areas emphasized will relate to fishing and the control of hazardous materials and maintenance of effluent standards. The program will vary to fit the specific needs of the offshore personnel. Briefings will be conducted under the direction of the Environmental Advisor.

8.8.1.3 Summary of Biophysical Mitigation

A summary of biophysical impacts is provided for the project in Tables 8.8-2 and 8.8-3. A summary of the mitigation proposed for each negative impact which was rated as minor or greater is presented. Comments on specific aspects of the mitigation proposed are also included. The residual impacts, those which remain after
<table>
<thead>
<tr>
<th>VEC Affected (Impact)</th>
<th>Mitigation</th>
<th>Comments</th>
<th>Residual Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Scallops (minor)</td>
<td>Discharge within regulatory standards</td>
<td>Intermittent to continuous discharges of produced water, cooling water, and miscellaneous discharges</td>
<td>Minor*</td>
</tr>
<tr>
<td>Ocean Quahaug (minor)</td>
<td>Maximization of dilution and dispersion. Discharge above thermocline.</td>
<td></td>
<td>Minor*</td>
</tr>
</tbody>
</table>

* If produced water is discharged above thermocline, minor impact rating may be reduced to negligible.
<table>
<thead>
<tr>
<th>VEC Affected (Impact)</th>
<th>Mitigation</th>
<th>Comments</th>
<th>Residual Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juvenile Cod and Haddock (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Silver Hake (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Flounder (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Sand Lance (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Fish Eggs and Larvae (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Sea Scallops (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Ocean Quahaug (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Alcids (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Shearwaters (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
<tr>
<td>Offshore Fisheries (minor)</td>
<td>Operational safety and accident prevention, oil spill response plan countermeasures</td>
<td>Reduced frequency and impact of accidental events</td>
<td>Minor</td>
</tr>
</tbody>
</table>

MARCH 7, 1990
all practical mitigation measures have been implemented as proposed, are also presented. These are discussed in Section 8.8.2.

8.8.1.4 Mitigation of Cumulative Impacts

Cumulative impacts will be mitigated through the mitigation presented for specific valued environmental components. Outside of mitigating the impacts, which are directly related to the proposed project activities, no mitigation specific to cumulative impacts is proposed.

8.8.2 RESIDUAL IMPACTS

Residual impacts are those which remain after all practical mitigation measures have been implemented. Residual impacts include those which were reduced but not eliminated, and those for which mitigative measures are not possible or not implemented. The residual impacts are identified in Tables 8.8-2 and 8.8-3.

As noted in Section 8.7, many of the interactions between the project and the biophysical environment result in negligible impacts that do not require mitigation. Some impacts, however, are predicted to have greater levels of impact. For the most part, mitigation has reduced predicted impacts to minor or negligible levels. The exceptions include accidental events where the risk of accidents can be reduced, but not eliminated.

8.8.3 COMPENSATION

8.8.3.1 Definition

Within the EIA process, there is only a relatively recent history regarding compensation methods to respond to impacts. These have usually been applied to new and incremental, capital infrastructure and operation maintenance costs, increased government delivery
costs, and direct payment for property damage, required as a result of a project (CEARC 1988). Several compensation options are available and depend upon a number of factors (Storey and Shrimpton 1987):

- The effects of the project, the strategies to be implemented, and the costs to be incurred

- Whether the proponent is a private corporation or government

- The socio-economic and political context of the project and the arrangements that can be negotiated between the corporate proponent and government

Traditionally, mitigation and compensation have fallen into three categories:

(1) Formal policy (including statues and regulations)
(2) Accepted practice
(3) Negotiated measures

Examples of formal policy are rare and inflexible by nature. Accepted practice is evolving; for example, it is accepted practice to compensate for damaged fishing gear when marine-based projects affect fishermen. Negotiated measures are most common. Negotiated compensation often has a strong public and/or political element and is thus not often an efficient process, but has the advantage of flexibility (CEARC 1988).

8.8.3.2 LASMO's Compensation Policy

Under the provisions of the Petroleum Resources Act, offshore oil and gas operators assume absolute and unlimited liability for their actions. This includes compensating other sea users where it can be demonstrated that the actions of the operator or his contractors
have resulted in damage to property or loss of income to other parties.

To meet these requirements, IASMO will develop a comprehensive fisheries compensation plan as part of its overall program to mitigate the potential impacts of the Cohasset/Panuke Development on the environment and other resource users. The plan will ensure that fishing interests who suffer damage to their equipment or loss of catch, directly attributable to actions by IASMO or its contractors, will be quickly and fairly compensated. It will be designed to meet the specific needs of IASMO and the fishing interests operating in the area. A specific plan will be developed in consultation with representatives of the fishing industry.

This plan will be modelled after the Fishermen's Compensation Policy of the Canadian Petroleum Association which came into force in 1984. This plan was established to ensure that fishermen could claim compensation for damages where the party responsible could not be identified, i.e., non-attributable damage. Under this policy, claims are assessed quickly by a board with an independent chairman and representatives of both the oil and gas, and the fishing industries. Claimants have the option of seeking redress through the courts if they feel the settlement is not adequate. However, this is a slow, cumbersome process and it can take years to have claims settled, with no guarantee that the award may in fact be larger than the original offer.

IASMO proposes to develop an approach to deal with potential compensation claims for damages directly attributable to the project. If IASMO or its contractors are responsible for an action causing damage, IASMO will deal directly with the claimant to arrive at an equitable settlement. If a vessel chartered by a third party causes an incident, IASMO will act to assist a claimant where it is clear that the damage is not IASMO's responsibility but where it feels it has an obligation to assist. Such a case would be where
a tanker loads at the site and leaves the project area but has an accident causing a condensate spill and damage to Canadian fishermen before leaving Canada's Exclusive Economic Zone. Although the condensate may not belong to IASMO at that time, the Company is prepared to assist claimants in identifying owners of offending vessels and dealing with the international organizations responsible for the administration of pollution claims funds such as TOVALOP and CRISTAL.

IASMO is prepared to discuss these approaches with the fishing community to ensure that the compensation plan ultimately developed is best suited to the individual needs of the project and the fishermen directly affected.

8.9

MONITORING

8.9.1

DEFINITION

There are two types of environmental monitoring which are normally carried out in association with major developments in Canada, environmental compliance monitoring (ECM) and environmental effects monitoring (EEM). Environmental compliance monitoring involves monitoring of a proponent's activities by regulatory authorities and the proponent, to ensure compliance with all regulatory and self-imposed environmental requirements. Environmental effects monitoring is environmental monitoring which is undertaken to validate impact predictions, and evaluate the effectiveness and identify the need to alter or improve mitigative measures. IASMO is committed to implementing a comprehensive monitoring program which incorporates both ECM and EEM.

8.9.2

ENVIRONMENTAL COMPLIANCE MONITORING

Environmental compliance monitoring can be divided into two elements:
Regulatory environmental surveillance is carried out by regulatory authorities. Self-regulatory environmental compliance monitoring is that which a proponent undertakes to monitor its own activities against internal and external environmental standards. Self-regulatory ECM overlaps with regulatory environmental surveillance where the external standards which are being monitored are regulatory in nature. However, self-regulatory ECM is a much broader concept and is an important tool for the implementation of mitigation. Self-regulatory ECM can involve:

- Monitoring of all environmentally-sensitive activities to ensure compliance with all laws, regulations, permits, and EIA commitments

- Monitoring of all environmentally-sensitive activities to ensure compliance with internal and external non-regulatory environmental standards

- Coordination of communication with regulatory authorities

- Provision of on-site environmental advice to project personnel

- Provision of assistance with EEM studies and other environmental programs associated with a project

The benefits of self-regulatory ECM were recognized by Barnes et al. (1985) who noted that government regulations are often vague or do not provide adequate direction or authority to regulatory authorities for regulatory environmental surveillance. As well, there are many environmental problems associated with projects for which no specific government regulations exist.
IASMO is fully committed to implementing an ECM Program. IASMO recognizes that without effective ECM, mitigation cannot be expected to succeed.

The principle mechanism for ECM, both for regulatory authorities and IASMO, will be the Environmental Protection Plan (EPP) (Section 8.9.4). The EPP provides the practical framework for the implementation of the environmental requirements of the development. As well, the EPP will provide a common reference document against which compliance can be judged by both regulatory authorities and IASMO.

The EPP will be developed to be compatible with the strict procedures and working environment in which the petroleum industry is accustomed to work. An important element of the EPP will be the clear articulation of the chain of command for environmental decision-making so that unforeseen problems can be handled expeditiously in the field. In the case of a remote, offshore operation like this development, this is particularly important.

To effectively implement mitigative measures, IASMO will assign environmental responsibility to various staff members. IASMO will have an Environmental Advisor who will be responsible for all environmental aspects of its operations. In addition to this, there will be a designated person on the site during construction and operation. This person will report to the Environmental Advisor. The Environmental Advisor will report directly to the Project Manager.

Under the direction of the Environmental Advisor, there will be an employee education and orientation program which will train personnel in environmental procedures. This program will ensure that all employees are fully trained in their environmental responsibilities and duties. The staff of all contractors will also be trained in this manner.
All contracts for the construction, maintenance, supply, and abandonment of the project facilities will include specific environmental clauses in the special and technical conditions. LASMO's environmental policy will be included in the general conditions.

To facilitate environmental surveillance, LASMO will cooperate with all government agencies to facilitate the execution of their duties. To keep government informed of its ECM activities, LASMO's Environmental Advisor will prepare a monthly report of its ECM activities. This document will be prepared for the project manager and will be circulated to the Canada-Nova Scotia Offshore Petroleum Board and other appropriate regulatory authorities. This ECM activities report will document any acts of non-compliance and identify the steps taken to remedy, overcome, and report any associated problems.

8.9.3
ENVIRONMENTAL EFFECTS MONITORING

8.9.3.1 Overview

Environmental effects monitoring is the taking of repetitive measurements over time of environmental variables to detect changes caused by external influences directly or indirectly attributable to a specific anthropogenic activity or development (Duinker 1985). EEM can be undertaken to:

- Improve environmental understanding of cause and effect relationships

- Provide an early warning of undesirable change in the environment

- Verify earlier predictions to lower uncertainty or risk
Beanlands and Duinker (1983) concluded that EEM must be well defined and focused to prevent the concept from becoming an excessive drain on time and financial resources. They noted that certain predicted changes may not require EEM and thus EEM should be concentrated on changes in those components most poorly understood or most critically in need of protection. IASMO recognizes its responsibility and is committed to the development of a focused environmental effects monitoring program in keeping with these conclusions.

IASMO has developed its EEM program carefully, following the recommendations of Barnes et al. (1985):

- The EEM program must be very conscious of the reason for and benefit of the study, and ensure that the program is scientifically practical

- EEM studies should be identified early in the EIA process, preferably during scoping, but there should be flexibility to accommodate EEM studies that are identified at a later date

- EEM studies should be designed and conducted as scientific studies; they require clear objectives and hypotheses, temporal and spatial controls, adequate duration, practical methodologies, and sufficient funding

IASMO will consider the following principles in developing its EEM Program:

- It is important to focus on valued ecosystem components of greatest ecological and social concern, and those which are least known or understood.

- Studies should be designed to allow the attribution of cause and evaluate the relative effectiveness of mitigative measures.
Studies should be designed to fill data gaps where it is required for the development of mitigative and compensatory measures.

With respect to the latter principle, the mitigation and compensation program proposed in Section 8.8 is properly termed "adaptive environmental management." Adaptive environmental management requires periodic evaluation of the status and trends of the managed system, to determine the responses of valued environmental components, along with revised projections of the potential effects of changes in actions (Salwasser and Samson 1985). It provides a mechanism for managers to make immediate use of new data and knowledge, and to further reduce the magnitude and extent of adverse interaction with project activities. IASMO recognizes the need to apply the principles of adaptive environmental management to refine and improve the effectiveness of its proposed mitigation program.

A proponent is responsible for seeing that an acceptable EEM program is carried out and for funding it. IASMO is prepared to conduct EEM studies where the information is essential for decision-making relative to the environmental acceptability of its proposal, and where it is necessary to evaluate the accuracy of predicted impacts of its proposed activities or contribute to the refinement of its mitigation program and development of a basis for compensation. However, IASMO is not prepared to conduct EEM studies which do not meet the criteria outlined in this section.

By using this focused approach to the development of the EEM program, IASMO will be able to fulfill its social role and environmental policy, by mitigating and minimizing predicted project impacts. It is clear at this time that several valued ecosystem components will require consideration for inclusion in a focused EEM program. These include, but would not necessarily be
limited to, all of those valued ecosystem components for which residual impacts are predicted to be minor or greater.

The following sections outline the studies which comprise IASMO's proposed EEM Program. For each study the requirement, objective, and responsibility are identified. The details of the program will be determined by an advisory EEM Advisory Committee, described below in Section 8.9.3.3.

8.9.3.2 Outline of Environmental Effects Monitoring Program

Commercially-Important Fish and Shellfish

Requirement. The proposed Cohasset/Panuke Development is situated within the 8600 km² DFO Fishery Statistical District 4Wf. In recent years, 4Wf has contributed only a small fraction to overall Scotian Shelf fishery landings. The most important catch in this area has been sea scallops and cod. The adjacent Districts, 4Wg and 4Wj (12,200 km² and 13,800 km², respectively), have been significantly more important to the Scotian Shelf fishery financially. In these districts, scallops, swordfish, pollock, cod, and halibut dominate the value of fish landings. Consequently, these adjacent districts are more critical than 4Wf to the Nova Scotia fishery.

During production activities, the development will discharge low levels (≤ 40 μg/L) of hydrocarbons with produced water. There have been concerns expressed that these low level discharges could potentially have toxicological or tainting effects on commercially-important fish and shellfish. Therefore, commercially important species should be the focus of a fisheries and shellfish EEM study. While it is possible to identify any incidence of toxicological abnormalities and tainting, it may not be possible to establish a cause and effect relationship with the development due to the difficulty in distinguishing project-related impacts from other potential sources. This EEM study will be necessary as an early
warning of unforeseen project-related impacts which may warrant additional or refined mitigative measures.

While it may be desirable to monitor the effects of the development on all commercially-important species, it is reasonable to select one or two species as biological indicators that are representative of the species of concern. It would be advantageous to select indicator species for which there is an existing database in the literature concerning the toxicity and tainting of the species by hydrocarbons. Scallops and a demersal fish may be good candidates in this regard. However, the species to be studied will be determined in consultation with the EEM Advisory Committee.

The spatial extent of any such study should be selected to reflect the potential extent to which project-related contamination, either through routine operations or accidental events, could be expected to extend. Sampling may be conducted along radial transects oriented in the direction of and perpendicular to the direction of current. This provides a sampling design which incorporates a "gradient to background" approach, a gradation from the point source of pollution to a point where background levels are observed.

The parameters to be tested under this program could include histopathology, mixed function oxidase induction, and bile metabolites, at the organism level, and condition index at the individual level.

Objective. The objective of the commercially-important fish and shellfish study will be to determine potential toxicological and tainting impacts to verify impact predictions, evaluate the effectiveness of mitigation, and identify the need to modify or refine the proposed mitigation strategy as appropriate.
Responsibility. IASMO will undertake to conduct such studies as may be appropriate. Any such studies undertaken will relate to the assessment of project-related impacts and the need to modify and refine mitigation as appropriate.

Physical and Chemical Parameters of Sediment

Requirement. Due to the nature of the proposed development, it is expected that there will be some minor hydrocarbon contamination of the water column and sediment in the vicinity of the facilities. A water column EEM study is not proposed because it will not be possible to isolate project-related contamination from other possible sources. Even if contamination could be linked to a project-related point source, the inference of cause and effect relationships in fish would not be possible.

IASMO feels that ECM activities to monitor compliance with effluent guidelines will ensure that unacceptable levels of contaminants are not released into the environment. In the case of an accidental event, i.e., where effluent discharge exceeds regulatory limits, there may be a need to implement a water column EEM study which meets the specific needs of the event.

In relation to the EEM studies which will investigate demersal fish and shellfish, it is necessary to conduct an investigation of the physical and chemical characteristics of sediment in the vicinity of development facilities. This study is necessary to document changes in the physical and chemical properties of sediment. This study would employ a "gradient to background" sampling methodology using radial transects, complementary to that described for demersal fish and shellfish.

Objective. The objective of the sediment EEM study will be to monitor changes in the physical and chemical parameters of the
seafloor sediment. This study will be related and complementary to the demersal and shellfish EEM studies.

Responsibility. IASMO recognizes its responsibility to conduct studies of this nature.

8.9.3.3 Implementation Strategy for EEM Studies

In developing its EEM program, IASMO has applied a focused set of principles which have enabled it to establish priorities for EEM (Section 8.9.3.1). IASMO proposes an implementation strategy which ensures that all EEM studies are conducted as scientific studies which have clear objectives and hypotheses, temporal and spatial controls, an adequate duration, practical methodologies, and sufficient funding.

IASMO will assign the responsibility for coordinating its portion of the EEM program to an Environmental Advisor. The Environmental Advisor will liaise with the Canada-Nova Scotia Offshore Petroleum Board, and other appropriate federal and provincial regulatory authorities, scientific authorities, and consultants. The Environmental Advisor will also ensure that the results of IASMO's EEM studies are reported, and that modifications to the mitigation strategy are identified and implemented.

To ensure that EEM studies satisfy the principles outlined in Section 8.9.3.1, the Environmental Advisor will prepare a terms of reference for each EEM study. To ensure that the EEM studies have terms of reference which satisfy the requirements of its EEM program, IASMO intends to establish a small, multi-disciplinary, EEM Advisory Committee. This Committee would involve the participation of impartial experts who have the advanced level of technical expertise necessary to guide the technical aspects of the proposed EEM studies. As appropriate, other regulatory agencies (e.g., Environment Canada and DFO) will be requested to review the terms of reference and final reports of the various EEM studies.
which have been developed under the guidance of the EEM Advisory Committee. The terms of reference and final reports will be submitted to CNSOPB for review and approval.

IASMO will retain the services of qualified professionals to assist in the development of terms of reference and to conduct the various EEM studies. In view of the criteria for EEM studies, the conduct of these studies will demand a high level of analytical and research capabilities.

IASMO is not the only group who will benefit from conducting this EEM program. Despite extensive plans for the development of offshore oil and gas in Atlantic Canada, should this development proceed as scheduled, it will be the first to actually be undertaken. As a consequence, a number of regulatory authorities, both federal and provincial, will obtain important management data and experience which may be applicable for the environmentally-acceptable development of future offshore oil and gas fields. This information will also be of benefit to the industry. As a consequence, IASMO is prepared to cooperate with other parties-at-interest to facilitate other research in relation to its activities.
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MARCH 7, 1990


COHASSET/PANUKE FIELD DEVELOPMENT PROJECT:
AIR EMISSIONS FROM BLOWOUTS AND OIL SPILLS

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K2P 0Y1

MARCH 1990
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<td>Hydrocarbon concentrations crosswind of a 2000 BOPD blowout</td>
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<td>Hydrocarbon concentrations downwind of an 8000 BOPD blowout</td>
</tr>
<tr>
<td>7</td>
<td>Hydrocarbon concentrations crosswind of an 8000 BOPD blowout</td>
</tr>
<tr>
<td>8</td>
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</tr>
<tr>
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</tr>
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<td>Downwind exclusion distances for operations near Cohasset/Panuke blowouts</td>
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<tr>
<td>12</td>
<td>Hydrocarbon concentrations crosswind of a 24.5 m³ batch spill</td>
</tr>
<tr>
<td>13</td>
<td>Hydrocarbon concentrations downwind of an 8000 m³ tanker spill</td>
</tr>
<tr>
<td>14</td>
<td>Hydrocarbon concentrations crosswind of an 8000 m³ tanker spill</td>
</tr>
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<td>15</td>
<td>Hydrocarbon concentrations downwind of a 31,800 m³ tanker spill</td>
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<tr>
<td>16</td>
<td>Hydrocarbon concentrations crosswind of a 31,800 m³ tanker spill</td>
</tr>
<tr>
<td>17</td>
<td>Downwind exclusion distances for first hour near Cohasset/Panuke batch or tanker spills</td>
</tr>
</tbody>
</table>
1.0 INTRODUCTION

This report is an analysis of air emissions of hydrocarbons from blowouts and oil spills from the proposed development of the Panuke and Cohasset fields off Nova Scotia. The study is a continuation of previous studies of the risk, behaviour and effects of oil spills and countermeasures for oil spills from the proposed development (S.L. Ross 1989 and 1989a) using a scenario approach.
2.0 PROPERTIES, BEHAVIOUR AND IMPACTS OF COHASSET/PANUKE OIL SPILLS

The following is a summary of the properties, predicted fate and behaviour, impacts and countermeasures for hypothetical oil spills associated with the proposed development of the Cohasset and Panuke fields.

2.1 FRESH OIL PROPERTIES

Table 1 shows the properties of the "fresh" (i.e., unweathered) Cohasset and Panuke crude oils at 1° and 15°C. Analytical procedures and results may be found in Appendix 1 of an earlier study (S.L. Ross 1989). In general both oils may be described as very light gravity crudes with very low pour points.

### TABLE 1
Properties of Fresh Cohasset and Panuke Crude Oils

<table>
<thead>
<tr>
<th>Property</th>
<th>Cohasset Temperature</th>
<th>Panuke Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1°C</td>
<td>15°C</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>800.2</td>
<td>790.0</td>
</tr>
<tr>
<td>Viscosity (mPas = cP)</td>
<td>2.79</td>
<td>2.06</td>
</tr>
<tr>
<td>Interfacial Tension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mN/m = dynes/cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air/oil</td>
<td>25.7</td>
<td>25.6</td>
</tr>
<tr>
<td>Oil/seawater</td>
<td>16.7</td>
<td>29.1</td>
</tr>
<tr>
<td>Pour Point (°C)</td>
<td>-30</td>
<td></td>
</tr>
<tr>
<td>Flash Point (°C)</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Fire Point (°C)</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>
2.2 PREDICTED SPILL BEHAVIOUR

A computer model was used to predict the behaviour of slicks of the two oils released from subsea or platform blowouts, subsea pipeline ruptures and tanker spills. Table 2 summarizes the survival times for hypothetical batch spills or survival distances for hypothetical continuous spills. Only slicks from large tanker spills have a possibility of surviving on the sea surface for any appreciable time since both oils evaporate and disperse rapidly.

Also shown in Table 2 is the total percentage of the slick predicted to be dispersed naturally (the remainder evaporates). In all the blowout and tanker spill cases a considerable volume of oil is predicted to be introduced into the water column.

Since spills of Cohasset and Panuke crude are predicted to disperse rapidly, another computer model was used to estimate the spreading and dilution of the dispersed oil plume (from blowouts) or cloud (from tanker spills). Table 3 summarizes the results of the model predictions. Dispersed oil concentrations from spills of Panuke and Cohasset crudes are predicted to be much higher than in the case of spills of more conventional crudes. Thus, the dispersed oil cloud or plume from a spill of Cohasset or Panuke crude requires significant times or distances to dilute to below 1 ppm.
<table>
<thead>
<tr>
<th>Spill Type</th>
<th>Oil</th>
<th>Slick Survival</th>
<th>Percent Naturally Dispersed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td>Average Sub-Sea Blowout</td>
<td>Cohasset</td>
<td>0.14 km</td>
<td>0.07 km</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>0.18 km</td>
<td>0.10 km</td>
</tr>
<tr>
<td>Worst-Case Sub-Sea Blowout</td>
<td>Cohasset</td>
<td>0.40 km</td>
<td>0.18 km</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>0.41 km</td>
<td>0.18 km</td>
</tr>
<tr>
<td>Average Above-Sea Blowout</td>
<td>Cohasset</td>
<td>0.83 km</td>
<td>0.49 km</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>0.87 km</td>
<td>0.49 km</td>
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<td>Worst-Case Above-Sea Blowout</td>
<td>Cohasset</td>
<td>2.25 km</td>
<td>0.77 km</td>
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<tr>
<td></td>
<td>Panuke</td>
<td>1.67 km</td>
<td>0.92 km</td>
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<tr>
<td>Average Tanker Spill</td>
<td>Cohasset</td>
<td>9.9 h</td>
<td>6.9 h</td>
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<tr>
<td></td>
<td>Panuke</td>
<td>10.7 h</td>
<td>5.9 h</td>
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<tr>
<td>Worst-Cast Tanker Spill</td>
<td>Cohasset</td>
<td>12.6 h</td>
<td>6.9 h</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>13.4 h</td>
<td>7.2 h</td>
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<tr>
<td>Intrafield Pipeline Spill</td>
<td>Panuke</td>
<td>0.46 km</td>
<td>0.18 km</td>
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<tr>
<td>Loading Line Spill</td>
<td>Cohasset</td>
<td>1.6 km</td>
<td>0.75 km</td>
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<tr>
<td></td>
<td>Panuke</td>
<td>2.0 km</td>
<td>0.82 km</td>
</tr>
<tr>
<td>Smaller Operational Spills</td>
<td>Both</td>
<td>2 hr</td>
<td>1 hr</td>
</tr>
<tr>
<td>Tanker Spills</td>
<td>Both</td>
<td>1 hr</td>
<td>0.5 hr</td>
</tr>
<tr>
<td>Small Platform Spill</td>
<td>Both</td>
<td>3 hr</td>
<td>1.5 hr</td>
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</tbody>
</table>
# TABLE 3
Summary of Dispersed Oil Cloud Spreading and Dilution

<table>
<thead>
<tr>
<th>Spill Type</th>
<th>Oil</th>
<th>Approximate Time/ Distance to Dilute to 1 ppm</th>
<th>Approximate Width/Area of Cloud at 1 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td>Average Sub-Sea Blowout</td>
<td>Cohasset</td>
<td>10 km</td>
<td>13 km</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>9 km</td>
<td>11 km</td>
</tr>
<tr>
<td>Worst-Case Sub-Sea Blowout</td>
<td>Cohasset</td>
<td>50 km</td>
<td>65 km</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>35 km</td>
<td>40 km</td>
</tr>
<tr>
<td>Average Above-Sea Blowout</td>
<td>Cohasset</td>
<td>11 km</td>
<td>14 km</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>7 km</td>
<td>9 km</td>
</tr>
<tr>
<td>Worst-Case Above-Sea Blowout</td>
<td>Cohasset</td>
<td>45 km</td>
<td>60 km</td>
</tr>
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<td></td>
<td>Panuke</td>
<td>22 km</td>
<td>25 km</td>
</tr>
<tr>
<td>Average Tanker Spill</td>
<td>Cohasset</td>
<td>60 hrs</td>
<td>90 hrs</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>50 hrs</td>
<td>70 hrs</td>
</tr>
<tr>
<td>Worst-Cast Tanker Spill</td>
<td>Cohasset</td>
<td>140 hrs</td>
<td>200 hrs</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>120 hrs</td>
<td>170 hrs</td>
</tr>
<tr>
<td>Intrafield Pipeline Spill</td>
<td>Panuke</td>
<td>6 km</td>
<td>12 km</td>
</tr>
<tr>
<td>Loading Line Spill</td>
<td>Cohasset</td>
<td>17 km</td>
<td>18 km</td>
</tr>
<tr>
<td></td>
<td>Panuke</td>
<td>13 km</td>
<td>14 km</td>
</tr>
<tr>
<td>Smaller Operational Spills</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanker Spills</td>
<td>Both</td>
<td>¼ hr</td>
<td>1 hr</td>
</tr>
<tr>
<td>Small Platform Spill</td>
<td>Both</td>
<td>0 min</td>
<td>10 min</td>
</tr>
<tr>
<td>Medium Platform Spill</td>
<td>Both</td>
<td>2 hrs</td>
<td>3 hrs</td>
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</table>
2.3 POTENTIAL SPILL IMPACTS

The potential impact on finfish and shellfish stocks and their fisheries was estimated for the hypothetical spills of Panuke and Cohasset oils. Despite model predictions of high concentrations of hydrocarbons in the water column and large areas of contamination, the risks to fish stocks and fisheries appear to be minor.

2.4 COUNTERMEASURES

The key components (S.L. Ross 1989a) of a response to a spill from the Panuke and Cohasset fields would be:

1) Tracking and surveillance to monitor dissipation of the slicks, including the deployment of tracking buoys, aerial surveillance and remote sensing and shipborne air and water column monitoring.
2) Use of chemical dispersant on slicks threatening the shores of Sable Island.
3) If the shuttle tanker calls on Canadian ports it should carry the package of equipment recommended by the Petroleum Association for the Conservation of the Canadian Environment (PACE) to deal with minor spills in port.
4) Ignition of the gas boil from sub-sea blowouts to enhance the evaporation rates of the oil.
3.0 AIR EMISSIONS MODELLING

In order to assist in determining the safety of undertaking operations near a blowout from the Panuke or Cohasset fields, the siting of relief well equipment and operating in the vicinity of batch or tanker spills of Panuke/Cohasset crude, the atmospheric dispersion of volatilized hydrocarbons (and natural gas) from such spills was modelled.

3.1 MODEL MECHANICS AND ASSUMPTIONS

The dispersion of vapours and gases from blowouts and tanker spills was modelled using a computerized version of the atmospheric dispersion equations of Turner (1970). This model expresses the concentration of gases, vapours or aerosols (particles less than about 20 um diameter) from a continuous, point-source release as a function of distance downwind (X), distance above, or below the plume centerline (Z) and distance cross-wind from the plume centerline (Y - Figure 1). The plume is assumed to have a Gaussian distribution of concentrations in any direction normal to the plume centerline; the standard deviation of this distribution in the horizontal and vertical planes is a function of atmospheric stability and distance downwind (wind speed affects the initial dilution of the emitting source and is considered in determining atmospheric stability). Other assumptions in the model are:

1) the wind speed is uniform from the surface to the mixing zone height;  
2) the emission rate is constant and continues for longer than the time for the plume to travel downwind the desired distance;  
3) total reflection of the plume occurs at the surface (i.e., no absorption or reaction);  
4) the equations are valid only for the distance downwind for the plume to spread and fill the mixing zone (from the surface to the mixing zone height).

Under these assumptions, and taking into account errors in estimates of the horizontal and vertical plume standard deviation coefficients, concentration estimates are accurate to within a factor of 3 for sampling (or exposure) times of 10 minutes or less for:
FIGURE 1 - SCHEMATIC REPRESENTATION OF AIR EMISSIONS DISPERSION MODEL FOR BLOWOUTS

ELEVATED PLUME

SURFACE PLUME

Wind Velocity $U$

$H$

$Z$

$Y$

$X$

Point Source

Plume Centerline

Mixing Zone Height (500m)

Gases Reflected
1) all stability classes for downwind distances of several hundred metres;
2) neutral to moderately unstable (A-D) classes for downwind distances of a few kilometres;
3) unstable class (A) under an inversion layer less than 1000 m high for downwind distances of 10 km or more.

For sampling (or exposure) times of greater than 10 minutes the actual concentration would be less than that predicted (mainly due to meandering of the plume in the horizontal plane). The concentration over an 8 hour period would be about ½ that predicted by the model. Because of the degree of uncertainty involved in the equations, the results are presented as predicted by the model; the errors for an 8 hour exposure could be too low by a factor of 1.5 (3 x ½) or too high by a factor of 6 (3/½).

3.2 MODEL INPUTS AND ASSUMPTIONS

3.2.1 General

In order to be conservative (i.e., err on the side of predicting too high a concentration) the following inputs to the model were assumed:

1) surface release with no initial plume rise (Figure 2);
2) mixing zone height of 500 m (range is 400-650 - Portelli 1977);
3) Panuke crude as the oil (Panuke crude is more volatile than Cohasset).

In addition, sea-level concentrations were calculated to provide conservative predictions of downwind hazard zones.

3.2.2 Blowouts

In the case of modelling the air emissions from blowouts it was further assumed that all the liquid hydrocarbons evaporated at source (the predicted at-source evaporation ranged from approximately 40% to 80%).
FIGURE 2
PICTORIAL COMPARISON OF SURFACE VERSUS PLATFORM GAS RELEASES

GAS RELEASED AT SURFACE

Air

Water

Water is boundary to downward diffusion of gas; reflection of gas to atmosphere is assumed

gas concentration distribution

GAS RELEASED FROM ELEVATED PLATFORM

Air

Water

Downward diffusion not restricted

Some reflection occurs downwind

gas concentration distribution

Plume
3.2.3 Batch and Tanker Spills

In the case of modelling the batch and tanker spills it was assumed that all the oil leaks out in one hour and all the volatiles of interest (i.e., aromatics, etc.) were evaporated in the first hour (actual total percent evaporated in the first hour is predicted to be in the 30 to 50% range) and the initial concentrations of volatiles of interest in the vapour phase are the liquid concentrations divided by the total fraction evaporated (in fact some volatiles would remain with the slick). Only the vapour generated in the first hour was modelled; subsequent evaporation would be much slower and contain little of the volatiles of interest.

In order to model the atmospheric dispersion of vapours from a slick a modification to the dispersion equations was made. Based on the cross-wind width of the slick at one hour (calculated as the square root of the slick area after 1 hour) an initial standard deviation in the horizontal axis is calculated (width/4.3). From this, a virtual distance upwind is calculated. This upwind distance, equivalent to the distance upwind that a point source would be from the area source to give the initial standard deviation (Figure 3), is used to calculate downwind horizontal dispersion. Vertical dispersion is not affected.

3.3 HUMAN EXPOSURE LIMITS

In order to define the safe approach distance to blowouts and batch or tanker spills, the "Threshold Limit Value" (TLV) for a number of volatile chemicals found in Panuke and Cohasset crudes was used. The TLV, a registered trademark of the American Conference of Governmental Industrial Hygenists, is a workplace number used as a guide to the maximum average exposure to a chemical for 8-hour days and 5 days per week. The TLV's for various volatiles found in Panuke and Cohasset crudes are given in Table 4. Also shown are the Lower Explosive Limit for crude oil vapours, the TLV for gasoline vapours (the closest analog to Panuke and Cohasset crudes that could be found) and the concentration of completely vapourized crude oil in air required for each chemical to be at a concentration equal to its TLV.
FIGURE 3 - SCHEMATIC REPRESENTATION OF AIR EMISSIONS DISPERSION MODEL FOR BATCH OR TANKER SPILLS
TABLE 4

TLV's and Concentrations of Chemicals in Panuke Crude Oil

<table>
<thead>
<tr>
<th>Chemical</th>
<th>TLV (mg/m³)*</th>
<th>Mass Fraction in Crude Oil</th>
<th>Concentration of Totally Volatilized Crude Vapours to Reach TLV (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>30</td>
<td>0.0004</td>
<td>75,000</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>1050</td>
<td>0.0201</td>
<td>52,000</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>435</td>
<td>0.0143</td>
<td>30,400</td>
</tr>
<tr>
<td>Hexane</td>
<td>180</td>
<td>0.0626</td>
<td>2875</td>
</tr>
<tr>
<td>Methane (tolerance limit)</td>
<td>700</td>
<td>0.01 (plus 0.01 for blowouts)</td>
<td>35,000</td>
</tr>
<tr>
<td>Toluene</td>
<td>375</td>
<td>0.0027</td>
<td>139,000</td>
</tr>
<tr>
<td>Xylenes</td>
<td>435</td>
<td>0.007</td>
<td>62,000</td>
</tr>
</tbody>
</table>

L.E.L.* = 65,000 mg/m³ for crude oil vapours
TLV* for gasoline vapours = 900 mg/m³

* from Environment Canada 1984
The "Short-Term Inhalation Limit" values, used as a guide to the concentration of a chemical at which respiratory and skin protection should be worn, for the chemicals in Table 4 are only 1.5 to 3 times the TLV's; taking into consideration the possible errors in estimating downwind dispersion the TLV's should be used as limits for personal protective equipment.

3.4 MODEL RESULTS FOR BLOWOUTS

Figure 4 shows the calculated decrease in plume centerline total hydrocarbon concentration in air at the water surface with downwind distance for a 2000 BOPD blowout. Families of curves are given for stability classes A (unstable), D (neutral), and F (stable). Four wind speeds are plotted for stability class D; only the lowest two are shown for stability classes A and F (these classes cannot exist at the higher wind speeds). Also shown on the y axes are the L.E.L., the TLV for gasoline and the total hydrocarbon concentrations in air required to reach the TLV's for the individual chemicals listed in Table 4.

In low wind conditions the TLV for gasoline would be exceeded up to 400 m downwind of the blowout in neutral stability conditions and up to 800 m downwind in stable conditions. No explosion hazard would exist 100 m or more downwind of the blowout. In calm wind conditions the gases and vapours would likely form a mushroom-shaped cloud in the vicinity of the blowout, with a high fire/explosion potential and unpleasant conditions near the site. No operations should be carried out near the site under calm conditions.

Figure 5 shows the crosswind total hydrocarbon concentrations in air at various distances downwind of a 2000 BOPD blowout of Panuke crude oil in a 7 m/s wind in a neutrally stable atmosphere (D). At a distance of 100 m downwind the plume is some 50 m wide and the TLV's for hexane and gasoline are exceeded; 500 m downwind the plume has spread to 100 m wide and the maximum total hydrocarbon concentration in the air has dropped to approximately 200 mg/m³ (30 ppm). The plume width would be narrower and the peak concentrations higher in lower wind speeds and in more stable atmospheric conditions (i.e., Class F); the plume width would be greater and the peak concentrations lower in higher wind speeds and in less stable atmospheric conditions (i.e., Class A).
FIGURE 4
HYDROCARBON CONCENTRATIONS DOWNWIND OF A 2000 BOPD BLOWOUT

TOTAL HYDROCARBONS IN AIR (mg/m³)

LEGEND
- WIND = 3 m/s
- WIND = 7 m/s
- WIND = 11 m/s
- WIND = 15 m/s

DISTANCE DOWNWIND (m)

0 100 1000 10,000

CLASS A
CLASS D
CLASS F

L.E.L.

Toluene TLV
Benzene TLV
Xylenes TLV
Cyclohexane TLV
Ethylbenzene TLV
Hexane TLV
Gasoline TLV
FIGURE 5
HYDROCARBON CONCENTRATIONS CROSS WIND OF A 2000 BOPD BLOWOUT

(WIND SPEED = 7m/s; STABILITY CLASS = "D")

LEGEND

- 100 m DOWNWIND
- 500 m DOWNWIND

- Toluene TLV
- Benzene TLV
- Xylenes TLV
- Cyclohexane TLV
- Ethylbenzene TLV
- Hexane TLV
- Gasoline TLV

TOTAL HYDROCARBONS IN AIR (mg/m^3) = \( \text{ppm} \times 0.154 \)

DISTANCE CROSS-WIND FROM PLUME CENTRELINE (m)
Figure 6 shows the downwind total hydrocarbon concentrations at the sea surface along the plume centerline for an 8000 BOPD blowout of Panuke crude oil. In stable atmospheric conditions (Class F) the L.E.L. could be exceeded up to about 150 m downwind. The TLV for gasoline would be exceeded in light winds 200 m downwind in unstable conditions (Class A), 800 m downwind in neutral conditions (Class D) and 2 km downwind in stable conditions (Class F). Under calm conditions no operations should be carried out near the site.

Figure 7 shows the crosswind total hydrocarbon concentrations in air for the 8000 BOPD blowout in a 7 m/s wind in neutral conditions (Class D). By 500 m downwind the plume has spread to 150 m wide; by 1000 m downwind the plume width has increased to almost 200 m. By 1500 m downwind the peak concentration is on the order of 150 mg/m³ (23 ppm).

Figure 8 shows the downwind total hydrocarbon concentrations (plume centerline at the surface) for a 12,600 BOPD blowout of Panuke crude. In stable atmospheric conditions (Class F) in light winds the L.E.L. could be exceeded up to 200 m downwind and the TLV for gasoline could be exceeded up to 3 km downwind. In light winds and a neutral atmosphere (Class D) the TLV for gasoline would be exceeded up to 1 km downwind; in light winds and an unstable atmosphere (Class A) the TLV for gasoline would be exceeded up to 250 m downwind. No operations should be conducted near the site in calm winds.

Figure 9 shows the cross-wind total hydrocarbon concentrations predicted for a 12,600 BOPD blowout in a 7 m/s wind and a neutral atmosphere (Class D). By 1500 m downwind the plume is some 250 m wide with a peak total hydrocarbon concentration of 200 mg/m (30 ppm).
FIGURE 6
HYDROCARBON CONCENTRATIONS DOWNWIND OF AN 8000 BOPD BLOWOUT

LEGEND
- WIND = 3 m/s
- WIND = 7 m/s
- WIND = 11 m/s
- WIND = 15 m/s

TOTAL HYDROCARBONS IN AIR (mg/m³)
(ppm = mg/m³ x 0.154)

DISTANCE DOWNWIND (m)
FIGURE 7
HYDROCARBON CONCENTRATIONS' CROSS WIND OF AN 8000 BOPD BLOWOUT

(WIND SPEED = 7 m/s; STABILITY CLASS = "D")

LEGEND
- 100 m DOWNWIND
- 500 m DOWNWIND
- 1000 m DOWNWIND
- 1500 m DOWNWIND

TOTAL HYDROCARBONS IN AIR (mg/m³)

DISTANCE CROSS-WIND FROM PLUME CENTRELINE (m)

- Toluene TLV
- Benzene TLV
- Xylenes TLV
- Cyclohexane TLV
- Ethylbenzene TLV
- Hexane TLV
- Gasoline TLV
FIGURE 8
HYDROCARBON CONCENTRATIONS DOWNWIND OF A 12,600 BOPD BLOWOUT

TOTAL HYDROCARBONS IN AIR (mg/m$^3$)$ \times 0.154$

LEGEND
- WIND = 3 m/s
- WIND = 7 m/s
- WIND = 11 m/s
- WIND = 15 m/s

CLASS F
CLASS D
CLASS A

DISTANCE DOWNWIND (m)

TOluene TLV
Benzene TLV
Hexane TLV
Cyclohexane TLV
Methane threshold
Ethylbenzene TLV
Gasoline TLV
FIGURE 9
HYDROCARBON CONCENTRATIONS CROSS WIND OF A 12,600 BOPD BLOWOUT

(WIND SPEED = 7m/s; STABILITY CLASS = "D")

LEGEND
- 100 m DOWNWIND
- 500 m DOWNWIND
- 1000 m DOWNWIND
- 1500 m DOWNWIND

- Toluene TLV
- Benzene TLV
- Xylenes TLV
- Cyclohexane TLV
- Ethylbenzene TLV
- Methane threshold
- Hexane TLV
- Gasoline TLV

TOTAL HYDROCARBONS IN AIR (mg/m³)

(1 ppm = mg/m³ × 0.154)

DISTANCE CROSS-WIND FROM PLUME CENTRELINE (m)
3.5 IMPLICATIONS FOR OPERATIONS NEAR BLOWOUTS

In order to determine safe working zones or exclusion zones downwind of a blowout, the distance for the total hydrocarbon concentration in the air at the sea surface along the plume centerline to drop below the L.E.L., the TLV and 1 hour LC_{10}¹ for gasoline (2700 mg/m³) was plotted against blowout rate. In order to be conservative only light winds (3 m/s) and stable atmospheric conditions were assumed (in higher winds and less stable conditions much shorter distances would be predicted). The results are shown on Figure 10.

For concentrations higher than the 1 hour LC_{10} for gasoline, air-supplied respiratory protection (i.e., Self-Contained Breathing Apparatus) and skin protective clothing would be required. For concentrations between the 1 hour LC_{10} and the TLV for gasoline, simple respiratory (i.e., cartridge gas masks) and skin protection is required.

For blowouts in the 2000 BOPD size range operations without protective gear would be possible about 1 km directly downwind of the site; for blowouts in the 10,000 BOPD size range this increases to 2.5 km downwind. It should be noted that the plume is predicted to be only a few hundred metres wide.

Vessels and aircraft should always approach the site from upwind and be prepared to move quickly to avoid the plume in the event of a wind change. Relief well location should take into account both downwind plume dispersion and prevailing winds (the best relief well location would be no closer than 200-300 m away from the blowout and in the direction that the wind comes from the most).

¹ the lowest concentration of gasoline vapours inhaled that has caused a mortality.
FIGURE 10
DOWNWIND EXCLUSION DISTANCES FOR OPERATIONS NEAR COHASSET/PANUKE BLOWOUTS
(based on light winds and stable conditions – class F)

- Air-supplied respiratory protection required
- Respiratory and skin protection required
- No protection required for 8 hr workdays

BLOWOUT RATE (BOPD)

10,000
12,000
14,000

DISTANCE DOWNWIND (m) (along plume centreline)

0
500
1000
1500
2000
2500
3000

TLV for Gasoline

1 hr LCI₀ for Gasoline

Lower Explosive Limit

Explosive Limit

1 hr TLV for Gasoline

0-10,000: Lower respiratory and skin protection required
10,000-12,000: Respiratory protection required
12,000-14,000: No protection required for 8 hr workdays

Having trouble understanding? Let me know if you'd like a more detailed explanation or another diagram. I'm here to help!
3.6 MODEL RESULTS FOR BATCH AND TANKER SPILLS

Figure 11 shows the predicted total hydrocarbon concentrations downwind of a 24.5 m³ batch spill of Panuke crude oil within one hour of the spill. The concentrations are at the sea surface along the plume centerline. Also shown are the total hydrocarbon concentrations required for the various chemical species to be at concentrations in the vapour equalling their TLV (calculated by dividing each chemicals TLV by its mass fraction in the liquid - see Table 4 - and by the total fraction evaporated in the first hour - in this case 50%). The L.E.L. for crude oil vapours and the TLV for gasoline are also shown.

In the first hour after a 24.5 m³ batch spill in light winds the TLV for gasoline is exceeded only within 200 m of the slick in stable conditions (Class F) and within less than 100 m in neutral conditions (Class D). In subsequent hours the concentrations of hydrocarbons downwind would be about one tenth of those in the first hour; 50% of the oil evaporates in the first hour (likely containing most of the volatiles listed on the graph) - in the second hour only 5% more evaporates.

Figure 12 shows the total hydrocarbon concentrations cross-wind of the plume centerline for the 24.5 m³ spill (with a slick width of about 200 m after one hour) in neutral atmospheric conditions (Class D) and a 7 m/s wind.

Figure 13 shows the hydrocarbon concentrations downwind of an 8000 m³ tanker spill (occurring in one hour). Because a large volume of vapour (32% of the liquid = 2550 m³ of liquid = 1.8 x 10⁶ kg = 2.8 x 10⁵ m³ of vapour) is released over a short time period (1.8 x 10⁶ kg/1 hr = 5 x 10⁵ g/s) initial hydrocarbon concentrations are relatively high; because the release area is large (4.25 km² = 2 km wide) these concentrations decrease with distance (i.e., time) much more slowly than for a point source. The L.E.L. is not exceeded more than 100m downwind. In light winds (3 m/s) the hydrocarbon concentrations would not fall below the TLV for gasoline for more than 10 km downwind in stable atmospheric conditions (Class F); in 5 km in neutral atmospheric conditions (Class D) and in 500 m in unstable atmospheric conditions. It should be noted that this refers only to the first hour after the spill when most of the volatiles are lost; between the first and second hour after the spill an
FIGURE 11

HYDROCARBON CONCENTRATIONS DOWNWIND OF A 24.5 m³ BATCH SPILL

Legend:
- Toluene TLV
- Benzene TLV
- Xylenes TLV
- Cyclohexane TLV
- Ethylbenzene TLV
- Hexane TLV
- Gasoline TLV
- Methane threshold

CLASS A

CLASS D

CLASS F

LEGEND
- WIND = 3 m/s
- WIND = 7 m/s
- WIND = 11 m/s
- WIND = 15 m/s

TOTAL HYDROCARBONS IN AIR (mg/m³)

100,000
10,000
1000
100

DISTANCE DOWNWIND (m)

CLASS A

CLASS D

CLASS F

(100, 1000) (1000, 100) (10,000, 1000)
FIGURE 12
HYDROCARBON CONCENTRATIONS CROSS WIND OF A 24.5 M$^3$ BATCH SPILL

(WIND SPEED = 7 m/s; STABILITY CLASS = "D")

LEGEND

- 100 m DOWNWIND
- - - - 200 m DOWNWIND
- - - - - - 300 m DOWNWIND

TOTAL HYDROCARBONS IN AIR (mg/m$^3$ x 0.154)

L.E.L.

100,000

10,000

1,000

100

DISTANCE CROSS-WIND FROM PLUME CENTRELINE (m)

150

100

50

0

-50

-100

-150

100 m DOWNWIND
200 m DOWNWIND
300 m DOWNWIND

Toluene TLV
Benzene TLV
Xylenes TLV
Cyclohexane TLV
Methane threshold
Ethylbenzene TLV
Hexane TLV
Gasoline TLV
FIGURE 13
HYDROCARBON CONCENTRATIONS DOWNWIND OF AN 8000 M³ TANKER SPILL

LEGEND
- WIND = 3 m/s
- WIND = 7 m/s
- WIND = 11 m/s
- WIND = 15 m/s

Toluene TLV
Benzene TLV
Xylenes TLV
Cyclohexane TLV
Ethylbenzene TLV
Hexane TLV
Gasoline TLV

TOTAL HYDROCARBONS IN AIR (mg/m³)
(ppm = mg/m³ x 0.154)

DISTANCE DOWNWIND (m)
additional 450 m$^3$ of liquid evaporate, an evaporation rate one fifth of that in the first hour. The vapour in the second hour likely contains very little of the chemicals of concern listed in Table 4.

Figure 14 shows the surface hydrocarbon concentrations crosswind of the plume centerline for an 8000 m$^3$ tanker spill. The wind speed is 7 m/s and a neutral atmosphere (Class D) was used. The plume is quite wide (about 3 km 100 m downwind of the slick that is 2 km wide). By 1000 m downwind the TLV for hexane and gasoline is still exceeded for approximately 500 m either side of the plume centerline. Ten kilometres downwind, concentrations of hydrocarbons in the air at the surface exceed 100 mg/m$^3$ (15 ppm) 1 km either side of the plume centerline.

Figure 15 shows the surface hydrocarbon concentrations in air, along the plume centerline, downwind of a 31,800 m$^3$ tanker spill (released within one hour). The very large amounts of vapour released (9805 m$^3$ of liquid = 7 x $10^6$ kg = 1 x $10^6$ m$^3$ of vapour) over a large area (1.5 km$^2$ = 4 km wide) in a short time (1 hours = 1.9 x $10^6$ g/s) result in a large, slowly dispersing cloud. The L.E.L. would be exceeded for about 200 m downwind only in light winds in a stable atmosphere (Class F).

In light winds (3 m/s) the concentrations of hydrocarbons in the air would not fall below the TLV for gasoline for 90 km in stable atmospheric conditions (Class F); for 20 km in neutral atmospheric conditions (Class D) and for 800 m in unstable atmospheric conditions (Class A). In the second hour after the spill, evaporation rates are predicted to be one fifth that in the first hour; most of the chemicals of concern would evaporate in the first hour.

Figure 16 shows the crosswind hydrocarbon concentrations at the surface in a 7 m/s wind with a neutral atmosphere (Class D). One hundred metres downwind of the slick the plume is predicted to be some 6 km wide (the slick is 4 km wide); 1 km downwind, the TLV for gasoline is exceeded for a distance of 1.5 km on either side of the plume centerline. Ten kilometres downwind of the slick the peak concentration in the plume has dropped below the TLV for gasoline; for a distance of 2.5 km either side of the plume centerline the hydrocarbon concentrations in air exceed 100 mg/m$^3$ (15 ppm).
FIGURE 14
HYDROCARBON CONCENTRATIONS CROSS WIND OF AN 8000 M$^3$ TANKER SPILL

(WIND SPEED = 7 m/s; STABILITY CLASS = "D")

LEGEN

- 100 m DOWNWIND
- 1000 m DOWNWIND
- 5000 m DOWNWIND
- 10,000 m DOWNWIND

TOTAL HYDROCARBONS IN AIR (mg/m$^3$)

(ppm = mg/m$^3$ x 0.154)

DISTANCE CROSS-WIND FROM PLUME CENTRELNE (km)
FIGURE 15
HYDROCARBON CONCENTRATIONS DOWNWIND OF A 31,800 m$^3$ TANKER SPILL

LEGEND
- WIND = 3 m/s
- WIND = 7 m/s
- WIND = 11 m/s
- WIND = 15 m/s

TOTAL HYDROCARBONS IN AIR (mg/m$^3$) (ppm = mg/m$^3$ x 0.154)

DISTANCE DOWNWIND (m)

Toluene TLV
Benzene TLV
Cyclohexane TLV
Ethylbenzene TLV

CLASS A
CLASS D
CLASS F
FIGURE 16
HYDROCARBON CONCENTRATIONS CROSS WIND OF A 31,800 m$^3$ TANKER SPILL

(WIND SPEED = 7m/s; STABILITY CLASS = "D")

LEGEND
- 100 m DOWNWIND
- 1000 m DOWNWIND
- 5000 m DOWNWIND
- 10,000 m DOWNWIND

TOTAL HYDROCARBONS IN AIR (mg/m$^3$)

TOTAL HYDROCARBONS IN AIR (mg/m$^3$) × 0.154

DISTANCE CROSS-WIND FROM PLUME CENTRELINE (km)

LEGEND
- Toluene TLV
- Benzene TLV
- Ethylbenzene TLV
- Cyclohexane TLV
- Xylenes TLV
- Methane threshold
- Hexane TLV
- Gasoline TLV
3.7 IMPLICATIONS FOR OPERATIONS NEAR BATCH AND TANKER SPILLS

Figure 17 shows the predicted downwind distances for the plume centerline concentrations of hydrocarbons in air at the surface to fall below the L.E.L., 1 hour LC_{10} for gasoline and TLV for gasoline as a function of spill size. The predictions are based on conservative dispersion conditions (light winds (3 m/s) and stable atmospheric conditions) and are for the first hour after the spill only (Distances for subsequent times would be much less).

Only very large (and improbable) spills (greater than 10,000 m³ = 63,000 bbls) pose an explosion risk downwind (operations in the slick should not be considered until the flash point of the oil has increased to well above ambient temperatures - 1 hour for uncontained, 1 cm thick slicks; 12+ hours for contained slicks with thicknesses greater than 10 cm - S.L. Ross 1989a).

The curve for the 1 hour LC_{10} for gasoline indicates that, in the first hour after the release, the hazard zone would be less than 100 m downwind for spills less than 100 m³ (630 bbls); for spills in the 100 to 1000 m³ size range the hazard zone would be up to a kilometre downwind. Spills in the 1000 - 10,000 m³ size range could create hazard zones up to 5km downwind; spills in the 10,000 - 32,000 m³ size range could create hazard zones up to 20km downwind over the first hour. It should be noted that these are conservative hazard zone estimates; in average summer conditions (7 m/s wind and assuming stability Class D) the hazard zone, based on the 1 hour LC_{10} for gasoline would be: 150 m for spills of 1000 m³, 500 m for spills of 1000 m³, and 1 km for a 31,800 m³ spill.

No person should operate on the surface in the area downwind of a batch or tanker spill of Panuke/Cohasset crude in the first hour without air-supplied respiratory protection and skin protection. Consideration should be given to locating the storage tanker in a direction such that it is crosswind from the production platform based on prevailing winds.
FIGURE 17
DOWNWIND EXCLUSION DISTANCES FOR FIRST HOUR NEAR COHASSET/PANUKE BATCH OR TANKER SPILLS
(based on light winds and stable conditions — class F)

- Lower Explosive Limit
- 1 hr LC₁₀ for Gasoline
- TLV for Gasoline

SPILL SIZE (m³)

DISTANCE DOWNWIND (km)

(along plume centreline)
4.0 SUMMARY AND RECOMMENDATIONS

4.1 SUMMARY

Air emissions from blowouts in average wind conditions would not create a health hazard except for a few metres directly downwind of a blowout at the Panuke or Cohasset well sites; the explosion zone from such blowouts would extend less than one hundred metres directly downwind. In light winds and stable atmospheric conditions the hazard zone could extend (depending on the size of the blowout) between two and three kilometres directly downwind of a blowout and the explosion zone could extend up to 200 m downwind.

Air emissions from small batch or tanker spills (less than 100 m$^3$ in volume) would not create a health hazard except for within a few hundred metres directly downwind of the slick within one hour of its release. Air emissions from large batch or tanker spills of the volatile Panuke and Cohasset crude oils could create significant hazard zones within one hour of their release directly downwind.

4.2 RECOMMENDATIONS

1. Vessels and aircraft should always approach the site of a blowout from upwind and be prepared to move quickly to avoid the plume in the event of a wind change. No one should approach a blowout in calm conditions.

2. Relief well location should take into account both downwind plume dispersion and prevailing winds (the best relief well location would be no closer than 200-300 m away from the blowout and upwind, based on the prevailing wind direction).

3. For blowouts in the 2000 BOPD size range in light winds, operations without protective gear would be possible about 1 km directly downwind of the site; for blowouts in the 10,000 BOPD size range this increases to 2.5 km downwind. It should be noted that the plume is predicted to be only a few hundred metres wide.
4. For concentrations higher than the 1 hour LCₘₐₓ for gasoline, air-supplied respiratory protection (i.e., Self-Contained Breathing Apparatus) and skin protective clothing would be required. For concentrations between than the 1 hour LCₘₐₓ and the TLV for gasoline, simple respiratory (i.e., cartridge gas masks) and skin protection are required.

5. No operations should be conducted in a batch or tanker spill oil slick until the flash point of the Panuke/Cohasset oil has increased to well above ambient temperatures (one hour for 1 cm thick, uncontained slicks; 12+ hours for contained slicks with thicknesses greater than 10 cm).

6. No person should operate on the surface in the area downwind of a batch or tanker spill of Panuke/Cohasset crude in the first hour without air-supplied respiratory protection and skin protection.

7. Consideration should be given to locating the storage tanker in a direction such that it is crosswind from the production platform based on prevailing winds.
COHASSET/PANUKE FIELD DEVELOPMENT PROJECT:
COUNTERMEASURES FOR OIL SPILLS

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DECEMBER 1989
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1.0 INTRODUCTION

This report is an analysis of offshore countermeasures for oil spills from the proposed development of the Panuke and Cohasset fields off Nova Scotia. The study is an extension of, and builds on a previous study of the risk, behaviour and effects of oil spills from the proposed development (S.L. Ross 1989) using a scenario approach.
2.0 PROPERTIES, BEHAVIOUR AND IMPACTS OF COHASSET/PANUKE OIL SPILLS

The following is a summary of the properties and predicted fate and behaviour of hypothetical oil spills associated with the proposed development of the Cohasset and Panuke fields.

2.1 FRESH OIL PROPERTIES

Table 1 shows the properties of the "fresh" (i.e., unweathered) Cohasset and Panuke crude oils at 1° and 15°C. Analytical procedures and results may be found in Appendix I of an earlier study (S.L. Ross 1989). In general both oils may be described as very light gravity crudes with very low pour points.

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>COHASSET</th>
<th>PANUKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMPERATURE</td>
<td>1°C</td>
<td>15°C</td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td>1°C</td>
<td>15°C</td>
</tr>
<tr>
<td>DENSITY (kg/m³)</td>
<td>800.2</td>
<td>790.0</td>
</tr>
<tr>
<td>VISCOSITY (mPas = cP)</td>
<td>2.79</td>
<td>2.06</td>
</tr>
<tr>
<td>INTERFACIAL TENSION (mN/m = dynes/cm)</td>
<td>25.7</td>
<td>25.6</td>
</tr>
<tr>
<td>Air/oil</td>
<td>23.8</td>
<td>23.7</td>
</tr>
<tr>
<td>Oil/seawater</td>
<td>16.7</td>
<td>29.1</td>
</tr>
<tr>
<td>POUR POINT (°C)</td>
<td>-30</td>
<td>-36</td>
</tr>
<tr>
<td>FLASH POINT (°C)</td>
<td>32</td>
<td>-30</td>
</tr>
<tr>
<td>FIRE POINT (°C)</td>
<td>36</td>
<td>-30</td>
</tr>
</tbody>
</table>
2.2 PREDICTED SPILL BEHAVIOUR

A computer model was used to predict the behaviour of slicks of the two oils released from subsea or platform blowouts, subsea pipeline ruptures and tanker spills. Table 2 summarizes the survival times for hypothetical batch spills or survival distances for hypothetical continuous spills. Only slicks from large tanker spills have a possibility of surviving on the sea surface for any appreciable time since both oils evaporate and disperse rapidly.

Also shown in Table 2 is the total percentage of the slick predicted to be dispersed naturally (the remainder evaporates). In all the blowout and tanker spill cases a considerable volume of oil is predicted to be introduced into the water column.

The exceptional evaporation and natural dispersion rates of the Cohasset and Panuke crudes are illustrated in Figure 1 which compares the predicted behaviour and fate of a 31,800 m\(^3\) tanker spill of Cohasset crude with the prediction for an identical spill involving Prudhoe Bay crude. The Cohasset spill is predicted to dissipate in about 13 hours; the equivalent Prudhoe Bay crude spill is predicted to survive for more than 4 weeks.

Since spills of Cohasset and Panuke crude are predicted to disperse rapidly, another computer model was used to estimate the spreading and dilution of the dispersed oil plume (from blowouts) or cloud (from tanker spills). Table 3 summarizes the results of the model predictions. Dispersed oil concentrations from spills of Panuke and Cohasset crudes are predicted to be much higher than in the case of spills of more conventional crudes. Thus, the dispersed oil cloud or plume from a spill of Cohasset or Panuke crude requires significant times or distances to dilute to below 1 ppm.
# TABLE 2

Summary of Surface Slick Survival Times for Spill Scenarios

<table>
<thead>
<tr>
<th>SPILL TYPE</th>
<th>OIL</th>
<th>SLICK SURVIVAL</th>
<th>PERCENT NATURALLY DISPERSED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SUMMER</td>
<td>WINTER</td>
</tr>
<tr>
<td>AVERAGE SUB-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>0.14 km</td>
<td>0.07 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>0.18 km</td>
<td>0.10 km</td>
</tr>
<tr>
<td>WORST-CASE SUB-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>0.40 km</td>
<td>0.18 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>0.41 km</td>
<td>0.18 km</td>
</tr>
<tr>
<td>AVERAGE ABOVE-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>0.83 km</td>
<td>0.49 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>0.87 km</td>
<td>0.49 km</td>
</tr>
<tr>
<td>WORST-CASE ABOVE-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>2.25 km</td>
<td>0.77 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>1.67 km</td>
<td>0.92 km</td>
</tr>
<tr>
<td>AVERAGE TANKER SPILL</td>
<td>COHASSET</td>
<td>9.9 h</td>
<td>6.9 h</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>10.7 h</td>
<td>5.9 h</td>
</tr>
<tr>
<td>WORST-CASE TANKER SPILL</td>
<td>COHASSET</td>
<td>12.6 h</td>
<td>6.9 h</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>13.4 h</td>
<td>7.2 h</td>
</tr>
<tr>
<td>INTRAFIELD PIPELINE SPILL</td>
<td>PANUKE</td>
<td>0.46 km</td>
<td>0.18 km</td>
</tr>
<tr>
<td>LOADING LINE SPILL</td>
<td>COHASSET</td>
<td>1.6 km</td>
<td>0.75 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>2.0 km</td>
<td>0.82 km</td>
</tr>
<tr>
<td>SMALLER OPERATIONAL SPILLS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TANKER SPILLS</td>
<td>BOTH</td>
<td>2 hr</td>
<td>1 hr</td>
</tr>
<tr>
<td>SMALL PLATFORM SPILL</td>
<td>BOTH</td>
<td>1 hr</td>
<td>0.5 hr</td>
</tr>
<tr>
<td>MEDIUM PLATFORM SPILL</td>
<td>BOTH</td>
<td>3 hr</td>
<td>1.5 hr</td>
</tr>
</tbody>
</table>
### TABLE 3
Summary of Dispersed Oil Cloud Spreading and Dilution

<table>
<thead>
<tr>
<th>SPILL TYPE</th>
<th>OIL</th>
<th>APPROXIMATE TIME/DISTANCE TO DILUTE TO 1 ppm</th>
<th>APPROXIMATE WIDTH/AREA OF CLOUD AT 1 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SUMMER</td>
<td>WINTER</td>
<td>SUMMER</td>
</tr>
<tr>
<td>AVERAGE SUB-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>10 km</td>
<td>13 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>9 km</td>
<td>11 km</td>
</tr>
<tr>
<td>WORST-CASE SUB-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>50 km</td>
<td>65 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>35 km</td>
<td>40 km</td>
</tr>
<tr>
<td>AVERAGE ABOVE-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>11 km</td>
<td>14 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>7 km</td>
<td>9 km</td>
</tr>
<tr>
<td>WORST-CASE ABOVE-SEA BLOWOUT</td>
<td>COHASSET</td>
<td>45 km</td>
<td>60 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>22 km</td>
<td>25 km</td>
</tr>
<tr>
<td>AVERAGE TANKER SPILL</td>
<td>COHASSET</td>
<td>60 hrs</td>
<td>90 hrs</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>50 hrs</td>
<td>70 hrs</td>
</tr>
<tr>
<td>WORST-CASE TANKER SPILL</td>
<td>COHASSET</td>
<td>140 hrs</td>
<td>200 hrs</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>120 hrs</td>
<td>170 hrs</td>
</tr>
<tr>
<td>INTRAFIELD PIPELINE SPILL</td>
<td>PANUKE</td>
<td>6 km</td>
<td>12 km</td>
</tr>
<tr>
<td>LOADING LINE SPILL</td>
<td>COHASSET</td>
<td>17 km</td>
<td>18 km</td>
</tr>
<tr>
<td></td>
<td>PANUKE</td>
<td>13 km</td>
<td>14 km</td>
</tr>
<tr>
<td>SMALLER OPERATIONAL SPILLS</td>
<td>TANKER SPILLS</td>
<td>BOTH</td>
<td>¾ hr</td>
</tr>
<tr>
<td></td>
<td>SMALL PLATFORM SPILL</td>
<td>BOTH</td>
<td>0 min</td>
</tr>
<tr>
<td></td>
<td>MEDIUM PLATFORM SPILL</td>
<td>BOTH</td>
<td>2 hrs</td>
</tr>
</tbody>
</table>
2.3 POTENTIAL SPILL IMPACTS

The potential impact on finfish and shellfish stocks and their fisheries was estimated for the hypothetical spills of Panuke and Cohasset oils. Despite model predictions of high concentrations of hydrocarbons in the water column and large areas of contamination, the risks to fish stocks and fisheries appear to be minor.
3.0 POTENTIAL COUNTERMEASURES

This section reviews the potential effectiveness of countermeasures for spills of Cohasset/Panuke crudes in terms of minimizing potential impacts. The key factors determining the potential effectiveness are the crude oils' high volatility and tendency to disperse naturally at high rates.

3.1 TRACKING AND SURVEILLANCE

The tracking and surveillance of oil spills at sea is crucial to effective and timely countermeasures to reduce impacts. For spills from the Cohasset/Panuke development there are three levels of effort that should be addressed: short-term tracking of small, "operational" spills; computer trajectory modelling of spills and; aerial and shipborne surveillance of large spills.

3.1.1 Tracking Buoys

At least six ORION or NOVATECH radio transmitting spill tracking buoys should be available on-site to be deployed in smaller slicks resulting from "operational" spills. These devices aid in locating slicks during and after periods of darkness and poor visibility and can be valuable in helping confirm that all oil has disappeared from the sea surface by locating the approximate area where the slick should be. Both shipborne and helicopter receiver units should be available for surveillance operations.

3.1.2 Computer Trajectory Model

A computerized trajectory model (incorporating at least residual current and wind drift, evaporation and natural dispersion components) should be rapidly available to the On-Scene Commander. This model should be able to predict the drift and survival time of surface slicks for all spills from the proposed development as well as the dispersion and dilution of the dispersed oil cloud from slicks. The inputs to the model
should be as simple as possible (i.e., wind speed and direction and time) and based on the properties of the Cohasset and Panuke crudes detailed in the previous report (S.L. Ross 1989). The outputs from the model should be graphic as well as tabular to allow quick and easy interpretation of results. The model should be capable of being updated and revised in a quick and simple manner based on data from the site and surveillance activities. A radius of coverage of 100 km around the fields should be sufficient to model even the largest spills, because the oils are expected to disperse naturally at a very high rate.

3.1.3 Aerial and Shipborne Surveillance

In the event of a major spill, such as a blowout or tanker spill, it will be necessary to mount a large surveillance and monitoring program. This should involve at least the following components:

Aerial Remote Sensing

An aircraft fitted with either the Esso Simple Remote Sensing System or a sensor package similar to that carried by the Canada Centre for Remote Sensing aircraft should be available on short notice to track and document the drift and dissipation of slicks from large spills.

Shipborne Air Monitoring

A vessel, positioned near a blowout, should have equipment to monitor the concentrations of gas and/or oil aerosol downwind of the blowout in order to confirm safe—approach distances. The equipment could range in complexity from a simple explosimeter to remotely—controlled vehicles carrying sensor packages.
Shipborne Water-Column Monitoring

A vessel, equipped with a towed fluorometer and appropriate sampling and analytical equipment, should remain in the vicinity of the slick to determine and document the concentrations, drift and dilution of dispersed oil from a spill.

3.2 CONTAINMENT AND RECOVERY

Personnel safety is paramount in all oil spill containment and recovery operations. The threat of fire and/or explosion during such operations is always a concern. Since both the Cohasset and Panuke crude oils are highly volatile, an analysis of the change in flash and fire points of the oils with evaporation was carried out. Figure 2 shows the increase in flash and fire point as a function of evaporative exposure. Also shown on the abscissa are the equivalent times for 1 cm thick and 10 cm thick slicks in a 5 m/s wind at 15°C. The 1 cm thickness represents that which would be expected on the water shortly after a large tanker spill and 10 cm represents the minimum thickness of oil in the pocket of containment boom offshore.

Applying a safety factor of 20°C above ambient temperatures, the data on Figure 2 suggest that it would not be safe to approach a slick of Cohasset/Panuke crude oil until at least an hour after it is spilled, and that even if it could be safely contained and thickened for mechanical recovery it would not be safe to deploy a skimmer into contained Cohasset/Panuke crude for at least 12 – 24 hours, a length of time over which it is unreasonable to expect that the oil could be held.

Luckily, the Cohasset/Panuke crude oil disperses naturally at a very high rate, and is unlikely to survive on the sea surface as a slick for more than a few hours and thus is unlikely to approach the nearest land, Sable Island.

Because the slicks are thin and thus evaporate rapidly, there would be little danger of fire and/or explosion associated with slicks from blowouts at the Cohasset and Panuke locations; moreover, these slicks are predicted to disperse within a few minutes of their release. Containment and recovery operations for blowouts would
FIGURE 2
EFFECT OF EVAPORATION ON FLASH AND FIRE POINT

FLASH or FIRE POINT (°C)

- Summer Temperature
- Winter Temperature

LEGEND
- Flash Point
- Fire Point
- PANUKE F-99
- COHASSET A-52

EVAPORATIVE EXPOSURE (θ = kt/x)

EQUIVALENT TIME (min) FOR A 1 cm THICK SLICK IN A 5 m/s WIND @ 15°C

EQUIVALENT TIME (min) FOR A 10 cm THICK SLICK IN A 5 m/s WIND @ 15°C
likely only encounter a small fraction of the oil released and, as was the case at the Vinland/Uniacke blowout, are not justified from a perspective of reducing the environmental impact.

The shuttle tanker, if it is to be in domestic trade, should carry the package of equipment recommended for Canadian tankers (reproduced in Appendix 1) by the Petroleum Association for the Conservation of the Canadian Environment (PACE 1981). This package consists of the following items, presumably for initial response to smaller spills in relatively calm waters:

* a workboat with a 40 HP motor for boom tending
* lightweight containment boom in 50 ft. sections totalling 1.5 ship lengths
* portable pump (explosion proofed)
* 100 ft. of 3-inch suction hose for pump (two 50-foot sections)
* 1 Slurp skimmer
* 6 long handled ladles
* 100 lbs. of sorbent pads
* 2 — 45 gallon drums of approved dispersant
* 2 hand-pump dispersant applicators
* 2 VHF transceivers capable of operating on PACE frequencies 1 and 2 and Marine Channels 10, 67 and 73
* 3 intrinsically safe walkie-talkies with VHF channels PACE 1 and 2 and Marine Channels 10, 16, 67 and 73 or UHF channels PACE 1, 2 and 3
Both the platform and the storage tanker should be supplied with quantities of particulate sorbent (e.g., diatomaceous earth) and sorbent pads.

3.3 CHEMICAL DISPERSANTS

3.3.1 Dispersibility of Cohasset and Panuke Crude Oils

Both the Cohasset and Panuke crude oils disperse naturally very quickly. Figure 3 shows the results of natural dispersion tests (Fingas 1989) conducted in a "rotating-flask" apparatus (Labofina). The percent dispersed is the amount of oil remaining in the water after a 5-minute settling time. Also shown for comparison are results for Alberta Sweet Mixed Blend (ASMB) crude oil — Environment Canada's standard test oil for dispersant effectiveness testing, Prudhoe Bay crude — akin to the oil spilled recently in Alaska's Prince William Sound, and Hibernia crude — discovered on the Grand Banks of Newfoundland. Both the Panuke and Cohasset crudes can be seen to be highly naturally dispersible, even when significantly weathered.

Figure 4 shows the results of chemical dispersant effectiveness tests on fresh and weathered Cohasset and Panuke crude oils (Fingas 1989). The tests were conducted at 15°C in saline water with Corexit 9527 using the recently-developed "swirling flask" apparatus (Fingas et al. 1987 and 1988) which is considered to best emulate field effectiveness results (Fingas 1988). For comparison, results for ASMB crude, Prudhoe crude and Hibernia crude are also plotted. Complete data on these and many other oils can be found in Appendix 2.

It is clear that both the Cohasset and Panuke crudes are exceptionally amenable to chemical dispersant application. It is worthy of note that no other of the 28 oils tested to date have shown an average dispersion greater than 63% with Corexit 9527. Even with significant degrees of evaporation, the average dispersant effectiveness of Corexit 9527 with the Cohasset and Panuke crudes exceeds 90%.

As such, the use of chemical dispersants as a countermeasure for spills of Cohasset/Panuke crude from tankers appears very promising. Since, unlike most other spill situations, the oils do not emulsify or weather to a point where their viscosities
FIGURE 3
NATURAL DISPERSION OF COHASSET AND PANUKE CRUDES

LEGEND
○ ○ PANUKE CRUDE
□ □ COHASSET CRUDE
△ △ ASMB CRUDE
▽ ▽ PRUDHOE CRUDE
◇ ◇ HIBERNIA CRUDE

PERCENT DISPERSSED

EVAPORATIVE EXPOSURE (θ = kt/x)
FIGURE 4
CHEMICAL DISPERSION OF COHASSET AND PANUKE CRUDES

LEGEND

- PANUKE CRUDE
- COHASSET CRUDE
- ASMB CRUDE
- PRUDHOE CRUDE
- HIBERNIA CRUDE

PERCENT DISPERSED

EVAPORATIVE EXPOSURE ($\theta = \frac{kt}{x}$)
exceed levels where dispersants become ineffective (2500 – 7000 cp), dispersant use is envisioned for slick remnants threatening shorelines or concentrations of seabirds. Because of the high natural dispersibility of Cohasset/Panuke crude oils, dispersant use is not recommended as a nearsource countermeasure; this would only increase already high dispersed oil concentrations.

3.4 APPLICATION SYSTEMS AND LOGISTICS

For chemical dispersants to be useful in dealing with the remnants of tanker spills of Cohasset and Panuke crude oils, the dispersant and application systems must be ready to be applied within a few hours. This precludes the use of large fixed-wing systems (located in British Columbia, Alaska and Arizona) and shore-based vessel spray system both of whose preparation and transit time to the site would exceed the expected survival time of the slicks. The best approach is to use a helicopter-slung spray bucket and dispersant stockpile located near the site, such as at the Sable Island helicopter refueling site. With this in place it would be possible to send a helicopter from the rig or even Halifax (about 300 km away) in time to prepare the bucket, fill it, hook it up and be ready to apply dispersant in a few hours.

Table 4 gives the specifications for the Rotortech TC3 spray bucket (Martinelli 1981) which has been used in dispersant sea trials off Canada. The device can be flown beneath a wide variety of commonly available helicopters and is easy to use. Table 5 shows typical times for a dispersant application with this bucket, assuming operations within a 50 km radius of Sable Island. (Figure 5 shows this in comparison to the predicted survival of tanker and operational spills at the proposed platform/storage tanker locations.)
TABLE 4

Rotortech TC3 Spray Bucket Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersant Payload</td>
<td>680 L (150 gallons)</td>
</tr>
<tr>
<td>Dispersant Pump Rate</td>
<td>45–380 L/min (10–85 gallons/min)</td>
</tr>
<tr>
<td>Spray Boom Length</td>
<td>10 or 6 m (30 or 20 ft)</td>
</tr>
<tr>
<td>Effective Swath Width (@ 6 m height)</td>
<td>13 or 10 m (42 or 30 ft)</td>
</tr>
<tr>
<td>Spraying Speeds</td>
<td>75–150 km/hr (40 to 80 kt)</td>
</tr>
<tr>
<td>Areal Coverage Rates</td>
<td>1.1–3.4 ha/min (2.8–8.4 acres/min)</td>
</tr>
<tr>
<td>Possible Dosage Rates (@ maximum pump rate)</td>
<td>110–340 L/ha (10–30 gal/acre)</td>
</tr>
<tr>
<td>Range of Treatable Oil Thickness @ 1:25 DOR</td>
<td>0.3–0.8 mm (0.01–0.03 inches)</td>
</tr>
<tr>
<td>Approximate Spraying Time per Payload</td>
<td>1.75 minutes</td>
</tr>
<tr>
<td>Approximate Total Swath Length per Payload (@150 km/hr)</td>
<td>4.4 km</td>
</tr>
<tr>
<td>Potential Volume of Oil Treated per Payload (@ 1:25 DOR)</td>
<td>17 m³ (100 bbl)</td>
</tr>
</tbody>
</table>

Adapted from Martinelli 1981
TABLE 5

Dispersant Application on Panuke/Cohasset Tanker Spills
50 km from Sable Island

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>TIME REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take off, pick up bucket and fly to spill @ 150 km/hr</td>
<td>25 minutes</td>
</tr>
<tr>
<td>position for 1st pass</td>
<td>5 minutes</td>
</tr>
<tr>
<td>apply 4 swaths (13 m wide x 1000 m long; 380 L/min @ 150 km/hr)</td>
<td>4 x 0.5 minutes = 2 minutes</td>
</tr>
<tr>
<td>reposition 3 times</td>
<td>3 x 5 minutes = 15 minutes</td>
</tr>
<tr>
<td>return, detach bucket and land</td>
<td>25 minutes</td>
</tr>
<tr>
<td>reload bucket (150 gallons) and check bucket operation/refuel</td>
<td>10 minutes</td>
</tr>
<tr>
<td>SUM OF TIMES</td>
<td>82 minutes</td>
</tr>
<tr>
<td>Helicopter Refuelling Factor (6 minutes per hour)</td>
<td>1.1</td>
</tr>
<tr>
<td>TOTAL TIME PER PAYLOAD</td>
<td>90 MINUTES</td>
</tr>
</tbody>
</table>
FIGURE 5

ESTIMATED DRIFT OF SURFACE SLICKS COMPARED TO DISPERSANT APPLICATION
Application of each bucket-load of 150 gallons of dispersant will require approximately 1½ hours. Assuming an average 12 hours of daylight the maximum amount of dispersant that could be applied is 8 loads or 5500 L (1200 gallons - about 27 drums). This could treat 46 ha (0.46 km²) of slick equivalent to about 20% of the thick slick area from the "worst-case" (31,800 m³) tanker spill and about 50% of the thick slick area from the "average" (8000 m³) tanker spill. Theoretically, the dispersant applied could deal with 136 m³ (855 bbl) of oil at a D.O.R. of 1:25.

The stockpiling of more than one day's worth of dispersant is not recommended because of the oil's high rate of natural dispersion; if further dispersant is required it could be obtained from Mulgrave (11,350 L – CCG), St. John (6810 L – CCG) or St. John's (92,500 L – ESRI).

3.5 IN-SITU BURNING

3.5.1 Burning with Fire Proof Boom

The use of fire proof boom to capture and contain oil from blowouts at the Cohasset and Panuke fields is not considered feasible because of the thin, wide slicks predicted and the rapid natural dissipation predicted.

The use of fire proof booms to capture and control slicks from tanker spills is not considered feasible because of the fire/explosion hazard to boom–tending vessels (see Figure 2) and the possibility of flashback to the stricken tanker if the volatile slicks were to be ignited.

3.5.2 Burning Uncontained Slicks

A relatively new technique that could be attempted, if conditions permit, is igniting an uncontained, spreading slick of Cohasset/Panuke crude and allowing it to burn unaided. This could be possible if the slick were far enough from the stricken tanker to ensure that flashback could not occur, and if the slick were thick enough to ensure efficient combustion (> 5 mm). This approach to in-situ burning has still not
been developed to an operational stage, but is included here since it is one of the few oil removal techniques that seem feasible for spills of Cohasset/Panuke crude. Because the technique is still in the research stage, no equipment stockpiling is recommended.

The ignition of the gas at the sea surface from a subsea blowout to eliminate hazards and further accelerate slick dissipation, should be seriously considered.
4.0 SUMMARY AND RECOMMENDED EQUIPMENT

4.1 SUMMARY

Spills of Cohasset and Panuke crude oils are predicted to evaporate and disperse very rapidly at sea; slicks from blowouts will only survive a few minutes and slicks from tanker spills will survive only a few hours. Containment and recovery operations for such spills are not recommended because of the high volatility of the oils; in-situ burning with fire containment booms are not recommended because of the chances of flashback to a stricken tanker.

In the event of a spill, a surveillance and monitoring program should be mounted to track the slicks and confirm their dissipation, measure water-column dispersed oil concentrations and measure airborne gas/oil aerosol concentrations (in the event of a blowout). Should slick remnants threaten sensitive areas, a helicopter/spray bucket dispersant operation could be mounted from a staging area on Sable Island.

4.2 RECOMMENDED EQUIPMENT

The following should be stockpiled at the platform/storage tanker:

- 6 Orion slick tracking buoys (three on the platform, three on the storage tanker)
- one shipborne Orion receiver unit or an RDF receiver of appropriate frequencies
- 2 Explosimeters (one each on platform and storage tanker)
- particulate sorbent and sorbent pads

The following should be stockpiled at the West Sable Island Light helicopter refuelling area:

- 1 Rotortech TC3 spray bucket c/w spares and fuel
- 1200 gallons Corexit 9527 dispersant
- 1 transfer pump c/w hose for bucket filling
The following should be available at the Halifax office:

- 1 helicopter-mountable Orion buoy receiver unit
- 1 computerized oil spill fate and trajectory model

The following should be available on short notice to the operator:

- 1 aerial remote sensing package and fixed wing aircraft
- 1 water column sampling package and sampling vessel.

If the shuttle tanker is to be in Canadian trade it should carry the oil spill response equipment recommended by PACE.
5.0 REFERENCES


Fingas, M.F. 1989. personal communication re dispersant tests in Appendix 2.


APPENDIX 1

P.A.C.E. GUIDELINE BULLETIN #11

OIL TANKER OPERATIONS RE OIL SPILL CONTAINMENT AND CLEAN-UPS
GUIDELINE BULLETIN #11

OIL-TANKER OPERATIONS RE OIL
SPILL CONTAINMENT AND CLEAN-UPS

Revised
June 1981

Prepared by
Marine Committee
for
Oil Industry Contingency Plans National Coordinating Committee

S. L. ROSS ENVIRONMENTAL RESEARCH LTD.
INTRODUCTION

The marine environment must be protected and every effort made to prevent spills. However, when such incidents do occur, it is imperative that immediate action be taken to contain and clean up the spills.

In the development of guidelines to containment and clean-up, five areas were examined:

1. Role of the tanker,
2. Response capabilities,
3. Products to be boomed and those not to be boomed,
4. Shipboard equipment,
5. Shipboard muster list and delegation of ship's complement for deployment.
1. **ROLE OF THE TANKER**

In response to an emergency involving a spill incident, the shipmaster must respond in accordance with the following order of priorities:

1. safety of life,
2. safety of the vessel,
3. containment and clean-up of the spill.

Most ship responses will be required in remote areas or where local PACE co-operatives or government agencies are not immediately at hand. In most instances, where a minor spill has occurred from 'over the side', instant response by ship's crew is the most effective way of minimizing environmental degradation.

In containment and clean-up of a spill, ship response capability must recognize:

(a) whenever a major incident occurs, priorities (1) and (2) may prevent any action in containment, beyond notification to authorities, ship and cargo owners,
(b) limitations of shipboard manpower availability,
(c) limitations to the type and size of equipment which can be stowed on board and deployed from a tanker.

2. **RESPONSE CAPABILITIES**

In order to provide a basis on which ship response capabilities can be designed, it is recognized that a tanker should be capable of containing and cleaning up a minor spill, i.e. less than 1000 gallons without outside assistance, providing priorities (1) and (2) do not intervene.

3. **PRODUCTS TO BE BOOMED AND THOSE NOT TO BE BOOMED**

The following products may be boomed adjacent to the ship for possible recovery back aboard the tanker by ship's crew and equipment:

1) All crude oils,
2) Bunker,
3) Asphalt,
4) Lube Oils,
5) Furnace Oils,
6) Diesels.

The following products should not be boomed adjacent to the tanker as they present too great a fire hazard to lives and property:

1) Gasolines,
2) All jets,
3) All aromatics.

However, the boom may still be used to advantage by the ship to isolate or re-direct the above away from sensitive areas, namely harbours, river entrances etc.
4. **SHIPBOARD EQUIPMENT**

The following equipment list has been developed over the past three years and has proven practical for Canadian areas of marine operations. The equipment list is intended for guideline purposes and, for each individual ship and area of operation, should be reviewed and adapted to best serve the cause previously outlined.

**Work Boat**

It has been recognized through practical experience that with modern and lighter booms, work boats can be powered by outboard motors ranging between 20 h.p. and 40 h.p., depending on the area of operations, but a 40 h.p. motor is recommended.

**Containment Boom**

Lightweight (recommended under 2 lb./ft.), 50 ft. sections and totalling 1-1/2 ship lengths.

**Clean-up Equipment**

- Portable pumping unit, 4-6 h.p. range, weight maximum 200 lbs., diesel or gasoline powered (suitably flame proofed), mounted on steel chassis designed for securing on work boat,
- 100 ft. (50 ft. sections) of 3 in. non-collapsible suction hose, with suitable adapters for pump outlet,
- 1 slurp skimmer,
- 6 long handled ladles,
- 2 open-ended 45 gal. oil drums,
- 100 lbs. of polyurethane sponge mats supplied in 18 in. squares or equivalent,
- 2 - 45 gal. drums of government approved dispersant,
- 2 hand pump dispersant applicators.

**Communication Equipment**

(a) By regulation, every vessel must carry two VHF marine transceivers. In addition to their other channels, these sets should be capable of operating on -

| PACE frequency 1 | 159.480/158.445 MHz | and |
| PACE frequency 2 | 159.480 MHz |
| and also - | |
| Marine Channel 10 | 156.5 MHz |
| 67 | 156.375 MHz |
| 73 | 156.675 MHz |

- 4 -
(b) Every vessel should carry three intrinsically safe walkie-talkies with 6-channel capabilities. It is recommended that VHF portables be used but UHF portables are an acceptable alternative. VHF portables should be capable of operating on VHF PACE frequencies 1, 2, Marine Channels 10, 67, 73 and the international distress frequency channel 16 which is 156.8 MHz.

If UHF portables are used, they should be capable of operating on the following frequencies:

- UHF PACE frequency 1 - 454.00/459.00 MHz,
- UHF PACE frequency 2 - 454.00 MHz
- UHF PACE frequency 3 - 453.5875 MHz and
  one company channel

In the event of an oil spill, the Master of the vessel will contact Canadian Coast Guard, local Region Headquarters, via marine channel 16 and request use of any one, two or three of marine channels 10 (the primary recommendation), 67 and 73 for immediate containment and clean-up of an oil spill under direction of the vessel's Master. Use will be authorized very quickly by CCG and a notice to shipping will be put out on continuous marine broadcast.

Should the spill require shore-directed containment and clean-up parties, these will be conducted on PACE frequencies 1 and 2. Work boats released by the vessel to assist in shore-controlled clean-up should operate on PACE frequencies 1 and 2.

Communication by the vessel with Coast Guard should continue on channel 16 and channels 10, 67 and 73, and PACE 1 and 2 should be used for communication with an on-scene commander on shore.

Communications equipment and procedures are discussed more fully in PACE Guideline Bulletin #6, "Directions for Use of Oil Spill Emergency Radio Frequencies and Equipment".

5. SHIPBOARD MUSTER LIST AND DELEGATION OF SHIP'S COMPLEMENT FOR DEPLOYMENT

Collisions and strandings throw additional demands upon the ship's complement and how best to handle such situations must be a matter of an 'on the spot' decision to judge how the equipment available is to be deployed to best advantage.

Attached is a shipboard muster list. All exercises carried out in conjunction with this muster list have been successful.

***************

In the interest of all concerned, the Committees urge all tanker owners/operators to adopt these guidelines.
SHIPBOARD OIL SPILL EMERGENCY

M.V./S.T._____________________

MUSTER LIST

Oil Spill Alert: Repeated sounding of the Morse letter S ... ... ... on ship's whistle and fire alarm.

Action: 
(A) Extinguish all naked lights.
(B) Close all openings (e.g. doors, ports, air conditioning, intake fans).
(C) Report to Stations with life jackets.

OIL SPILL STATIONS

1. Oil Spill Assessment Group
Supervisors report to OSC on bridge with walkie-talkies.

1.(A) OSC - Master
1.(B) Supervisor (spill) - Chief Officer
1.(C) Boat Supervisor - Watchkeeping Officer
1.(D) Recovery Supervisor - Chief Engineer

2. Oil Spill Work Crews


2.(B) Boom Launching Crew - 6 Seamen - Report to Boom Storage Station and clear for deployment Nos.

2.(C) Work Boat Crew - 2 Seamen - Report to Launch Station with Jacob's ladder Nos.

2.(D) Spill Recovery Crew - 3 Seamen - Report to Recovery Equipment Station and prepare for deployment Nos.

3. Engine Room personnel on watch should remain in Engine Room and await instructions.

4. All Seamen not identified in above Stations should report to midship manifold and await instructions.

Note: In the above list Nos. shown refer to same Nos. displayed in cabin for life boat and fire stations.

Reference to 'Seamen' means all ship's complement.
APPENDIX 2

NATURAL AND CHEMICAL DISPERSIBILITY RESULTS
NATURAL DISPERSABILITY
MEASURED USING A LABOFINA APPARATUS AT AN O/W RATIO
OF 1:1000 AND A SETTLING TIME OF 5 MINUTES

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_LF, December, 1989_
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**EXPLANATION OF TESTS**

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**1-DROP** - REFLECTS LARGEST AMOUNT DISPERSED AT A DISPERSANT TO OIL RATIO OF 1:10
- TEST MEASURES HOW OIL/DISPERSANT COMBINATION FUNCTIONS WITH REAL APPLICATION

**2-DROP** - REFLECTS LARGEST AMOUNT DISPERSED AT A DISPERSANT TO OIL RATIO OF 1:10 BUT DELIVERED IN TWO DROPS
- TEST MEASURES THE HERDING EFFECT OF THE OIL/DISPERSANT COMBINATION WHEN COMPARED TO THE ONE DROP TEST

BQ AND II ARE EXPERIMENTAL DISPERSANTS MADE BY EETD

TL = TO LOW TO MEASURE
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SECTION 9. SOCIO-ECONOMIC CONSIDERATIONS

9.1 INTRODUCTION

This section discusses the social and economic impacts and presents a summary of the industrial opportunities associated with the proposed Cohasset/Panuke Development Project.

Economic impacts are assessed in terms of overall activity which is measured by changes in net output (value added), gross output, employment, and government (federal and provincial) revenues. Estimated expenditures and their effects are presented for both the development (engineering and construction) and production operations phases.

The economic impacts are confined to those associated with the project capital and operating expenditures. The analysis does not include the impact of net revenues that may be generated by the project (corporate taxes and royalties). A detailed analytical analysis has not been performed for the social impacts due to the relatively small size of the project. Several subjective and judgemental comments are presented relating to the social infrastructure within Nova Scotia. The information presented should not be confused with a cost-benefit analysis that considers alternative uses of the resources employed.

The industrial opportunities associated with the project, while considered modest by comparison with other proposed offshore developments in Canada, nevertheless, will provide an opportunity for renewed and sustained activity within the Nova Scotian offshore supply and services sector. The industrial opportunities section describes LASMO's principles and procedures for the procurement of materials, equipment and services, employment policies, programs for industry and community consultation and personnel training.
9.2 PROJECT OVERVIEW

9.2.1 FACILITIES

The Cohasset/Panuke Development Project involves the combined development of two condensate fields located approximately 42 km southwest of Sable Island. The fields are about 9 km apart. The water depth in the area ranges from 38 to 44 m. The reservoirs are at an approximate depth of 2400 m.

A wellhead jacket is to be installed at each field. The jacket at Panuke will support four wellheads and production trees, while the jacket at Cohasset will support nine to ten wellheads and production trees. The wells will be drilled with a jack-up rig, which will also serve as the production unit at the Cohasset site. The Panuke facilities will be unmanned and will be remotely operated from the production jack-up at Cohasset. Subsea flowlines and control lines will be installed between the Panuke and Cohasset jackets.

Produced condensate will be stored in a storage tanker moored on a continuous basis during the production season. A shuttle tanker will be used to transport the condensate to final market destinations. Market destinations could include Dartmouth, N.S., Portland, Maine and other international locations.

It is intended to produce condensate on a seasonal basis during the seven months, April through October. It is expected that the reserves would be recovered during six production seasons. At the end of the last season, the wells would be abandoned and the wellhead jackets, flowlines and tanker loading system removed from the fields.
9.2.2 PROJECT SCHEDULE

Final engineering studies are in progress. Assuming government project approvals are obtained in June 1990, expenditures for materials, equipment, services and construction would begin in August 1990. The project management, construction, installation and drilling phase is expected to last about two years, with production start-up in April, 1992. Production would continue until 1997. When production is terminated, all facilities would be removed from both fields and the locations returned to their original state.

9.2.3 CAPITAL AND OPERATING COSTS

Total capital costs are estimated to be $160.0 million (1990 Canadian dollars). Operating costs are estimated to be $53.1 million in the first year of production, then rising to and stabilizing at $71.2 million when production reaches maximum level in year three. Total operating costs are estimated to be $405.0 Million (1990 Canadian dollars).

9.2.4 EMPLOYMENT

The project is expected to create about 680 person-years of direct employment during the development phase. Annual direct employment onshore and offshore during the production phase is estimated to be about 165. Development and production phase direct employment by activity are presented in Tables 9.2-1 and 9.2-2.

9.2.4.1 Project Activities During Development

To facilitate the assessment of the economic and social impacts, the project is broken down into the following activities:
### TABLE 9.2-1

**COHASSET/PANUKE DEVELOPMENT PHASE DIRECT EMPLOYMENT**

(PERSONS - YEARS)

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### TABLE 9.2-2

**COHASSET/PANUKE**

**PRODUCTION PHASE ANNUAL DIRECT EMPLOYMENT, 1992-1997**

(PERSONS)

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<tbody>
<tr>
<td>Abandonment (1997)</td>
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MARCH 7, 1990

9.4
Preliminary Studies

These include biophysical, geophysical and geotechnical studies, storage, transportation and market studies, and preliminary engineering and design work completed during the early stages of development planning. Local Nova Scotia consultants have been used during the study phase.

Development Drilling and Completions

The drilling program involves 11 wells, seven at the Cohasset field and four at Panuke. They would be drilled with a jack-up rig through wellhead jackets. The wells at Panuke would be drilled and completed first, and then the rig would be moved to Cohasset. The program would take about one year to complete and would be supported by shore-based facilities, supply and standby vessels and one helicopter. Significant Nova Scotia employment would take place in support of drilling operations.

Wellhead Jacket Fabrication and Installation

Two steel piled wellhead jackets would be fabricated and installed. Fabrication of each is expected to take about six months. Each jacket would contain several well conductors. The jackets would be comprised of about 1,200 tonnes of steel each (including piles and conductors). They would be barged to location and installed with the assistance of the jack-up rig or a derrick barge. The capacity and technical skills exist within Nova Scotia for the construction of these jackets.

Production Facilities Manufacturing, Assembly and Installation

Prior to the commencement of development drilling operations, the production facilities will be installed on the deck of the jack-up rig. These facilities consist of oil processing, water injection, water processing and oil transfer equipment. Approximately 700 tons
of production equipment will be integrated into existing rig systems, with some modifications. This installation work is likely to be conducted in Halifax.

**Interfield Flowline and Export Line**

The pipe will be either line pipe or flexible pipe. The specific material will be specified at the final engineering design stage. Regardless of which type is selected, it is likely to be laid from a reel barge operated by an international contractor. The scope for onshore manufacture in Nova Scotia may be limited. Marine support operations could be provided from Nova Scotia.

**Management and Engineering**

This consists of LASMO's management group in Halifax, communications, services, insurance and consulting engineering.

**Tanker Loading/Mooring System**

Engineering studies are in progress for mooring system design. The specific arrangements for new construction of a CALM type (proprietary designs) loading buoy will depend on competitive commercial arrangements. The capacity to build such a buoy exists within Nova Scotia.

9.2.4.2 **Project Activities During Production**

**Management/Engineering/Administration**

These would be located in Halifax and would be carried out on a year-round basis.
Production Operations

This covers offshore activities including operation of the production facilities on the jack-up unit, supply and stand-by vessel operations, helicopter transport, support services (e.g., communications, catering, weather forecasting, repair and maintenance, etc.) and supply base operations. The jack-up unit would be contracted from an international contractor. However, the majority of the personnel, support services, supplies, etc. would be sourced within Nova Scotia.

Tanker Operations

This includes operations of the mooring and offloading systems, the storage tanker and the shuttle tanker on a seven month seasonal basis. Depending upon competitive commercial arrangements, yet to be made, these contracts could contain significant Nova Scotia content.

Well Workovers

This includes recompletions and pump maintenance for Cohasset and Panuke. Workovers will be carried out with the production jack-up unit primarily during the winter period. Rig personnel, suppliers and services are likely to be sourced within Nova Scotia.

Abandonment

This includes plugging the wells and removing well jackets, interfield flowlines and control lines and the tanker mooring and offloading buoy. This work is likely to be carried out with the jack-up unit, diving support vessel and a marine barge. Personnel and support services are likely to be sourced within Nova Scotia.
9.3 **SOCIO-ECONOMIC IMPACTS**

9.3.1 ASSUMPTIONS

Information on the magnitude and location of project activities is fundamental to the assessment of socio-economic impacts. Offshore projects often present difficulties in this regard. While the magnitude of activities may be well known, many of them may not be tied to specific locations until the tendering process is completed during the implementation phase and after project approvals have been obtained.

This project is similar in many respects to offshore projects elsewhere. There are several site-specific activities such as management, development drilling, the installation of production facilities. There are several activities for which the location will not be known until contractors are selected such as design engineering and the wellhead jacket construction.

The analysis of socio-economic impacts requires assumptions about the location of non-site-specific activities. As a general principle, it is assumed that if Nova Scotia industries have the capability of carrying out specific activities, then these activities would be located in the province. Following this assumption, the activities forming the basis of the impact assessment are summarized below. They are reflected in project expenditures set out in Tables 9.3-1 and 9.3-2.

- a portion of the preliminary studies, engineering, management and administration
- development drilling and completions
- wellhead jacket fabrication
- a portion of production facilities fabrication, assembly and installation
- offshore and land-based production activities
# Table 9.3-1

**COHASSET/PANUKE FIELD DEVELOPMENT**

**CAPITAL COST BREAKDOWN BY PROVINCE AND COMMODITY**

($ millions)

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**NOTE:** For commercial reasons, individual component capital and operating costs are being kept confidential.

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**MARCH 7, 1990**
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**NOTE:** For commercial reasons, individual component capital and operating costs are being kept confidential.

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<td>3</td>
<td>Well Workovers</td>
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<td>4</td>
<td>Management &amp; Administration</td>
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<td>5</td>
<td>Field Abandonment</td>
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<td>- Labour</td>
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<td>- Diving Support</td>
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<td></td>
<td>- Marine Transport</td>
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<tr>
<td></td>
<td><strong>GRAND TOTAL</strong></td>
<td>23.4</td>
<td>3.0</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
<td>42.8</td>
<td>71.2</td>
</tr>
</tbody>
</table>

NOTE: For commercial reasons, individual component capital and operating costs are being kept confidential.
9.3.2 SCALE OF THE PROJECT

Impacts on the socio-economic environment generally arise from a disruption caused by some activity different from, or on a scale which is larger than, normally experienced. The disruption may be due to the demands placed on housing or commercial and social services by a migrant labour force, or due to the demands placed on physical infrastructure, or land and resources by a new industrial activity.

The major difference between this project and many other offshore projects (including the proposed Hibernia and Venture projects) is one of scale. The Cohasset/Panuke Development Project is relatively modest in size. The project activities are ones which, for the most part, can be carried out in existing facilities. The jackets, for example, could be fabricated in two or three locations in the province without major adjustments to facilities or labour force. Similarly, there are at least two locations which have the facilities and infrastructure to support the drilling program.

The nature and magnitude of the Cohasset/Panuke Development Project activities in relation to the socio-economic environment in Nova Scotia suggests that the impacts of the project will be generally positive. The size of the project is such that the demands placed on social and physical infrastructure will be relatively small and easily absorbed.

9.3.3 DEVELOPMENT PHASE IMPACTS

9.3.3.1 Preliminary Studies

Many of the studies are site-specific to Nova Scotia and are being carried out by established Nova Scotian companies using existing staff and facilities. These studies will have a positive impact on the consulting industry. No negative socio-economic impacts could
be identified. Studies not conducted in Nova Scotia will be carried out primarily by Alberta-based companies.

9.3.3.2  Development Drilling and Completions

This work is specific to the Cohasset and Panuke field locations. It will generate a demand for several types of specialized equipment including a jack-up drilling rig, supply vessels and helicopter. The consumables and services required are standard for offshore wells and are likely to be sourced within Nova Scotia.

The drilling and completion schedule is approximately 12 months. There are, at present, no Canadian owned/operated rigs of the type required for this program and the demands generated by this project are not likely to lead to the development of a local supply capability. Accordingly, it is assumed that the rig will be non-Canadian. The rig crew, on the other hand, could very well be recruited from Nova Scotia. At the height of exploration activity in offshore Nova Scotia during 1985, a total of 8 rigs were active and employed over 800 persons. Some 60 to 70 percent of the rig crews were residents of Nova Scotia. Most of the 70 crew and support staff required for this project will be recruited locally. Combined with the work and shore leave arrangements there will be considerable positive employment and income impacts and few, if any, negative effects.

Similar conclusions hold for supply vessel and helicopter requirements. These are expected to be supplied by local contractors and will provide employment for about 50 Nova Scotians.

Other requirements for the drilling program include consumables (such as fuel, lubricants, mud, casing and bits), services (such as diving, mud logging, communications, weather forecasting and catering), and shore-based facilities. Many of the consumable items are not available in Nova Scotia and will be brought in from outside the province. The services will be provided, in part, by
existing Nova Scotia companies who have survived the downturn in offshore exploration and, in part, by the more specialized companies who will return to the province with the resumption of activity.

The resulting impacts are expected to be positive. The demand for warehouse and office space can easily be met in the Halifax/Dartmouth area. There has continued to be growth in both types of space, despite the downturn in offshore activity. Similarly, employment impacts will be positive. There will be some influx of technical services people, though the numbers for this project (in the order of 25-40) would be modest in relation to the supply of housing and social and physical infrastructure available.

9.3.3.3 Wellhead Jackets

The two wellhead jackets could be fabricated in existing facilities in Nova Scotia. A final decision on where to place the contract(s) would depend on technical and commercial factors. For purposes of the impact assessment, it is assumed the work will be done in Nova Scotia. Each of the jackets is expected to be fabricated over a six-month period and employ up to 150 persons at peak.

That the size and complexity of the jackets allows them to be fabricated in existing facilities simplifies the impact assessment. Negative impacts generally arise as the result of new, large-scale developments involving the movement of substantial numbers of people into small communities. This will not be the case with this project. The use of existing facilities to fabricate the wellhead jackets means virtually no disruption to the socio-economic environment. There may be some need to upgrade workforce skills and to invest in new equipment and systems to meet stringent industry standards but, these additions should easily be managed.
9.3.3.4 **Production Facilities**

The production facilities are generally comprised of oil/gas/water separation equipment, water injection equipment, produced water and seawater clean-up equipment, electrical and safety systems. Some items are fabricated while others will require new manufacture. New manufactured equipment would be sourced from existing specialty manufacturers within Canada, USA and UK. Off-skid piping spools, skid framing and assembly work could take place in existing Nova Scotia facilities. Final selection of vendors/contractors will depend on the evaluation of competitive technical and commercial factors. For purposes of the impact assessment, it was assumed that some fabrication/assembly work could be done in Nova Scotia and all of the installation work would likely be done in Nova Scotia. Portions of the fabrication would be done within the Maritimes, with main equipment being supplied out of Ontario, Quebec, Alberta, USA and UK. The use of existing facilities should enhance positive impacts and effectively preclude any negative effects.

9.3.3.5 **Interfield Flowlines and Export Line**

It is likely that a proprietary design and manufacturer for these flowlines will be selected. Specialized manufacturing and assembly would take place in the USA or France. Given the technology involved, Nova Scotia impacts for this work are likely to be minimal. Special purpose marine vessels would be contracted for the installation phase from international contractors. Some vessel support (i.e., fuel, consumables, crew) could be sourced within Nova Scotia.

9.3.3.6 **Engineering and Management**

This will generate a demand for office space in Halifax and may lead to an inflow of personnel into the city. With the high current and projected vacancy rates for office and commercial space, meeting the project requirements would be straightforward.
Similarly, there is an excess of residential housing and relatively high vacancy rates in the rental market with new space currently under construction. No negative aspects are expected.

9.3.4

PRODUCTION PHASE IMPACTS

9.3.4.1 Onshore Activities

The key onshore activities during production are management and administration and supply base operations. LASMO's management and administration team is expected to number about 25. This is lower than the corresponding group during development. The transition from development to production is also expected to result in a reduction in the demands placed on the supply base. This means a decrease in vessel traffic and possibly a slight decline in direct employment. The supply base and other shore services are expected to provide direct employment for about 10. There would be no incremental impact on social and physical infrastructure following the transition from the development to the production phase.

9.3.4.2 Offshore Activities

During development, most of the project impacts are onshore. The transition from the development to the production phase means a shift in the location of activity from onshore to offshore and an overall reduction in onshore impacts. Direct employment on offshore facilities and vessels is expected to be about 130 (including turn-around crews, where appropriate), with about 70 employed in production operations, 30 on supply and stand-by vessels and helicopter, and another 30 for storage and shuttle tanker operations. Incremental employment arising from the abandonment of facilities in 1997 is expected to be about 15.

These jobs are expected to be filled primarily by Nova Scotians and represent an important positive impact. The nature of work offshore is such that employees are able to continue to reside in their
existing homes while on shore leave and consequently, any onshore impacts will be negligible.

9.3.5

SOCIAL AND ECONOMIC ISSUES

9.3.5.1 "Boom Bust" Cycle

The project will not have a significant effect on national inflation and it is possible to accommodate a modest project of this size within the local economy without triggering any local inflationary effects. Excess capacity exists in many sectors and the project demands can be easily absorbed without any supply disruptions.

9.3.5.2 Population

The project impacts on population will be minimal within Halifax/Dartmouth and the surrounding areas. While there will be some single persons and families relocating to Nova Scotia, no measurable increases are expected, within the normal swings of in-migration and out-migration occurring on a regular basis. Many of the employment opportunities, either directly with IASMO or related service/supply companies, will be filled by Nova Scotians currently residing in the province. Relocations from within the province may be possible.

9.3.5.3 Housing/Offices

There exists a wide selection and availability of both single dwellings and rental accommodation units within the main Halifax area. No excessive demands are projected due to Cohasset/Panuke employment during the life of the project. Commercial office space within the metro area and adjacent industrial parks is available for re-establishment of service and supply companies. Several inactive service companies have retained office space and warehouse

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space in the area during the exploration drilling downturn since 1986/87.

9.3.5.4 Public Infrastructure

There will be minimal impacts on schools, hospitals, municipal, commercial and industrial services and facilities within Nova Scotia.

9.3.5.5 Social Services

No impacts on existing social service programs are expected as a result of this relatively modest project.

9.3.5.6 Work Camps

Existing industrial and marine facilities would be used for the project fabrication, construction and shore-based support services. No work camps are being proposed for this project.

9.3.5.7 Labour Force Displacement

It is not expected that the project will cause undue competition for workers from various industrial sectors within Nova Scotia and the Maritime region. Within the intended time frame for Cohasset/Panuke (i.e., 1990-1997), it is not expected that other proposed offshore projects (i.e., Hibernia and Terra-Nova) will be far enough into their respective implementation stage to place excessive demands or current labour force levels within various trade sectors. Migration of transient labour is not expected to present a problem.

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9.18
9.4  ECONOMIC IMPACT

9.4.1  INTRODUCTION

Estimates of the economic impact of the project on the Province of Nova Scotia are contained in this section. Both the development and production phases are examined. Impacts are expressed in terms of total income (Gross Domestic Product) and employment. Also presented is the impact on government revenue, both at the provincial and municipal level.

The 1984 version of the Nova Scotia Input-Output Model is used to estimate the impacts.

9.4.2  PROJECT DIRECT EXPENDITURES

The project has an estimated capital cost of $160 million. A preliminary review of project requirements suggests that as much as $60.4 million of the capital cost could be spent in Nova Scotia. Of the balance, $52.8 million is assumed to be spent in the rest of Canada and $46.8 million on imported goods and services.

Annual operating costs during full production are estimated to be $71.2 million. Of this, $23.4 million is likely to be spent in Nova Scotia, $5.0 million spent in other provinces and $42.8 million spent on imports.

9.4.3  THE NOVA SCOTIA INPUT-OUTPUT MODEL

The 1984 Nova Scotia Input-Output Model determines the impacts of an increase in final demand in Nova Scotia on industry output, income and employment. The current version of this model derives its form from the Canada input-output system which is an advanced example and forerunner of the commodity-by-industry accounts promoted by the United Nations. The assumptions and methodology underlying this model are outlined below:

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9.4.3.1 Assumptions

All models of economic behaviour rely on simplifying assumptions. The following major assumptions underlie the 1984 Nova Scotia Input-Output Model.

- Limited Time Dimension: All impacts of a change in final demand are effective within whatever period of analysis is chosen. In this sense, the model is "static" and does not attempt to show the pattern of change over time.

- Limited Sensitivity to Relative Price Changes: All prices are fixed and do not change over time.

- Fixed Technology: Industries are assumed to operate using technologies used in 1984.

- Constant Returns to Scale: All inputs are assumed to change in the same proportion as any change in an industry's output.

- No Supply Constraints: I/O models assume that whatever is demanded by industries as inputs can be supplied. They assume no productive capacity constraints.

- Fixed Consumption Patterns: The consumption patterns that result in household responding multipliers are assumed to be fixed and linear.

9.4.3.2 Operation of the Model

The input-output method is an empirical representation of a general theory of production based on the notion of economic interdependence. In an input-output model, each industry in the economy is dependent upon every other industry for the supply of intermediate goods. The model assumes that prices and wages are
fixed and the supply of both intermediate goods and final goods is unlimited.

The basic question traditionally asked in economic impact analysis is 'What are the gross-output and income flows associated with a specified economic change?' An input-output provides the answer by tracing the transmission of a demand shock throughout the economic system. In this case, the shock takes the form of project expenditures. The impacts are usually estimated in terms of increases in industry output, incomes earned by resource owners and employment.

These impacts are usually distinguished as direct, indirect and induced. Direct impacts refer to effects caused by the direct purchases of project inputs. Indirect impacts refer to income and employment effects arising from inter-industry purchases of goods and services, while induced impacts refer to the effects caused by consumer spending of incomes earned in direct and indirect activities.

The analysis uses open and closed versions of the input-output model. The open model provides a measure of direct and indirect impacts. Household incomes earned in direct and indirect activities are not included. In other words, they are treated as leakages from the system. Alternatively, in the closed model, the multiplier effects of incomes spent on goods and services are captured. To obtain a measure of induced impacts, one may subtract the open model results (indirect plus direct impacts) from the closed model results (indirect, direct and induced impacts).

For the development phase, the model reports the impacts arising from total capital expenditures. For the sake of simplicity, impacts are reported as though they occurred at a single point in time. In reality, they would be spread over the project life. Impacts for the production phase are based on a single year's expenditure and consequently represent the impacts related only to
a typical year (at peak production). These impacts would be recurrent for as long as production lasts. For both the development and production phases, impacts are reported in 1990 dollars.

9.4.4 RESULTS OF THE ANALYSIS

The Nova Scotia Input-Output model simulations provide information on income or value added (GDP), employment and provincial and municipal government revenues. The results distinguish between the development and operation phases and identify direct and indirect impacts (in combination) and induced impacts.

9.4.4.1 Development Phase

Direct project expenditures in Nova Scotia are assumed to be $60.4 million. A breakdown of expenditures by project component is provided in Table 9.3-1.

Direct and Indirect Impacts

Total income in Nova Scotia is expected to rise by approximately $24 million. This rise in income will result from the more than 1,050 jobs created by the project. Total provincial and municipal government revenues arising from this direct and indirect impacts is estimated at $1.3 million. Direct and indirect impacts of the project are presented in Table 9.4-1.

Induced Impacts

Induced activity is expected to cause incomes to rise by an estimated $10.5 million. The number of jobs created as a result of this increased consumer spending is expected to be about 230. Total provincial and municipal government revenues are expected to increase by $3.8 million.
TABLE 9.4-1
COHASSET/PANUKE DEVELOPMENT PHASE IMPACTS IN NOVA SCOTIA
(millions $ 1990)

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Direct &amp; Indirect Impacts</th>
<th>Induced Impacts</th>
<th>Overall Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>23.5</td>
<td>10.5</td>
<td>34.0</td>
</tr>
<tr>
<td>Employment Created</td>
<td>1,050</td>
<td>232</td>
<td>1,282</td>
</tr>
</tbody>
</table>

Government Revenues
- Provincial: 0.8
- Municipal: 0.5
- Total: 1.3

Overall Impacts

In total, income in the province is expected to rise by about $34 million. The model predicts this will result in the creation of 1,282 jobs. Total provincial government revenues generated by the project are expected to be about $3.9 million. Municipal revenues are expected to increase by $1.2 million.

Individual Industry Impacts

Details of output by industry sector in Nova Scotia are shown in Table 9.4-2 the industries receiving the greatest stimulus from the project would be business services, transportation and wholesale trade.
<table>
<thead>
<tr>
<th>Industry</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Services</td>
<td>17.2</td>
</tr>
<tr>
<td>Petroleum, Chemicals, Plastics</td>
<td>0.5</td>
</tr>
<tr>
<td>Transportation</td>
<td>7.3</td>
</tr>
<tr>
<td>Construction</td>
<td>0.5</td>
</tr>
<tr>
<td>Accommodation &amp; Food Service</td>
<td>0.7</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>3.3</td>
</tr>
<tr>
<td>Ship &amp; Boat Building &amp; Repair</td>
<td>2.2</td>
</tr>
<tr>
<td>Finance, Insurance, Real Estate</td>
<td>2.1</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>34.0</strong></td>
</tr>
</tbody>
</table>
Production Phase

Annual direct project expenditures, at peak production in Nova Scotia, are assumed to be $23.4 million. A breakdown of this spending by province is project component and is provided in Table 9.3-2.

Direct and Indirect Impacts

Total income in Nova Scotia is expected to rise by almost $10 million. This rise in income will result from the 278 jobs created by the project. Total provincial and municipal government revenues arising from these direct and indirect impacts is estimated at $0.6 million. It should be noted that provincial revenues exclude any royalties or taxes related to oil production. Direct and indirect impacts of the operation phase of the project are presented in Table 9.4-3.

Induced Impacts

Induced activity is expected to cause incomes to rise by an estimated $4.4 million. The number of jobs created as a result of this increased consumer spending is expected to be about 60. Total provincial and municipal government revenues are expected to increase by $1.6 million.

Overall Impacts

In total, income in the province is expected to rise by about $14 million. The model predicts this will result in the creation of 339 jobs. Total provincial and municipal government revenues generated by the project are expected to be about $2.2 million.
TABLE 9.4-3
COHASSET/PANUKE PRODUCTION PHASE IMPACTS IN NOVA SCOTIA
(millions $ 1990)

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Direct &amp; Indirect Impacts</th>
<th>Induced Impacts</th>
<th>Overall Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>9.7</td>
<td>4.4</td>
<td>14.1</td>
</tr>
<tr>
<td>Employment Created</td>
<td>278</td>
<td>61</td>
<td>339</td>
</tr>
<tr>
<td>(person-years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government Revenues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Provincial</td>
<td>0.4</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>- Municipal</td>
<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>0.6</td>
<td>1.6</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Individual Industry Impacts

Details of output by industry sector in Nova Scotia are shown in Table 9.4-4. The table shows that the industries receiving the greatest stimulus from the project would be business services and transportation. Construction, accommodation and food service and wholesale trade industries will each receive approximately $0.8 million.
### Table 9.4-4

<table>
<thead>
<tr>
<th>Industry</th>
<th>GDP Impact (1990)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Services</td>
<td>4.8</td>
</tr>
<tr>
<td>Petroleum, Chemicals, Plastics</td>
<td>0.3</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.4</td>
</tr>
<tr>
<td>Construction</td>
<td>0.8</td>
</tr>
<tr>
<td>Accommodation &amp; Food Service</td>
<td>0.8</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>0.8</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>14.1</strong></td>
</tr>
</tbody>
</table>

#### 9.5

**CANADA/NOVA SCOTIA INDUSTRIAL OPPORTUNITIES - PRINCIPLES AND PROCEDURES**

#### 9.5.1

**PRINCIPLES**

The Cohasset/Panuke Development Project will generate important economic activity and provide industrial opportunities within Nova Scotia and Canada. In recognition of this, IASMO is committed to using and encouraging capable Nova Scotian and Canadian companies that can provide high quality and competitive goods and services in both the development and production phases of the project.

#### 9.5.1.1

**Industrial**

IASMO’s industrial opportunity commitments are to:

- Ensure that all goods and services considered for the project meet the standards necessary to have a safe and efficient operation.

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- Provide qualified Nova Scotian and other Canadian manufacturers, consultants and service companies with a full and fair opportunity to bid competitively.

- Evaluate tenders for goods and services on a "best total value" basis.

- Give first consideration to Nova Scotian goods and services which are competitive.

- Encourage and support the enhancement of Nova Scotian and Canadian technology, expertise and facilities.

- Encourage the transfer of foreign technology and expertise to Nova Scotian and Canadian industry through joint ventures, licensing arrangements or other mechanisms.

- Optimize both short and long term benefits to Nova Scotia and Canada.

- Obtain reliable information and understanding of Nova Scotian and Canadian supply and service capability.

- Ensure that the above principles of full and fair opportunity and first consideration will be part of the obligation of the project contractors and significant sub-contractors.

9.5.1.2  Employment and Training

IASMO is committed to the principles of providing fair and equal employment and training opportunities consistent with the Canadian Charter of Rights and Freedoms. Within IASMO's general employment policy, first consideration will be given to qualified individuals resident in Nova Scotia.
The most important objective is that all project activities are executed by personnel who are knowledgeable and well trained and have the background and skills necessary to perform their jobs in a safe and effective manner.

Most of the people employed on the project during the development phase will work for contractors and suppliers. IASMO will ensure that these companies are aware of the project employment principles, guidelines, and commitments.

IASMO will encourage participation in the project by members of employment disadvantaged groups.

The production phase employment will be determined by the unique nature of this project. Experienced production management, supervision and production operators will be required. They will be from IASMO's staff or from available Nova Scotian or Canadian sources. Experienced operating and maintenance staff will be obtained locally to the degree possible. The contractors' representatives for the jack-up drilling and production unit, the storage tanker, and the shuttle tanker may not be Canadian. IASMO will require that these contractors present a definitive succession plan for the ultimate employment of Nova Scotians and Canadians.

9.5.1.3 Socio-Economic

IASMO will provide information describing project development and production programs and procurement and employment needs to the CNSOPB, government agencies, and to interested groups in Nova Scotia.

A community consultation and information exchange program will be established to respond to community sensitivities. IASMO will provide timely information on its plans and activities. A management team will be available through which interested and concerned individuals and groups may obtain relevant information.
on community impacts and express comments and opinions on IASMO's proposals.

IASMO will provide project information to any agencies, institutions, or communities to assist in assessing the need for changes to programs or infrastructures. The size of the Cohasset/Panuke Development Project is not expected to over-extend any of the existing social and community programs in the province or require any expansions to facilities or infrastructure.

9.5.2 PROCEDURES

9.5.2.1 Industrial

The present industrial capacity of Nova Scotia and Canada will be able to handle a large proportion of this project. It will not be necessary to initiate significant supplier development or research activities although these will be encouraged.

IASMO will implement the following procedures to guide the engineering, procurement, construction and production phases of the Cohasset/Panuke Development Project.

- Establish a Head Office in the province for project management, engineering, and administration activities.

- Establish a shore base and wharf facility to support exploration activities and project development and production operations within the province.

- Actively encourage the participation by Canadian and, in particular, Nova Scotia engineering firms and individual contractors in project management and engineering activities.
- Package bid requests to encourage both large and small Nova Scotian and other Canadian suppliers to take part in the bidding.

- Inform suppliers of the bidding procedures and the names and locations of personnel who purchase goods and services. This will include contractors and significant sub-contractors where appropriate.

- Request Nova Scotian and Canadian Benefits information as part of the bid solicitation process in sufficient detail to assess adequately the benefits to be derived from the individual bids.

- Evaluate bids on a "best total value" basis. "Best total value" means the optimum combination of technical acceptability including quality, overall price, delivery, and service. The benefits to Nova Scotia and Canada including future requirements for similar products or services and the need to develop long term and secure sources of supply will also be considered. First consideration will be given to services from the province and goods manufactured in the province where these services and goods are competitive in terms of fair market price, quality, delivery, and service.

- Maintain an active communication with the business community. Provide useful information on project requirements and opportunities through written material, meetings, and seminars.

- Establish management systems and procedures to ensure that all project contractors and significant sub-contractors are aware of and implement all LADSO's commitments to Nova Scotian and Canadian Industrial Benefits.

- Enter into long term agreements with the offshore services support industry to provide a revitalization or relocation of these companies back into the Halifax area.
- Encourage Nova Scotian and Canadian contractors, suppliers and service organizations to enter into joint venture relationships, licensing arrangements or other mechanisms with foreign companies thus enhancing their expertise and technology base for participation in this project, future projects and internationally.

9.5.2.2 Employment and Training

The objectives of the employment procedures are to provide employment opportunities for qualified Nova Scotians and other Canadians and ensuring that performance and safety standards are not compromised. To achieve these objectives, the following activities will be undertaken by IASMO:

- Assist government agencies and training institutions in identifying suitable pre-employment programs.

- Assist Nova Scotia residents to become aware of short and long term employment opportunities through appropriate communication initiatives.

- Provide government agencies and the business community with information on the labour needs and employment opportunities.

- Apply the principle of equal opportunity employment in hiring, training, and employee development programs.

- Provide a full and fair opportunity for participation to qualified members of employment disadvantaged groups.

- Ensure that development and operations personnel are given the special training required for this project.
- Require that project contractors and significant sub-contractors are aware of and implement LASMO's employment and training commitments.

- Require all contractors to provide a succession plan whereby qualified Nova Scotians and Canadians can enter positions initially held by non-Canadians.

9.5.2.3 Socio-Economic

IASMO will apply the following procedures in order to meet its regional opportunities objectives:

- The project will be designed, constructed and operated so as to minimize potential negative effects and maximize opportunities, as far as practical, in the communities and regions that may be affected.

- Measures to enhance opportunities and mitigate impacts will be designed and implemented through consultation with community representatives.

- A public information program, which will include community consultation, will be implemented to provide to interested parties, timely and realistic information about the nature, scope and timing of the project.

9.6 Categories of Industrial Demand

Goods and services are grouped into four categories of Industrial Demand.

- Fabrication, construction and installation
- Equipment
- Bulk materials
- Services

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9.6.1 FABRICATION, CONSTRUCTION AND INSTALLATION

All fabrication, construction and installation will take place during the development phase of the project. The major components of this category include:

Wellhead Jackets

There will be two wellhead jackets, one at each of the Panuke and Cohasset locations. Each jacket would be comprised of a total of 1200 tonnes of tubular and plate steel, piles and conductor pipe. Fabrication is expected to take about six months for each jacket. They would then be barged to location and installed with the assistance of a derrick barge or jack-up rig.

Production Facilities and Installation

Prior to the commencement of development drilling, the production facilities will be installed on the jack-up rig. This will comprise approximately 700 tonnes of skid mounted oil processing, water injection, water processing and oil transfer equipment. Since these facilities will be integrated into existing rig utility and safety systems, some modifications to the rig will be necessary.

Interfield Flowlines and Loading Lines

This will consist of approximately 9 km of subsea flowlines for both produced condensate and injection water. The pipe will be either line pipe or flexible pipe and size is expected to be 152 - 203 mm. A reel vessel would be used for installation.

Tanker Loading and Mooring Facilities

A CALM type loading buoy and chain mooring system is being proposed to position the storage tanker in the field on a continuous basis during the production season. Once suitable storage and shuttle
tankers have been selected, modifications to these vessels would be required.

9.6.2 EQUIPMENT

A detailed equipment list is presented in Appendix A of this section. Some of the major equipment components include:

Wellheads

A total of 11 wellheads and production trees will be required. Because of the relatively low reservoir pressure, these wellheads will be initially designed at a 34 MWP working pressure level. Wellhead equipment and trees are available from a number of suppliers.

Pumps

Items in this category would include electric powered submersible production pumps, water injection pumps and motors, crude oil transfer pumps and sump pumps.

Production Equipment

The major items in this equipment category will be the pressure vessels (separators) flash drums, heaters, water filters, instrumentation and control valves.

Electrical

Approximately 9 km of subsea electrical control cable is being evaluated for installation between the Cohasset and Panuke wellhead jacket. Additional electrical equipment at the Cohasset production facilities include motor control centres and switchgear.
9.6.3 MATERIALS

Items in this category include steel tubulars and plate, flexible pipe, casing and tubing, valves, cement, wire and cable, drilling mud and fuel.

A detailed material list for both the development and operation phases of the project is presented in Appendix B of this section.

The equipment and material requirements were developed from preliminary engineering studies. As detailed engineering is completed, more definitive information will be made available.

9.6.4 SERVICES

The main items in this category are contracts that can be divided into:

Drilling Related

These include contracts that are directly related to development well drilling operations and include the drilling rig and drilling services such as mud supply, mud logging, cementing, well logging, coring, directional drilling control, wireline and well servicing, etc.

Construction Related

These include contracts that relate solely to the development phase of the project. Some examples of these include pre-engineering and scoping, detailed design engineering, environmental, geotechnical, wellhead jacket design/construction/installation, loading buoy design/construction/installation, production facility design and procurement, etc.
Development and Production Related

These include contracts that are ongoing throughout both the development and production operations phases of the project. They include IASMO's office, shorebase, supply vessels, helicopter, catering, communications, etc.

A detailed list of the contracts expected to be awarded for the project development and production is presented in Appendix C of this section.

9.7 CANADIAN INDUSTRIAL CAPABILITY

This section will review the capability of Nova Scotian and Canadian industry to provide the fabrication facilities and to supply the goods and services required by the Cohasset/Panuke Development Project.

At this time, IASMO has placed the greatest emphasis on fabrication and construction for two reasons:

- The demands for goods and services in the other categories of materials, equipment and services is directly related to the levels of fabrication and construction activity in Nova Scotia, the region and the rest of Canada.

- The requirements in the fabrication and construction category are currently reasonably well defined, permitting a generally accurate assessment of capability. Information of similar quality will not be available for materials and equipment until detailed design engineering has been completed.

The preceding Sections 9.2 and 9.3 discussed, in general terms, IASMO's assessment of Nova Scotian and Canadian industrial capability. In particular, Tables 9.3-1 and 9.3-2 provide a
detailed cost breakdown of the capital and annual operating cost projections by province and commodity.

The following summarizes these assumptions by industrial category:

9.7.1 FABRICATION, CONSTRUCTION AND INSTALLATION

The capability exists within Nova Scotia, the region and the rest of Canada to fabricate, construct and install most of the major components of the project. Some businesses will require upgrading of engineering capability, quality assurance programs, site facilities and skill levels.

Wellhead Jackets

The capability and technical skills exist at two or three locations within Nova Scotia to fabricate and outfit the jackets. The final decision on where to place the contracts will be based on technical and commercial considerations, however it is assumed the work will be done in Nova Scotia. Each of these jackets will require approximately six months to construct and employ up to 150 persons at peak.

Jack-Up Rig Modifications

Prior to the commencement of development drilling, the production facilities are to be installed on the jack-up. These production systems will be integrated with rig systems i.e., electrical, fire/gas, safety, utilities/services. Some deck structural modifications may be required. The installation work is expected to be completed in Halifax Harbour.

Production Facility

The production facilities comprise oil/water/gas separation equipment, water injection equipment, produced water and seawater
clean-up equipment, electrical and safety systems. Most of these components will be constructed as skid mounted packages for ease of installation. It is assumed that some of the fabrication/assembly work and all of the installation work would be done in Nova Scotia. Part of the fabrication would be done within the region, however, main equipment would be supplied out of Ontario, Quebec, Alberta, USA and UK.

**Interfield Flowline and Export Line**

These lines will be of steel line pipe or flexible pipe material. Actual material will be selected at the final engineering design stage. In either case, proprietary design and manufacturing considerations or, lack of steel pipe manufacturing capability, will minimize the ability of Nova Scotia onshore industry to participate. Some local employment could result on the foreign contracted installation vessel that would be used. Additionally, some marine support, i.e., fuel, lubes and consumables, would be supplied from Nova Scotia.

**Tanker Loading/Mooring System**

Engineering Studies are in progress for the mooring system design. The specific arrangements for new construction of a CALM type (proprietary design) loading buoy will depend on competitive commercial arrangements. The capacity to build such a buoy exists within Nova Scotia.

**Storage and Shuttle Tanker Modifications**

Studies are currently being carried out to determine mooring design and market availability. The results of these studies will determine the design of the mooring system and size of both tankers. Depending upon competitive commercial arrangements, yet to be made, these contracts could contain significant Nova Scotia
content as bow loading, mooring and propulsion systems may have to be installed or modified on these tankers.

9.7.2 EQUIPMENT

The plant facilities to manufacture the major equipment required for the project do not currently exist in Nova Scotia. Due to the modest size of the project, new facilities are unlikely to be available. The wellheads, for example, will have to be sourced from Western Canada through licensed distributors of USA, UK or Far East manufacturers. Submersible production pumps, down hole equipment, separators, water injection pumps and motors, control valves and switchgear will have to be sourced from existing specialty manufacturers in Canada, USA or UK where this manufacturing technology already exists. The major impact of the use of this type of equipment will be felt by the service industry. Service personnel, spare parts, and repair facilities will be required during the development, commissioning and production operations phases of the project. New service facilities may be established in Nova Scotia. Existing Nova Scotia companies who have survived the downturn in offshore exploration may expand facilities. More specialized companies are likely to set up new operations in Nova Scotia.

9.7.3 MATERIALS

Many of the consumable items required for development drilling, with the exception of fuel, lubricants and possibly cement, are not available in Nova Scotia but are available in the Atlantic Region or other parts of Canada. Casing and tubing is available in Canada up to 244 mm size. Large dimension casing and conductor pipe will have to be imported from USA or abroad. A limited inventory of drilling bits and drilling tools still exists in Nova Scotia. It is expected that revitalization of the supply/services sector will occur as the result of the project despite its relatively modest size. Steel plate, tubulars, steel sections, and line pipe are all
available from Central and Western Canada. Some capability exists in the province to supply valves and fittings, electrical and instrumentation materials, HVAC and supplies. The exact requirements in terms of type, quantity or size of consumable materials will not be fully known until more detailed design engineering has been completed.

9.7.4 SERVICES

The supply of services under both short and long term contractual agreements represents the largest requirement of industrial demand for the project. The Nova Scotia, regional and Canadian service sector has the capability to provide many of these services either as prime contractors or sub-contractors. A detailed list of the contracts/services expected to be awarded for the project construction and production requirements is presented in Appendix C of this section.

9.7.5 PROCUREMENT

9.7.5.1 Principles

IASMO's procurement principles are consistent with the normal commercial practice of the offshore petroleum industry. Equipment and facilities will have to meet the high standards necessary for a safe and efficient operation. Capable Nova Scotian and other Canadian suppliers will be given full and fair opportunity to bid competitively.

IASMO is committed to the following principles to stimulate industrial opportunities in Nova Scotia and Canada and to execute a successful project:

- Ensure that all materials, equipment and services considered for the project meet the standards necessary to have a safe and efficient operation.
- Provide qualified Nova Scotian and other Canadian manufacturers, consultants, contractors, and service companies with a full and fair opportunity to bid competitively.

- Purchase goods and services on a "best total value" basis.

- Give first consideration to Nova Scotian goods and services which are competitive.

- Ensure that the above principles of full and fair opportunity and first consideration will be part of the obligation of the project contractors and significant sub-contractors.

- Encourage and assist the Nova Scotian and Canadian supply community to identify possible market opportunities.

9.7.5.2 Procedures

The present industrial capability of Nova Scotia and Canada will be able to provide a large portion of the goods and services for this project. The modest project size and overall schedule will not require significant supplier development or research activities. IASMO is committed to encouraging Nova Scotian and Canadian supply and service industries to participate in these new technical and commercial opportunities.

IASMO will implement the following procedures to guide the engineering, procurement, and construction phases of the Cohasset/Panuke Development Project.

- Become familiar with the abilities and capacities of individual Nova Scotian and other Canadian suppliers.

- Announce the need for goods and services as early as possible.
- Review specifications to ensure that they do not unfairly prevent Nova Scotian and Canadian suppliers from participating in the bidding process.

- Ensure that technically and commercially qualified Nova Scotian and Canadian suppliers are included on bid lists.

- Inform suppliers of the bidding procedures and the names and locations of personnel who purchase goods and services, including contractors where appropriate.

- Hold pre-bid meetings with suppliers where necessary.

- Include Nova Scotian and Canadian opportunities information in the bid solicitation process.

- Hold pre-bid meetings with representatives from the CNSOPB and Provincial Government Representatives.

- Evaluate bids on a "best total value" basis. "Best total value" means the optimum combination of technical acceptability including quality, overall price, delivery, and service. Consider Nova Scotia and Canadian content including future requirements for similar products or services. Give first consideration to Provincial services and manufactured goods where these services and goods are competitive in terms of fair market price, quality, delivery and service.

- Communicate with unsuccessful bidders, when requested, to help them bid more competitively in the future.

- Maintain active communications with the business community. Provide information on project requirements and opportunities through written material, meetings, and seminars where appropriate.
9.8 EMPLOYMENT

9.8.1 PRINCIPLES

IASMO is committed to the following principles:

- Providing fair and equal employment and training opportunities consistent with the Canadian Charter of Rights and Freedoms.

- Giving first consideration to qualified individuals resident in Nova Scotia.

- Contributing to the improvement of manufacturing and fabrication skills in Nova Scotia and Canada in order that offshore development and production standards can be achieved.

9.8.2 LABOUR DEMAND

This section will review the expected demand on the labour market in Nova Scotia and Canada during the development and production phases of the project. The estimates are limited to direct demand i.e., the personnel required to manage, design, fabricate, construct, and install the production components, drill the wells during developments, and the personnel required to operate the facility during production.

The preceding Sections 9.2 and 9.3 discussed, in general terms, IASMO's assessment of Nova Scotian and Canadian employment levels. In particular, Tables 9.2-1 and 9.2-2 provide a detailed employment projection for the development and production phases of the project.

9.8.2.1 Development Drilling

At present, there are no Canadian owned/operated jack-up rigs of the type required for this project. It is assumed that the rig will
be non-Canadian. The rig crew could be recruited from Nova Scotia. This employment of Nova Scotians could be achieved by drawing on the pool of experienced offshore rig workers who lost jobs during the downturn in exploration activities and who still reside in the area or who are currently employed on rigs in other parts of the world and may wish to return to Nova Scotia on a permanent basis. This could create up to 70 jobs and generate a total of 175 person-years of employment.

In addition, employment will be created for about 10 persons in shore base operations and another 30 for supply vessel, stand-by vessel and helicopter support. Significant employment for Nova Scotians should result from these support activities.

9.8.2.2 Construction

Direct employment during the design, fabrication, construction and installation of the production facilities is projected to require 380 person-years. The expertise that exists in the province for positions in management, engineering, surveying, drafting, EDP operations and secretarial services indicates that a majority of these jobs will be filled by Nova Scotians.

Preliminary engineering studies have been completed and local Nova Scotia consultants were used. IASMO's head office in Halifax consisting of management, engineering and support staff is expected to provide a further 105 person-years of employment.

9.8.2.3 Production Operations and Maintenance

Upon the completion of construction and installation work, the employment emphasis will shift from onshore to offshore activities. Table 9.2-2 provides an estimate of annual direct employment during this phase. The onshore management, administration and supply base operation activities will require approximately 35 personnel. Some
of the staff from the development phase would remain for these positions.

Offshore production operations employment will increase to approximately 130 positions beginning in 1992 through 1997. These will include supervisory, industrial trades, labour and marine positions in:

- Production Management
- Engineering
- Technicians
- Production Operators
- Maintenance (mechanical, electrical, instrumentation)
- Communications
- Weather Forecasting
- Medical
- Labour
- Supply and Stand-By Vessel Crew
- Storage and Shuttle Tanker Crew
- Helicopter Crew

These jobs represent an important opportunity for Nova Scotians to obtain employment.

Production management and supervisory positions will be filled initially by IASMO's staff and experienced personnel available in Nova Scotia and Canada. IASMO will implement a recruitment and training program early in the production phase to ensure that production operator positions are filled by Nova Scotians.

9.9 REPORTING

IASMO will provide an appropriate internal organizational structure to implement its Nova Scotia and Canadian industrial opportunity commitment during the project. Specifically, IASMO is committed to:

- Providing clearly identified contacts for coordination of information flow from IASMO to the CNSOPB and/or other agencies.

- Determining, through consultation, the contracts and/or purchase orders which the CNSOPB or other government agencies consider important to Nova Scotian or Canadian interests, and, as such, require special reporting at the bid list, pre-bid and pre-award stages of the competitive bidding process.

- Establishing a procedure for monitoring and reporting actual Nova Scotian and Canadian content.

- Monitoring project contractors and significant sub-contractors to ensure that they adhere to IASMO's Nova Scotia and Canadian industrial reporting commitments.
EQUIPMENT LIST

PRODUCTION PROCESS SYSTEM

Stage 1 Separator
Stage 2 Separator
Test Separator
Inlet Manifold
Panuke Inlet Test Heater
Panuke Inlet Riser Manifold

Wellhead Hydraulic Unit

Crude Inlet Heater
Crude Oil Transfer Pump
Meter Prover

Produced Water Flash Drum
Skimmed Oil Tank
Skimmed Oil Pump
CPI Separator
Flotation Cell

Drain Separator
Drain Separator Pump
Drain Separator Recycle Pump
High Pressure Relief Drum
Low Pressure Relief Drum
Low Pressure Drum Return Pump
Wellhead Area Sump Pump
Deck Area Sump Pump
Open Vent Separator
Flare Tips

Injection Water Cartridge Filters
Injection Water Deaerator
Vacuum Pump Knockout Drum
Vacuum Pump
Injection Water Charge Pump
Water Injection Pump
Motor Cooling Blowers

High Pressure Fuel Gas Scrubber
Power Generating Unit
Fuel Filter

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Sodium Hypochlorite Supply Pump
Sodium Hypochlorite Storage Tank
Hypochlorinator Units

Instrument Air Dryer Package
Purge Gas Producer

Bactericide Tank
Corrosion Inhibitor Tank
Scaling Inhibitor Tank
Foam Inhibitor Tank
Oxygen Scavenger Tank
Demulsifier Tank
Tote Tanks (3)

Corrosion Inhibitor Injection Pump
Scaling Inhibitor Injection Pumps
Foam Inhibitor Injection Pumps
Oxygen Scavenger Injection Pumps
Demulsifier Injection Pumps
Bactericide Injection Pumps

AFFF Package
CO₂ System Package
Monitor Foam Package
Firewater Valve Stations
Injection Water Manifold
Portable Extinguishers

Battery Room Unit Heater
Electrical Room Air Heater
Control Room Air Heater
Safety Room Unit Heater
Battery Room Blower
Electrical Room Exhaust Fan
Safety Room Exhaust Fan

Remote ESP Control Panel
Well Control Panel
Process Control Panel
600 Volt Control Centre 1A
600 Volt Control Centre 1B
4160 Volt Switchgear
Variable Speed Drive Controller
Variable Speed Drive Transformers
600/4160 Volt Step-Up Transformers
600 Volt Transformer Feeders
UPS Inverter/Battery System

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Coalescer
Coalescer Heater
Recycle Pump
Crude Offloading Pump
Vacuum Strip Unit
Offloading Meter Prover

WELLHEAD JACKETS

Power Generation (Emergency)
Aids to Navigation
SOLAS Equipment
Fire Fighting Equipment
Electrical Distribution
Communication Systems (radio, telephone)
Hydraulic Systems
Corrosion Prevention System
Anti-Scour Mats
Utility Cranes and Monorails

SUBSEA FLOWLINES

Flexible Pipe and Riser Systems
Manifolds
Control Systems
Safety Systems

DEVELOPMENT DRILLING

Cementing Stingers
Drill String Stabilizers
Solids Removal Equipment
Drill Cuttings Cleaning Equipment
Surface Wellhead Assemblies
Production Christmas Trees
Production Tubing 89 mm through 178 mm
Tubing Crossover Subs
Production Packers (Retrievable)
Seal Assemblies
Subsurface Safety Valves
Hydraulic Control/Chemical Injection Lines
Electrical Submersible Pumps
Power Cables for Electrical Submersible Pumps
Emergency Shut-down Valves
Downhole Pressure Gauges
Tubing Landing Nipples
Tubing Sliding Sleeves
Tubing Plugs
Production/Water Injection Manifolds
Pile Drivers

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PRODUCTION LOADING BUOY AND MOORING SYSTEM

CALM Buoy
Heating Unit
Generator
Fenders
Anchors
Remote Valve Operators
Thimbles
Load Cells
"Smit" Bracket
Closure Devices
MATERIALS LIST

PRODUCTION PROCESS SYSTEM

Schedule 40 Line Pipe and Fittings
Schedule 80 Line Pipe and Fittings
Instrument Tubing and Fittings
Structural Shapes and Plates
Miscellaneous Fabrication Steel
Electric Cable and Fittings
Electrical Boxes, Marine Grade and Explosion Proof Instruments (general)
Safety Equipment and Systems

WELLHEAD JACKETS

Electrical Cable and Fittings
Structural Steel Plate
Structural Steel Shapes
Miscellaneous Steel
Grating
Line Pipe, Fittings and Valves
Helideck Fittings
Paint

SUBSEA FLOWLINES

Valves
Miscellaneous Steel and Piping

DEVELOPMENT DRILLING

Oilwell Casing 178 mm through 762 mm
Oilwell Cement
Cementing Chemicals
Casing Centralizers
Casing Float Shoes and Float Collars
Mudline Suspension Systems
Drilling Bits 311 mm through 914 mm
Drilling Mud and Chemicals
- viscosifiers
- thinners
- weight additives (barite)
- bentonite
- polymers
- potassium chloride
- fresh water
Chemicals
- wax solvents
- scale removers
- corrosion inhibitors
- stimulation treatment chemicals
- de-emulsifiers
- oxygen scavengers
- biocides
Wireline Bridge Plugs
Perforating Charges
Fuel
- marine diesel
- aviation fuel
Lubricants

PRODUCTION LOADING BUOY AND MOORING SYSTEM

Steel Plate and Shapes
Machined Fittings
Fluid Swivel
Paint
Lights
Telemetry
Steel Plate and Shapes
Chain
Connectors
Steel Pipe
Cast Steel
Connectors
Cast Steel Valves
Gaskets
Fasteners
Nylon Rope
Steel Chain
Rubber Hoses
Flotation Hoses
APPENDIX C

CONTRACTS/SERVICES
PRELIMINARY

DEVELOPMENT DRILLING

Jack-up Drilling/Production Rig
Rig Structural Modifications (legs, jacks, spud cans)
Catering
Rig Services/Consumables
  - Cement
  - Mud
  - Bits
  - Logging
  - Coring
  - Fuel
  - Water
  - Lubricants

PRODUCTION PROCESS SYSTEM

Rig Modification for Production Equipment
Process Equipment Design, Procurement, Expediting
Process Equipment Installation on Rig
Wellhead Jacket Design, Fabrication, Installation
Loading Buoy Design and Fabrication
Loading Buoy/Mooring System Installation Contract
Subsea Flowline Design, Manufacture and Installation
Safety Training Programs
Diving/Inspection Service
Tanker Contracts
Production Equipment Spare Parts
Maintenance

MISCELLANEOUS

Halifax Project Office
Halifax Office Equipment, Supplies, Services
Environmental Engineering Studies
Geotechnical Studies
Management/Engineering
Certification
Shore Base Operations
Helicopter Services
Supply Vessels
Standby Vessels
Transportation Studies
Marketing Studies
Communications

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Weather Forecasting
Quality Assurance Services
Customs Brokerage
SECTION 10
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SECTION 10. CERTIFICATION PLAN

10.1 INTRODUCTION

The Cohasset/Panuke Development Project will utilize capital cost components such as production facilities, well jackets and flowlines, a well as leased components such as a jack-up drilling unit, tanker mooring and offloading system, storage tanker and shuttle tanker. This section describes the plan to apply for and receive government approvals for each component and ultimately a Certificate of Fitness (COF) issued by the selected and approved certifying authority (CA).

This section has two main subsections, 10.2, Scope of Certification and 10.3, Quality Assurance and Quality Control. Section 10.2 describes the organizations involved, the scope of work and the basic approach to submitting documentation to the regulatory authorities. Section 10.3 describes the Quality Control and Quality Assurance plan required to obtain the necessary documentation.

10.2 SCOPE OF CERTIFICATION

Under the Canada Certificate of Fitness Regulations, a Certifying Authority (CA) may issue a Certificate of Fitness (COF) on behalf of the CNSOPB for the major components of the Cohasset/Panuke Development Project.

IASMO has selected Lloyd's Register of Shipping (Lloyd's) as the Certifying Authority for the project. Lloyd's scope of work is broadly broken down into 20 activities:
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<th>Activity</th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Review Design Criteria</td>
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<td>2</td>
<td>Review Wellhead Jackets</td>
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<td>Review Production Facilities</td>
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<td>4</td>
<td>Review Flowlines</td>
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<td>5</td>
<td>Review CAIM</td>
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<td>6</td>
<td>Review Jack-Up</td>
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<td>7</td>
<td>Review Tankers</td>
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<td>8</td>
<td>Survey Structural Steel</td>
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<td>Survey Critical Items</td>
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<td>Survey Jackets</td>
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<td>13</td>
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<td>Survey Modifications to Tanker</td>
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<td>15</td>
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<td>Survey Installation of Jackets</td>
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<td>17</td>
<td>Survey Installation of CAIM</td>
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The estimated budget for the C.A. work is approximately 4000 hours, $400,000 Canadian.

The basic certification scheme is shown in Figure 10.2-1.

All CA tasks will fit in with the overall project schedule. The schedule will be regularly updated.
BASIC CERTIFICATION PROGRAM

FIGURE 10.2-1
10.2.1 SCOPE OF CERTIFICATION DETAILS

A further breakdown of the certification activities is as follows:

(1) Review Design Criteria

(a) Review environmental data
   - wind
   - waves
   - currents, tides
   - ice (floes and structure icing)
   - temperatures, etc.

(b) Review geotechnical data

(c) Review design specifications

(d) Review structural specifications
   - materials
   - welding
   - heat treatment
   - non-destructive and destructive testing
   - construction and installation

(e) Review topside facility specifications
   - mechanical installations and pipework
   - electrical installations
   - lifting equipment
   - welding
   - fire fighting and lifesaving equipment

(2) Review Wellhead Jackets

(a) Review computer program documentation
(b) Review design specifications

(c) Carry out computer analyses on the jacket structure
   - static in-place analysis
   - fatigue analysis
   - foundations

(d) Carry out other design calculations
   - boat impact assessment
   - load out, tow out and installation

(e) Review corrosion protection systems and coatings

(f) Review drawings

(3) Review Production Facilities

(a) Drilling, Production and Utilities Systems
   - piping and instrumentation drawings
   - piping systems, calculations
   - ventilation schematics
   - flare and vent systems
   - emergency power and black starting arrangements
   - diving systems
   - construction of tanks
   - hazardous chemical systems
   - hydraulics and pneumatic systems
   - steam and hot water systems
   - fuel burning and transfer systems
   - drains

(b) Electrical Systems
   - main and emergency power systems
   - ratings on electrical machines
   - feeders on main and emergency switchboards
- cable details
- details of circuit breakers and fuses
- circuit diagrams of generators, inter-connectors and feeder circuits
- short circuit calculations
- electrical equipment in hazardous areas
- general arrangements of major electrical equipment items

(c) Control and Instrumentation Systems
- emergency and process shutdown
- loop diagrams
- alarm systems
- programmable electronic systems
- testing and commissioning documentation

(d) Fire Protection
- structural fire protection (general arrangement, construction details and protection and penetrations)
- blast protection
- certificates of approval and fire test data
- fire and gas detection and alarm systems
- details of equipment and hazardous area rating
- locations of main and emergency power supplies
- fire fighting systems
- materials and construction of fire main systems
- method of storage or supply of extinguishing medium
- rate of application and duration of supply

(e) Emergency Escape
- escape routes
- access

(f) Life Saving Appliances
(g) Helideck

(h) Accommodation Arrangements

(i) Noise and Vibration

(j) Operations Manual

(4) Review Flowlines and Risers

(a) Review Environmental Conditions

(b) Review Geotechnical Conditions
   - seabed profile survey
   - free spanning criteria

(c) Review Routing

(d) Review Computer Program Documentation

(e) Review Plans

(f) Review Installation Procedures
   - trenching procedures
   - dimensioning
   - specifications
   - coatings
   - crossings
   - reinforcements
   - corrosion protection
   - proof pressures
   - stresses applied during laying
   - inspection requirements
(g) Riser Protection against Impact

(h) Review Inspection Sequences

(5) Review Single Point Mooring System (CAIM)

(a) Review design and material specifications, tank model tests and seabed reports

(b) Review environmental criteria

(c) Assess critical load cases

(d) Assess environmental and tanker loads (based on model test results)

(e) Assess foundation

(f) Assess CAIM structure

(g) Review CAIM tethering and anchorages

(h) Assess mooring hawser

(i) Assess piping, electrical, hydraulic and control systems

(j) Approval of detail plans

(k) Review of flexible riser

(l) Review of operating conditions

(m) Review of installation procedures

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(6) Review Jack-Up

(a) Assess unit for long-term operation

(b) Assess unit for compliance with the requirements of the Production Regulations

(c) Foundation
   - site investigation
   - preloads and overturning moment
   - penetrations, bearing capacity, sliding resistance, scour
   - settlements
   - positive scour prevention measurements

(d) Strength
   - increased wave loads due to marine growth

(e) Fatigue
   - review of leg structures and leg hull interfaces

(f) Boat Impact
   - review for COGLA boat impact requirements

(g) Added topside structures
   - modules
   - structural skids
   - flare tower or boom
   - vent shacks
   - crane pedestals

(7) Review Tankers

(a) Storage Tankers
   - assessment of wave loads and motions
- assessment of tank sloshing
- structural modifications
- longitudinal strength investigation
- reinforcements required for shuttle loading
- corrosion protection system
- helideck structure
- crude transfer boom
- cranes
- plan approvals
- accommodation/safety equipment
- machinery and equipment
- electrical and control installations
- fire protection, detection and extinction

(b) Shuttle Tanker
- review class requirements

(8) Survey Structural Steel

(a) Monitor Steel Production
(b) Monitor the inspection organization
(c) Witness mechanical testing
(d) Review and endorse mill certificates

9. Survey Critical Items

(a) Pressure vessels
(b) Heat exchangers
(c) Lifting appliances
(d) Wellhead equipment
(e) Fire pumps
(f) Emergency generator
(g) Tanks for hazardous fluids
(10) Survey Jackets

(a) Assess fabricator's quality assurance and quality control system

(b) Assess construction proposals

(c) Review material control and identification system

(d) Approve welding specification and any heat treatment proposals

(e) Approval weld procedure qualification tests

(f) Monitor welder qualification and welder identification controls

(g) Monitor welding quality record system

(h) Approve non-destructive and destructive testing proposals and review results or reports

(i) Monitor the procedure for examination and acceptance of sub-fabricated items

(j) Survey the construction and make random examination of structure

(k) Survey the structural fire protection

(l) Monitor procedures for repair, retest and acceptance

(m) Witness relevant pressure, functional or other tests which are not to be repeated offshore
(n) Monitor load out and survey the attachment of seafastenings to the structure

c) Prepare/agree Punch List of items to be completed offshore

(11) **Survey Processing Installations**

(a) Assess fabricator's quality assurance and quality control system

(b) Assess construction proposals

(c) Review material control and identification system

(d) Approve welding specification and any heat treatment proposals

(e) Approval weld procedure qualification tests

(f) Monitor welder qualification and welder identification controls

(g) Monitor welding quality record system

(h) Approve non-destructive and destructive testing proposals and review results or reports

(i) Monitor the procedure for examination and acceptance of sub-fabricated items

(j) Survey the construction and make random examination of structure

(k) Survey the structural fire protection

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(l) Monitor procedures for repair, retest and acceptance

(m) Witness relevant pressure, functional or other tests which are not to be repeated offshore

(n) Monitor load out and survey the attachment of seafastenings to the structure

(o) Prepare/agree Punch List of items to be completed offshore

(12) **Survey Flowlines**

(a) Review Contractor's quality system

(b) Inspection of seamless pipe

(c) Approval of the manufacturing processes employed by the steelmaker

(d) Approval of NDT procedures and operators

(e) Verify chemical properties of the steel against specification

(f) Witness all mechanical testing in accordance with agreed specifications

(g) Monitor stamping and marking of pipes

(h) Ensure certificates are issued for pipes inspected

(i) Inspection of welded pipe
(j) Witness weld procedure and weld performance qualification tests

(k) Ensure incoming steel plate is checked against documentation

(l) Approval of radiographic and any other NDT procedures and operators

(m) Witness mechanical tests

(n) Monitor non-destructive testing by either ultrasonic or radiographic methods

(o) Witness external examination of pipe surface and welded seam for any defect and dimensional check of pipe

(p) Witness and verify stamping and marking of pipe and ensure certificates are issued for the pipes inspected

(q) Inspection of coating

(r) Check incoming pipes against documentation for verification and against damage in transit

(s) Monitor wrapping and coating of pipe against agreed specification

(t) Check quality of concrete, placement of reinforcement and application of weight coat against specifications

(u) Ensure certificates are issued for coated pipes inspected
(v) Inspection of anode fabrication

(w) Inspection at fabricator's works will include:

- conformance check with material specifications
- visual inspection of all welds, brazes to anode material, witnessing of NDT where required

(13) Survey Modifications to Jack-Up

(a) Condition survey

(b) Modification survey as follows:

- Assess fabricator's quality assurance and quality control systems
- Assess construction proposals
- Review material control and identification system
- Approve welding specification and any heat treatment proposals
- Approval weld procedure qualification tests
- Monitor welder qualification and welder identification controls
- Monitor welding quality record system
- Approve non-destructive and destructive testing proposals and review results or reports
- Monitor the procedure for examination and acceptance of sub-fabricated items

- Survey the construction and make random examination of structure

- Survey the structural fire protection

- Monitor procedures for repair, retest and acceptance

- Witness relevant pressure, functional or other tests which are not to be repeated offshore

- Monitor load out and survey the attachment of seafastenings to the structure

- Prepare/agree Punch List of items to be completed offshore

(14) **Survey Modifications to Tanker**

(a) Survey structural modifications

(b) Survey any additional plant or equipment installations

(15) **Survey Modifications to the CALM**

(a) Condition survey for existing mooring system

(b) Survey structural modifications

(c) For new unit survey see list of items in 10 above
(16) **Survey Installation of Jackets**

(a) Witness the lift of the jacket, its upending and setting on the seabed

(b) Monitor the pile installation process and establish that the necessary pile penetrations have been achieved

(c) Monitor the grouting procedure and the casting of test samples

(d) Obtain confirmation that the water depth of the jacket is as considered in the design, and monitor the checking of levels and orientation

(e) Monitor any welding operations, removal of sea fastenings, etc.

(f) Monitor removal of sea fastenings and dressing of primary structure

(17) **Survey Installation of CAIM**

(a) Approve all weld procedure and performance qualification tests or alternatively, accept previously approved tests.

(b) For the mooring, witness piling operation, or alternatively, establish that the approved mooring arrangement is achieved

(c) Witness attachment of the mooring/tanker
(18) Survey Installation of Production System

(a) Survey any construction
(b) Monitor the procedure for clearing punch-listed items
(c) Survey the installation of equipment and piping and completion of systems
(d) Monitor procedures for repair, retest and acceptance
(e) Random examination of structure and structural fire protection
(f) Witness relevant pressure, functional or other hook-up tests
   - pressure tests
   - leak testing of hydrocarbon systems
   - function testing of equipment and associated safety devices
   - load tests on lifting appliances
   - installation tests on electrical equipment
(g) Check escape routes, handrailing and stairways

(19) Survey Installation of Flowlines

(a) Installation of flowlines will be monitored as follows:
   - Witnessing of weld procedures and welder's qualification tests
   - Documentation for incoming pipes is verified and pipes checked for damage in transit

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- Approval of radiographic and any other NDT procedures and operators

- Monitoring alignment of pipes prior to welding including inspection during root, hot pass, filling and capping runs

- Witnessing and acceptance of radiographs and any other non-destructive testing

- Witnessing of wrapping and coating of field joints

- Certificates are issued for pipelaying monitored

- Trenching of flowline and backfilling operations, if performed

- Review of video and sidescan sonar

- Testing and commissioning of the flowlines and risers are witnessed in accordance with the specifications and overall certificates issued for the installed lines

(20) Survey Hook-Up and Commissioning

Relevant commissioning function tests are witnessed and calibration is monitored for:

(a) Main and emergency sources of power

(b) High and low voltage power distribution

(c) Rotating machinery
   - diesel engines
- gas turbines
- compressors
- reciprocating and centrifugal pumps

(d) Heating, ventilation and air conditioning, including differential pressurization

(e) Systems for emergency shutdown and depressurization of hydrocarbon systems

(f) Fire and gas detection system

(g) Active fire fighting

(h) Well control equipment

(i) Drilling system running gear and equipment
   - manriding winches
   - utility winches
   - casing stabbing board
   - drawworks braking system

(j) Lifting appliances

(k) General platform alarms and public address

(l) Navaids

(m) Lifeboats and lifesaving appliance
10.2.2 APPROACH TO PROJECT APPROVALS

The Certifying Authority will establish at which milestones and key events it will perform certain tests, surveys and inspections. LASMO will provide up to date schedules to allow the CA to plan and allocate resources in accordance with the schedule requirements.

LASMO will specify to which quality standards equipment suppliers and fabricators must conform. The CA will review these requirements and where there is a difference of opinion, discuss them with LASMO. Finally, both parties will reach an agreement on which of the categories of the CSA Z299 series of codes or other equivalent codes is applicable to which part of the development project.

Having established schedules and quality requirements, the CA will carry out all required tests, inspections and surveys and will issue to LASMO certificates testifying that the inspected components have met the design, fabrication and installation criteria and are, therefore, accepted parts of the project.

As the completion of the construction and installation activities, all components of the project having been found acceptable, the Certifying Authority will issue a Certificate of Fitness.

LASMO will submit a maintenance program to the CA before operation commences which will detail maintenance procedures and routines that will assure the proper functioning and protection of all key components of the development project. A continuous inspection program designed jointly by LASMO and the CA will assure that the requirements of the Certificate of Fitness are maintained. It is the intent that an extension to the five year validity of the Certificate of Fitness will be applied for.
10.2.3 REPORTING AND DOCUMENTATION

The Certifying Authority (Lloyd's Registry) was appointed by IASMO in February 1990. The monthly reports will be submitted to the Chairman of the Canada/Nova Scotia Offshore Petroleum Board, until the Certificate of Fitness has been received.

The report will contain the following:

- a schedule showing milestones and key events in the certification process as well as all other survey and inspection activities to be carried out by the CA

- a description of the tests, inspections and surveys performed over the previous month, the results thereof and the certificates, if any, obtained

- a prognosis of the following month's program

10.2.3.1 Documentation

A document control program will be set up to keep track of all project documentation. Documents include mill test and inspection certificates, drawings and non-conformance reports.

IASMO, together with the CA, will establish a detailed listing of all documents to be reviewed and certificates to be obtained. A document register will be kept which will control the preparation, review, approval, distribution and revision of drawings, specifications, procedures, manuals, instructions and sketches, whether these were originated by IASMO, the engineering contractor, any subcontractors, or consultants.

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10.3 QUALITY ASSURANCE AND QUALITY CONTROL

LASMO values quality and believes that a quality design and strict quality control in the execution of the construction, fabrication and installation contracts are vital not only to maintaining the technical integrity of the project, but also to meet the project cost and schedule goals.

The LASMO overall quality assurance and quality control program is being developed in detail and will be finalized during the final engineering phase. Once in place, the program will form the basis for the total project quality assurance and quality control.

Figure 10.3-1 is a schematic outline of a quality assurance flow chart for the project.

10.3.1 STANDARDS

Part I, Section 3 of the Canada Oil and Gas Installation Regulations makes reference to the Canadian Standards Association Z299 series of quality program standards. LASMO will reference these standards in its quality assurance program and will impose them on its contractors, subcontractors and consultants. Where contractors have not been certified as being capable of working to the Z299 requirements but do have somewhat equivalent procedures in place in accordance with other national or international codes or standards, then LASMO may recognize these procedures.

LASMO and the CA will review requests for revisions, amendments and changes to the QA/QC program manual. The principal philosophies of the CSA Z299 series will not be compromised, however.

The key to selecting the appropriate levels of the Z299 series is a reliability analysis of all major components of the development project. The analysis will provide probabilistic values which
should not be exceeded for component failures. From these values the Z299 categories are set. Figure 10.3-2 shows the main features and structure of the Z299 standards as one progresses from the simplest Z299.4 to the most stringent Z299.1. With each step, the requirements, as shown in the comparison matrix, increase in number to become more comprehensive.
PROJECT QUALITY ASSURANCE FLOW CHART

QUALITY STANDARDS CNA3-2299 → CONTRACT DOCUMENTS → COHASSET/PRUKE QUALITY ASSURANCE PLAN

PROJECT QA/QC PROGRAM MANUAL

PROJECT QA/QC DETAIL PROCEDURE

PROJECT QUALITY DOCUMENTATION

CERTIFICATION STATUTORY APPROVAL

FIGURE 10.3-1
MAIN STRUCTURE OF CANADIAN QUALITY ASSURANCE STANDARDS

FIGURE 10.3-2
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APPENDIX A

MARCH 12, 1990
SECTION 11. SAFETY PLAN

11.1 INTRODUCTION

Offshore exploration, development and production operations utilize a combination of petroleum and marine technology and expertise to operate safely.

LASMO Nova Scotia Limited recognizes the fundamentals of a safe offshore operation to be the following:

- Establishment of an organization, philosophy and structure that ensures safety is an integral component to all facets of the operation

- Recognition that safety is an obligation of all personnel involved in the operation

11.2 POLICY STATEMENT

It is the goal of LASMO to reduce risks and thereby minimize the losses due to personal injury and property and environmental damage in the conduct of development and production operations offshore Nova Scotia.

LASMO will plan its activities in order to conduct the safest possible operation. All personnel will have the responsibility to ensure equipment and procedures are safe. Unsafe conditions, procedures or hazards observed will be reported and corrected immediately.

11.3 SUPPLIER AND CONTRACTOR SELECTION

LASMO purchasing procedures will ensure that safety and lifesaving equipment and material required for the activity are appropriate for their intended use and meet all applicable standards.
A review will be carried out on chemical substances procured for the project to ensure they are not potentially hazardous to worker health or the natural environment.

All contractors will be required to comply with all applicable government regulations. IASMO will establish a contractor safety program evaluation format to ensure contractors' programs comply with government's, industry's and IASMO's standards.

Through the bidding process and contract documentation, contractors will be required to have in-place, or to develop, a safety program that is acceptable to IASMO.

IASMO has adopted the plan outlined below for its offshore program and will, as planning moves into operations, expand this outline into fully supportive safety procedures and instructional documentation.

A full-time Safety Coordinator has been appointed to develop, implement and maintain the program. It will be his responsibility to monitor the program's compliance with IASMO policy, industry standards and existing/pending legislation and guidelines, including:

- Canada Oil and Gas Drilling Regulations 1988 (COGDR)

- Drilling for Oil and Gas on Frontier Lands - Guidelines and Procedures - September 1986

- Oil and Gas Occupational Safety and Health Regulations

- Marine Occupational Safety and Health Regulations

- Safety requirements published in regulations promulgated pursuant to the Canada Shipping Act
11.4 SAFETY MANAGEMENT

The LASMO Safety Plan will involve a modern accident prevention program. A Safety Program Manual will document all facets of the plan pertaining to jack-up drilling units, production facilities, platforms, and subsea and transportation systems.

11.4.1 JOB PROCEDURES

LASMO is adopting techniques used within modern safety programs that involve procedural job safety. Each critical function will be reviewed and, in conjunction with the engineered safety considerations already built into the process, a safe and proper job procedure will be developed under the guidance of knowledgeable supervisory staff and the competent workers responsible for the completion of the task.

Quality Control plays a significant role in this process. A critical element in a proper job procedure program is the understanding that certain tasks will change as situations and equipment change.

LASMO will conduct a review of the job procedure on a regular basis to ensure that any changes to assigned tasks are reported, investigated, and the procedure amended as necessary.

Performance standards and procedures will be documented in operating manuals. A system for updating the manuals will ensure that documented procedures remain current and improvements to safe work practices are incorporated.

Safe work procedures will be developed. These procedures will outline the acceptable standards involving the following concerns:

- hot work
- confined space entry
- personal protective equipment
- pressure testing
- flammable and toxic material handling
- hazardous area control
- lock-out and tag-out systems

11.4.2 HEALTH SERVICES

Medical expertise will be available to assist in early identification of potential work-induced health problems.

IASMO will arrange, through competent and professional medical practitioners, full medical coverage for its shore-based and offshore employees. The doctors will also support the occupational health needs of the employees.

A primary step in the provision of health services is the IASMO requirement for all employees to undergo a pre-employment medical examination to ensure the physical capability of the individual to complete the tasks associated with the position.

Emergency medical care and response, for contractor and subcontractor personnel working offshore on IASMO operations, shall be provided.

It is intended to conduct this medical services program through a group of physicians/medical support staff experienced in providing 24-hour offshore emergency medical care.

Medical services onboard the offshore production unit shall be provided by trained and competent medics (per the Canada Oil and Gas Drilling Regulations - November 1988, Section 35(4) (c)), who meet the requirements of the Oil and Gas Occupational Safety and Health Regulations and the Drilling for Oil and Gas on Frontier Lands (Guidelines and Procedures - September 1986).
These offshore medics will be supported by the team of shore-based physicians. The medics will keep an accurate, confidential medical log of all of their activities and these logs shall be reviewed on a monthly basis by the shore-based medical support service.

On a semi-annual basis the offshore installation's medical and health services shall be inspected and a report prepared for IASMO by a physician from the medical support services group.

**ACCIDENTS/INCIDENTS**

Accidents or incidents (situations resulting in a potential accident) occurring in an offshore operation indicate that a breakdown in the control of the operation exists. Proper procedures to report, investigate and follow up will be required to ensure the basic cause of the breakdown is identified. Appropriate recommendations will be developed and implemented. In addition, reports will be maintained and a data base developed in order to conduct statistical analysis.

IASMO will provide a system of reporting both accidents and incidents. A IASMO-specific accident and incident report form will be designed in order to provide a standardized format for the collection and distribution of accident information throughout the project. This report form will, of course, be in addition to those incident reporting forms already required by the regulatory authorities. IASMO will require its personnel and all contractors to report accident and near-miss incidents.

*Every accident and significant incident will be the focus of an accident investigation. The severity or potential severity will determine the degree of investigation required. In all cases, on-site supervisors will review the incident, prepare a report and ensure corrective action is taken to prevent similar incidents from re-occurring. IASMO intends to use the information resulting from the investigations in a positive, pro-active manner.*
Accident investigations will be analyzed to identify causes, not fault, and will be used to reduce the potential of future accidents resulting from these circumstances. A proper analysis will expose trends and identify substandard acts or substandard conditions such that these hazards may be eliminated or controlled immediately.

11.4.4 ENGINEERING

Engineering design policies have been adopted by IASMO that recognize construction and operational hazards. These policies actively engineer the reduction and elimination of identified hazards in IASMO workplaces.

System design standards that emphasize loss prevention are instrumental in achieving a safe offshore work environment.

IASMO’s design standards for equipment and systems will incorporate the "BAST" philosophy (Best Available Safety Technology) and will consider unique local conditions. All applicable industry and government design standards will be met or exceeded.

IASMO has implemented a formal design review process (Conceptual Safety Review) which includes periodic safety reviews during the design and construction of major systems and facilities. This design review process identifies conditions that require design modifications in order to improve safety and thereby eliminate "built-in" hazards.

Hazard and operability studies will be conducted during the design phase and a hazard/operability survey will be conducted prior to final commissioning and start-up.

11.4.5 EQUIPMENT MAINTENANCE

An extensive preventative maintenance system (PMS) will be put in place in encompassing all components of the development project.
The extent of the maintenance program established for each individual component will depend on the reliability level assigned to that component. High reliability requirements mean intensive preventative maintenance programs.

Leased equipment will be subject to the same maintenance requirement criteria as the IASMO-owned equipment.

The PMS will include coded equipment indices, maintenance routines, trade assignments, man-hour estimates, scheduling by accumulated running hours or time intervals, history records for each component, and work activity reports.

11.5 OCCUPATIONAL SAFETY AND HEALTH

The IASMO Occupational Safety and Health (OSH) program is designed to support IASMO's policy dedicated to reducing workplace risks. It will also conform to Canadian and regional regulatory requirements, such as those embodied in the Canada Labour Code (Part II) and the safety regulations pursuant to the Act.

Occupational Safety is a broad program that will centralize its efforts on a number of significant points.

11.5.1 HAZARD AWARENESS

Supervisory staff and workers must be made aware of physical and chemical workplace hazards. Procedures are being developed (Section 11.4.1) to minimize the effect of selected hazards. Procedures dealing with other specific hazards will be developed/implemented as required.

IASMO will fulfill the requirements of this general category by conducting the following:
- pre-job safety meetings (critical or potentially hazardous operations); and

- regular safety inspections conducted by competent individuals (every two months per unit).

IASMO will implement a safety audit program to assess the degree of implementation of the safety process. This will include compliance with OSH regulations.

The objective of the audits will be to identify strengths and weaknesses in the program. Follow-up action and feedback will be essential components of the safety auditing process. In addition to IASMO's program, contractor programs will be audited for OSH compliance.

IASMO employees, and all personnel working on IASMO premises, shall be made aware of chemical hazards.

All personnel shall be required to have completed the mandatory Workplace Hazardous Materials Information System (WHMIS) program.

11.5.2 SAFETY MEETINGS

Regular safety meetings will be held in conjunction with active, participatory workplace Health and Safety Committees. Committees will be formed with representation from all sections of the offshore workplace. Meetings will be minuted.

Supervisors will attend and participate in these meetings and the minutes will receive wide internal distribution. A system will be established to ensure follow-up action is initiated for items identified at these meetings.
In addition to communications through committee representation, personnel will be reminded of the continuous need for safety through bulletins, posters and other media.

Safety performance statistics of the operations will be displayed. The goal will be to instill a pride in all personnel regarding the safety record achieved by the operation.

11.5.3 OFFSHORE HEALTH

Noise level and light level surveys of designated areas are to be conducted annually, or when deemed necessary by supervisors or the Workplace Safety Committee.

The types and quantities of personnel protective equipment required will be established. Only equipment that meets or exceeds regulatory standards will be used. All personnel will be instructed regarding the proper operation of the equipment and under what conditions the equipment should be used.

Potable water quality samples will be taken and analyzed on a routine basis.

11.5.4 EMERGENCY DRILLS

A program will be implemented to ensure ongoing emergency drills are conducted. Drill guidelines and reporting procedures will ensure personnel remain familiar with emergency procedures and that new personnel have an effective opportunity to learn unit emergency procedures. Drill frequency and content will comply with the requirements noted on the COGDR and the September 1986 Guidelines.
11.5.4.1 Evacuation and Abandonment

This scenario will be conducted on a weekly basis, under command of the Offshore Installation Manager (OIM). A full procedure will be developed for each installation/vessel.

Generally, the evolution will consist of the alarm, crew response actions, debriefing, and assessment/notes for improvement.

11.5.4.2 Fire Fighting

This scenario will be conducted on a weekly basis under command of the OIM. A full procedure will be developed for each installation/vessel. Generally, the evolution will consist of the alarm, crew response actions, debriefing, and assessment/notes for improvement.

11.5.4.3 Stability Control

This scenario will be conducted at the OIM's discretion, but at intervals of not more than 14 days. A full procedure will be developed for each installation. Generally, the evolution will consist of the alarm, crew response actions, debriefing, and assessment/notes for improvement.

11.5.4.4 Man Overboard

This scenario will be conducted at the joint discretion of the OIM and the Standby Vessel Master, but at intervals of not more than 14 days. A full procedure will be developed for each installation/vessel. Generally, the evolution will consist of the alarm, crew response actions, debriefing, and assessment/notes for improvement.
11.5.4.5 Hydrogen Sulphide (H₂S) Release

An analysis of both Cohasset and Panuke reservoir fluid properties has indicated that hydrogen sulphide is not present in either formation.

However, in recognition that certain well stimulation techniques can promote the development of H₂S, IASMO will train its offshore installation crews in response to an H₂S release and will introduce H₂S awareness to support and standby vessel crews as well.

A full procedure will be developed for each installation/vessel. Generally, the evolution will consist of the alarm, crew response actions, debriefing, and assessment/notes for improvement.

11.5.4.6 Well Control

This scenario will be conducted at the joint discretion of the OIM and Senior Drilling Supervisor onboard, at weekly intervals for each drilling team. A full procedure will be developed for each installation. Generally, the evolution will consist of the alarm, crew response actions, debriefing, and assessment/notes for improvement.

11.5.4.7 Oil Spill

This scenario will be conducted under the direction of shore-based management, in compliance with the COGDR 151(d) requirement for an annual Oilspill Countermeasures Exercise.

The exercise shall normally involve the crews of the support vessels, helicopters and elements of the industry response organization ESRI (Eastcoast Spill Response Inc.). Drilling and production installation crews will be drilled in on-deck and local spill control and clean-up operations as appropriate to the equipment normally available onboard.
LASMO Nova Scotia Limited recognizes the critical importance of both professional and emergency response training programs necessary to support offshore drilling, development and production operations.

A significant training effort will be undertaken by LASMO. The Safety Coordinator will be responsible for the provision and administration of industrial safety training programs for both offshore and shore-based staff.

Increasing the proficiency of employees will improve the safety and efficiency of the operation. Formal courses or on-the-job skills training will be conducted to ensure personnel understand operating and emergency procedures related to their specific jobs. Safety will be emphasized during this training.

First Aid and Cardiopulmonary Resuscitation training will be provided for employees in sufficient numbers to comply with appropriate regulations.

All personnel employed offshore will be required to successfully complete a recognized offshore survival training program. The LASMO standard is the Basic Survival Training (BST) course, or equivalent.

It is LASMO's intention to require this certificate to be displayed by the individual prior to boarding any transportation offshore.

Personnel responsible for specific emergency duties will be required to complete specialty courses. These will include courses for the following:

- H2S training
- lifeboat coxswains
11.6.1 CREW TRAINING


LASMO will require personnel working offshore to have completed the required training prior to departing for the installation. Exceptions will be limited.

To ensure all personnel have the appropriate certification, LASMO's Safety Coordinator will administer a safety training report that will report to LASMO management the current status on company, contractor and subcontractor personnel training.

Copies of LASMO employees' training certificates will be kept on file and contractors and subcontractors will receive direction to comply with a similar record-keeping effort.

Excerpts from the Industry Guidelines for Training Qualifications/Standards of Crew Personnel for Operations on Canada's Offshore Frontiers - Second Edition, January 1990, are attached. These excerpts, involving key offshore personnel, are included to
demonstrate the industry training standards that IASMO will follow. They can be found in Appendix A.

11.6.2 STANDBY VESSELS

This subsection outlines the crew manning and training requirements necessary to comply with government regulations and industry standards applicable to an offshore vessel while in the Standby Mode.

Vessel manning requirements, pursuant to COG manning regulations, vary depending on the size of the vessel, the extent of its voyage, the waters in which it sails, and the tasks it is expected to perform.

Each marine position, and most notably the positions requiring marine Certificates of Competency, are the subject of federally regulated training requirements.

Industry's specialized requirements for Standby Vessel crews are outlined in the previously mentioned Industry Training Qualifications and Standards document.

11.7 CONTINGENCY PLAN

Please refer to Section 12 of this Preliminary Development Application.

11.8 PROCEDURES

11.8.1 ENVIRONMENTAL PROCEDURES

Please refer to Section 8 of this Preliminary Development Application.
11.8.2 OPERATIONAL PROCEDURES

LASMO's procedures will form Volume II of the Offshore Safety Operations Manual planned for the project. These procedures shall provide the operational framework of the LASMO safety program and shall deal with emergency requirements as well as routine policy matters. These procedures shall include:

11.8.2.1 Near Miss/Collision Avoidance

Response procedures for offshore and shore-based management to be used as activity guidelines in the event of a direct approach of a vessel to the installation, where successful two-way communication has not been accomplished.

11.8.2.2 Drill and Exercise Guidelines

Guidelines for the conduct and assessment of drills and exercises for offshore units, and for the coordination between offshore and shore-based emergency teams when joint exercises are held. These guidelines will also incorporate government and contractor participation in exercises of larger scope.

11.8.2.3 Helideck Safety Procedures

Guidelines for safe activity on offshore unit helidecks. These procedures will detail administrative policies for check-in, baggage handling, cargo loading, minimum crew, and refuelling and will detail guidelines for the Helideck Landing Officer (HLO) to use during emergency operations (fuel spill, fire, crash on-deck).

11.8.2.4 Medical Standards Guidelines

A reprint of the Canadian Petroleum Association Offshore Remote Medical Committees' Offshore Remote Medical Standards in which is
outlined the minimum care standards for CPA Frontier Division offshore member companies.

11.8.2.5 Standby Vessel Operating Procedures

Guidelines for the safe and effective operation of a standby vessel when in standby mode. These guidelines will form the IASMO Marine Operations Manual and will detail company procedures for the execution of routine and emergency situation marine tasking.

11.8.2.6 Personal Protective Equipment

This policy will detail the minimum standards of acceptable PPE for use in IASMO's offshore project. It will include respiratory protection, hearing conservation, ergonomic considerations, flame-resistant protective clothing, industrial safety equipment (hard hats, gloves, boots, etc.) and personal flotation protection.

11.8.2.7 Accident Investigation/Reporting

IASMO shall develop its own accident/incident investigating and reporting procedures and forms. A policy on accident reporting, and training in the accurate completion of the reports, shall be given to all supervisors.

The procedures shall follow the outline presented earlier in this chapter (Section 11.4.3).

11.8.2.8 Contractor Emergency Procedures

Procedures dealing with emergency situations that have been developed by IASMO's contractors for their own offshore units shall be reviewed by IASMO and assessed for their compatibility to IASMO's policies.
Discrepancies shall be corrected so as to conform with IASMO's safety procedures.

11.9 PRODUCTION INSTALLATION

Details of the production installation design specifics are being developed. They shall be provided when the various design concepts have been finalized. Selected areas are discussed below.

11.9.1 MEDICAL EMERGENCIES

The facilities and supplies to be provided to handle medical emergencies shall conform to the requirements outlined in the various regulations having jurisdiction over offshore operations. These include, but are not limited to:

- Canada Oil and Gas Drilling Regulations
- Oil and Gas Occupational Safety and Health Regulations
- Drilling on Frontier Lands - Guidelines and Procedures, September 1986

and in the initial well drilling phase:

- Standards Respecting Mobile Offshore Drilling Units

A fully qualified medic shall be provided and he will be supported by the shore-based physician support group as described earlier in this chapter (Section 11.4.2).

11.9.2 RESCUE EMERGENCIES

To assist the standby vessel in coping with rescue emergencies, the production unit shall be fitted with its own rescue craft and shall
have trained crews available at all times to effectively operate the unit.

11.9.3  HAZARDOUS MATERIALS

LASMO will ensure that all offshore personnel have received effective training in the Workplace Hazardous Materials Information Systems (WHMIS) and are thoroughly briefed in all hazardous chemicals to which they may be exposed.

LASMO will require Transportation of Dangerous Goods (TDG) training and employer's certification for those personnel required to handle Dangerous Goods as defined in the TDG Act and regulations.
### APPENDIX A

#### OFFSHORE INSTALLATION MANAGER

**Relationship**
The Offshore Installation Manager (OIM) is the person in charge of the drilling unit at all times.

**Function**
The OIM is responsible for:
- the safety of onboard personnel
- the integrity of the unit
- the protection of the environment

The senior drilling or marine person onboard may be designated as the OIM if that individual fulfills the training and qualification requirements of the OIM position.

**Mandatory Training**
- Appropriate marine certification (Bottom-Founded MODU Limited Certificate or MODU endorsement to a conventional Certificate of Competency)
- Basic Offshore Survival, or equivalent Marine Emergency Duties, Level D
- H₂S Alive (in known/suspected H₂S concentrations)
- Stability for Self-Elevating Drilling Units *
- Second Line Supervisor's Offshore Well Control

---

* NOTE: Stability for Self-Elevating Drilling Units is a requirement of OIM’s assigned to a self-elevating (jack-up) bottom-founded unit. OIM’s assigned to a column-stabilized
(submersible) bottom-founded unit shall complete the standard Stability and Ballast Control course as described in the "Mandatory Special Function Training" section.
RIG SUPERINTENDENT

Relationship

The Rig Superintendent is the Contractor’s senior onboard representative.

Function

The position is in charge of and fully responsible for all aspects of the drilling operations. This responsibility is subject only to the advice and direction he receives from the Operator’s Drilling Supervisor, and from the person in charge (OIM) - if he does not also hold that designation.

The position directs the work of the drilling crew and is responsible for the operation, maintenance and repair of all drilling equipment and ancillary systems.

Mandatory Training

- Basic Offshore Survival, or equivalent
- H₂S Alive (in known/suspected H₂S concentrations)
- Second Line Supervisor’s Offshore Well Control
### Alternate Titles
- Rig Captain
- Offshore Installation Manager
- Platform Manager

### Role
Has overall responsibility for the safety of the Mobile Offshore Drilling Unit and its personnel.

### Relationship
Reports to the OIM, if not filling the responsibilities of that position. Liaises with Senior Toolpusher.

### Prerequisites
- Requires Master Mariner Certificate with MODU endorsement, or Bottom-Founded MODU Limited Certificate of Competency, or equivalent as determined by the vessel’s Flag State requirements.

- Has satisfied the prerequisites for First Mate and has been employed in the capacity of First Mate for 52 weeks on a rig, during which time he has satisfactorily relieved as Master.

- Has adequately demonstrated to management, through on-the-job experience, an ability to competently and safely perform the tasks as defined in the Job Description and Offshore Task Analysis for a Master. This would normally take 52 weeks of MODU First Mate experience.

- Has demonstrated an ability to work independently, to exercise leadership and supervision skills and to provide a safe work example for rig personnel.

- Individual must have demonstrated mechanical aptitudes and technical ability.

- Shall be thoroughly familiar with company policy and procedures, with the requirements of applicable regulatory bodies, and with all pertinent legislation.
- Has completed on-the-job training deemed necessary by the Contractor.
The candidate shall have demonstrated good managerial skills and shall have successfully liaised with client representatives in regard to the Drilling Program. Where minor alterations are necessary, shall have successfully negotiated the necessary changes.

**Mandatory Training**
- Offshore Orientation
- Basic Survival Training or equivalent
- H₂S Alive
- Ballast Control Operations (or marine equivalent)
- On-Site Ballast Control
- Second Line Supervisor's Offshore Well Control
- Emergency Team Leader Training (MED program)

**Development Training**
- Supervision Training
- Drilling Operations Modular Home Study Courses
- Specialized Equipment Training

To complement the Task Analysis for Master, the following basic job description gives general guidance on the duties of the position:

- Directs safe working of the installation under all operational and environmental conditions.

- Ensures stability during rig moves is maintained within specified limits.

- Maintains required hull and deck load distribution through scheduling work and consulting with Senior Toolpusher on drilling program.

- Directs anchor and towing operations, including navigation of the vessel during rig moves.

- Supervises Marine Crew (when onboard during rig moves)

- Is responsible to ensure all safety equipment is maintained in good working order.
- Ensures serviceability of the installation is maintained through scheduled inspections and maintenance.
Supervises Rig Medic and oversees provision of medical services.

Supervises senior catering representatives and ensures provision of food and good housekeeping standards.

Ensures maintenance of installation logs and reports and ensures compliance with regulatory and class requirements.

Makes up station bills per flag state requirements and oversees conduct of emergency drills and exercises.

Conducts regular safety committee meetings with Senior Toolpusher.

Responsible for training and evaluating personnel.
APPENDIX A

BARGE COORDINATOR (Rig-Specific)

Alternate Titles
(Rig-Specific) - Barge Master
- Barge Engineer

Relationship
Reports to the Senior Toolpusher.

Role
Carries out responsibilities as directed by the Senior Toolpusher.

Prerequisites
- Has adequately demonstrated to a supervisor, through on-the-job experience, an ability to competently and safely perform the tasks as designated by the Drilling Contractor's job description.
- Individual must have demonstrated safety and supervisory skills, as well as mechanical aptitude and technical ability.
- Shall have completed on-the-job training as deemed necessary by the contractor.

Mandatory Training
- Offshore Orientation
- Basic Survival Training or equivalent
- H₂S Alive
- Offshore Fire Team Training
- Basic Stability Training or marine equivalent (to assist Rig Mover as required)

Development Training
- Supervision Training
**MEDIC**

<table>
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<th>- Representative of Safety and Training (RST) (rig-specific)</th>
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<td>Relationship</td>
<td>Reports to Rig Captain, MOU Master, Rig Superintendent or Senior Toolpusher.</td>
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<td>Role</td>
<td>Administers emergency first aid. Provides routine minor health services. On certain rigs the Medic will act as the Safety Representative, and may also be responsible for certain administrative functions.</td>
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- experience with helicopter of fixed wing evacuation for medical purposes

- holder of Advanced Cardiac Life Support (ACLS) certificate, or Basic Cardiac Life Support (BCLS) Instructor’s certificate and

(a) registered nurse (recognized by provincial laws) with two years clinical experience in intensive care or emergency practice; or

(b) paramedic certificate issued by a college and three years clinical experience; or

(c) Occupational Qualification VI B Medical Assistant (Canadian Military certificate)

**Additional Industry Prerequisites:**

- Demonstrates ability to work in professional isolation.

- Has been interviewed and recommended by the Contractor’s medical advisor.

- Has completed on-the-job training deemed necessary by the Contractor.
Mandatory Training
- Offshore Orientation
- Basic Survival Training or equivalent
- H₂S Alive
- CPR (BCLS) Training
- Radio Operator’s License (RC-MV Class)

Supplementary Training
- First Aid Instructor Certificate
- CPR Instructor Certificate
- H₂S Rescue
- Fire Training (where acting as Safety Representative)
- Supervisory Training
- Rig Medic Refresher Training
# SECTION 12

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SECTION 12. CONTINGENCY PLAN

12.1 INTRODUCTION

Contingency planning is undertaken on the assumption that at some time one or more of the accident prevention elements may fail and an emergency situation may develop. These plans provide a system for quick communication of the essential details of an emergency or impending emergency to the necessary personnel and agencies, and ensure that the correct response is taken to mitigate the threat.

IASMO is committed to developing a comprehensive Alert and Emergency Response Plan. This Plan will outline in detail the procedures to be followed in the event of any emergency.

The Plan will be accessible to and will serve as a working document for all personnel involved in the drilling, construction, production, storage and transportation phases of the project.

The Plan will be comprised of the following components:

- An alert plan to provide advance notice of potential emergencies

- An emergency response plan that documents the preferred immediate reaction to all emergency situations

- Guidelines and procedures to support actions necessary to minimize consequences of an incident

- An inventory of supplemental sources of emergency personnel, equipment and materials

- A list of data supporting operational and emergency planning
12.2 SCOPE

This section is a brief description of information that will be provided in the comprehensive Alert and Emergency Contingency Plan, and is organized into the following sections:

- Emergency Contingency Planning
- Alert and Emergency Response
- Emergency Communication List
- Additional Emergency Resources
- Emergency Procedures and Guidelines
- Operational Data

12.3 EMERGENCY CONTINGENCY PLANNING

This section discusses the preparation of the Emergency Contingency Plan, and is organized in the following sections:

- Purpose
- Alert and Emergency Response Plan
- Classification of Emergency
- Documentation
- Chain of Command
- Response Organization
- Operational Limits

12.3.1 PURPOSE

The Alert and Emergency Response Plan will provide company and contract personnel with the appropriate information to initiate an organized response to an emergency situation, including the mobilization of personnel and equipment.

The training and experience of on-site personnel in blow-out prevention policies and drills, safety equipment, lifeboat drills,
fire drills, man overboard drills, First Aid and CPR application, basic survival training and spill prevention ensures that a timely and proper response will be carried out. The plan also ensures that appropriate LASMO or contractor personnel and government contacts will be notified and assistance will be requested when necessary. This Alert and Emergency Response Plan will provide a checklist for response personnel.

12.3.2 ALERT AND EMERGENCY RESPONSE PLAN

The alert component of the Plan will bring operator and contractor personnel to a higher state of preparedness in the event of a potential emergency. Adverse conditions might include forecasts of excessive wind speeds, well control difficulties, or structural problems that pose a threat to the safety of personnel, jack-up drilling and production unit, structures or offshore vessels.

The emergency response plan section will define the purpose and scope of the emergency response plan, classification of emergencies, reporting procedures, emergency response organization and action required under each emergency.

12.3.3 CLASSIFICATION OF EMERGENCIES

Emergencies will be assigned a code classification and LASMO will formulate a system for rapid communication of essential details of the emergency to the appropriate personnel.

The code classifications that will be utilized are listed in the following table:
<table>
<thead>
<tr>
<th>Code</th>
<th>Class</th>
<th>Description</th>
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<tr>
<td>1</td>
<td></td>
<td>Personal injury or death</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Loss of well control</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Structural damage or threat of damage</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Fire or explosion</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Collision with vessels</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Heavy weather</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Overdue or lost aircraft</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Lost or in-distress vessel</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Diving emergency</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>On-site condensate spill</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Condensate spill from in-transit tanker</td>
</tr>
</tbody>
</table>

The above codes are complete, however, to cover all phases of operations such as construction, some descriptions may be modified to fit a potential incident.

12.3.4 DOCUMENTATION

Regardless of the nature and extent of an Alert or Emergency, all events and actions taken will be well documented, for subsequent internal and external investigation and follow-up.

12.3.5 CHAIN OF COMMAND

The Alert and Emergency Plan will clearly define the individual who has overall responsibility for the jack-up drilling and production unit, the wellhead platforms, the storage and shuttle tankers, and all personnel onboard at all times.
12.3.6  EMERGENCY RESPONSE ORGANIZATION

An organization chart will be prepared that describes the emergency organization of IASMO Nova Scotia Limited and its principal contractors. All positions will be filled with experienced local staff or contract personnel.

The organization will also handle simultaneous emergencies of different classifications. The responsibilities of all individuals will be defined for each type of emergency. It is anticipated that emergency communication exercises will be held prior to and during offshore operations.

12.3.7  OPERATIONAL LIMITS

The Alert and Emergency Response Plan will include a section regarding operational limits. As an example, if forecasted conditions exceed a pre-determined value, then IASMO will determine the level of operational reduction and evacuation.

12.4  ALERT AND EMERGENCY RESPONSE

This section discusses the alert and emergency response and covers the following:

- Alert and emergency call-out procedure
- Emergency contact list flow chart
- Emergency job responsibilities

12.4.1  ALERT AND EMERGENCY CALL-OUT PROCEDURES

The senior personnel offshore and onshore may declare an alert when that person has reason to believe that an anticipated condition warrants such action.
When an Alert or Emergency is declared, the emergency task force will be activated as described on the attached emergency task force organization chart shown in Figure 12.4-1. Each task force member will initially be required to notify only the necessary specific personnel and proceed to his duty station immediately.

**12.4.2 EMERGENCY CONTACT LIST FLOW CHART**

An emergency contact list flow chart, shown in Figure 12.4-2, will be prepared for quick reference which indicates the primary contacts required to respond quickly to any emergency.

**12.4.3 EMERGENCY JOB RESPONSIBILITIES**

This section will be organized by the type of emergency, with the responsibilities of each member of the response organization being listed in detail. It is likely that more than one code or class of emergency will result, and in such cases it may be more expedient for the individual in charge to delegate the responsibility for the appropriate responses to one or more individuals.

**12.5 EMERGENCY COMMUNICATION LIST**

A comprehensive emergency communication list will be developed for IASMO, government, contractors, consultants and other operators in the area. The list will reflect up to date telephone numbers, fax numbers, and addresses, and will be grouped by organization. These lists will be available internally throughout IASMO and externally to government agencies. It will be the responsibility of each individual involved in the response organization to ensure that this section is accurate and is kept current.
TYPICAL ORGANIZATION CHART
LASMO EMERGENCY RESPONSE TASK FORCE

GENERAL MANAGER
HALIFAX

PUBLIC AND GOVERNMENT AFFAIRS
MEDIA

ENGINEERING MANAGER
ENGINEERING STAFF

OPERATIONS MANAGER

LOSS PREVENTION ADVISOR

LOGISTICS & PROCUREMENT MANAGER
LOGISTICS SUPERVISOR
AIRPORT COORDINATOR
SUPPLY BASE SUPERVISOR
PURCHASING

ADMINISTRATION ACCOUNTING

ENVIRONMENTAL ADVISOR
ENVIRONMENT STAFF AND CONSULTANTS

MARINE SUPERINTENDENT

DRILLING SUPERINTENDENT

TANKER IN TRANSIT

PRODUCTION SUPERINTENDENT

DRILLING SUPERVISOR

STORAGE TANKER
STANDBY VESSEL
PRODUCTION FACILITIES

JACK-UP DRILLING UNIT

NOTE: THE ABOVE STRUCTURE MAY CHANGE WITH THE DIFFERENT PHASES OF OPERATIONS.

FIGURE 12.4-1
TYPICAL EMERGENCY CONTACT LIST - FLOW CHART
LASMO NOVA SCOTIA LIMITED

SENIOR SUPERVISOR
AT DRILLING RIG/PLATFORM
UNDER CERTAIN CIRCUMSTANCES, RIG/PLATFORM MAY COMMUNICATE DIRECTLY WITH SAR AND AIRPORT COORDINATOR
(902) EMERGENCY ONLY

STAND-BY VESSEL

LOGISTICS MANAGER
NAME OF PERSON
(902) OFFICE
(902) HOME

AIRPORT COORDINATOR
NAME OF PERSON
(902) OFFICE
(902) EMERG. ONLY
(902) HOME PAGER

HELIPORT FACILITY
NAME OF PERSON
(902) OFFICE
(902) HOME

CENTRAL FLIGHT FOLLOWING
NAME OF PERSON
(902) EMERG. ONLY
(902) GENERAL FLIGHT INFO.

EMERGENCY ALTERNATE LANDING SITE
WINDSOR PARK CFB HALIFAX
(902) 24 HOURS

HELICOPTER CONTRACTOR
NAME OF PERSON
(902) OFFICE
(902) HOME

SUPPLY VESSELS
NAME OF PERSON
(902) OFFICE
(902) HOME

DOCTOR - AOMA
NAME OF PERSON
(902) OFFICE
(902) HOME

OTHER AIR AND MARINE RESOURCES AS REQUIRED

RADIO OPERATOR
NAME OF PERSON
(902) OFFICE
(902) HOME

FIGURE 12.4-2
12.6 ADDITIONAL EMERGENCY RESOURCES

In addition to company resources, various other sources of assistance would be available during an incident, including the following:

- Co-operatives
- Other operators
- Other resources

12.6.1 CO-OPERATIVES

IASMO will be submitting an application to join Eastcoast Spill Response Incorporated (ESRI) to provide manpower and equipment as necessary during a condensate spill incident. Other oil industry co-operatives within Canada have equipment available for non-members. Inventories of this type of equipment would be kept in the Operational Data Volume (Section 12.8).

12.6.2 OTHER OPERATORS

From time to time, other companies will be operating on Canada's east coast. All operators have agreed to provide emergency assistance to each other in the event of an emergency through a Joint Sharing Agreement.

This agreement covers drilling rigs, supply boats, and helicopters. While there is not a formal agreement between operators, personnel and equipment have been made available to other companies during previous incidents.

12.6.3 OTHER RESOURCES

Supplementary to the government and industry resources discussed in this section, a listing of IASMO international personnel and
equipment, international co-ops, and local consultants and contractors will be compiled in this section. This worldwide pool of resources will provide an additional source of personnel and equipment if required.

12.7

EMERGENCY PROCEDURES AND GUIDELINES

In the event of an incident, many of the correct procedures, approaches and responsibilities will be contained in various guidelines and procedures. Rather than incorporate all of these guidelines and procedures into the job descriptions in the main contingency plan, they will be contained in this section.

Examples of the types of material to be found in this section are as follows:

- Ice reconnaissance procedures
- Weather forecast interpretative guidelines
- Well control policies and operational limits
- Inventory and weather operational limits
- Standby vessel duty guidelines
- General evacuation plan
- Medical emergency procedures
- Central flight following manual
- Condensate spill clean-up manual
- Condensate spill monitoring plan

To eliminate large cumbersome manuals, job-specific guidelines and procedures will be compiled in a separate volume and provided to appropriate personnel.
12.8 **FLIGHT FOLLOWING OPERATIONS**

Routine flying operations and emergency flight requirements, e.g., precautionary downmanning and medevacs) will proceed only under the guidance of an operator-provided flight following system.

During normal operations, flight following will be manned approximately one hour prior to take-off. This will allow proper communications checks, flight plan verification and weather data acquisition.

Flight Following staff will maintain in-flight contact with the helicopter crew at 15-minute intervals and will monitor position, course, speed, fuel, load status and ETA at destination. Flight Following will enter into an air traffic agreement with Flight Services Station Halifax and will be officially approved to act on behalf of the Ministry of Transport with respect to opening/closing flight plans, enroute air advisories, etc.

Emergency response procedures will be predicated on a loss-of-contact situation between Flight Following and the aircraft. A detailed response plan is being developed, however, the alert and response criteria will be as listed in Table 12.8-1.

12.9 **LOSS OF AVIATION SUPPORT**

In a situation involving the downing of the IASMO aviation support, IASMO's Flight Following operation would respond in accordance with the plan outlined in Section 12.8.

Government Search and Rescue (SAR) support would be provided by the Canadian Forces/Canadian Coast Guard. Rescue Coordination Centre (RCC) Halifax would be the responding group to an offshore emergency, and has the ability to task a number of primary and
### TABLE 12.8-1

**ALERT AND RESPONSE CRITERIA**

<table>
<thead>
<tr>
<th>Call-in time 15 minutes</th>
<th>- Routine operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call-in plus 1 minute</td>
<td>- Flight Following challenges the helicopter aircrew to respond. Continues until:</td>
</tr>
<tr>
<td>(uncertainty phase)</td>
<td></td>
</tr>
<tr>
<td>Call-in plus 5 minutes</td>
<td>- Flight Following notifies offshore installation and standby vessels of communications breakdown.</td>
</tr>
<tr>
<td>(alert phase)</td>
<td>- Notifies IASMO emergency response team of loss of contact.</td>
</tr>
<tr>
<td></td>
<td>- Continues to attempt contact until:</td>
</tr>
<tr>
<td>Call-in plus 10 minutes</td>
<td>- Flight Following notifies all offshore units, notifies IASMO emergency response team, notifies Department of National Defence Search and Rescue of missing aircraft. DND will initiate air search operations at this time.</td>
</tr>
<tr>
<td>or MAYDAY received</td>
<td></td>
</tr>
<tr>
<td>(distress phase)</td>
<td></td>
</tr>
</tbody>
</table>

MAY 2, 1990
secondary rescue resources (refer to Appendix A for specifications).

CFB Summerside is home to 413 Rescue Squadron Buffalo fixed-wing aircraft and twin-rotor CH-113 Labrador helicopters. Three of each aircraft type are usually stationed at Summerside. However, usually only one is on rescue duty as one is used for training and one is stood-down for maintenance. Response time is two hours to take off on weekdays from 0800 to 1600 hrs and four hours on weekends and after hours. Flying time from Summerside to Halifax is approximately one hour. Refuelling at CFS Shearwater is 45 minutes, with Shearwater to Sable Island taking another 1-1/2 hours. In late 1990 and early 1991, CFB Summerside will be closed and 413 Squadron transferred to CFB Greenwood.

CFB Greenwood presently has no attached SAR unit, but is the home of three squadrons of Aurora anti-submarine aircraft which may be tasked by RCC Halifax to assist as On-Scene Commander.

CFB Gander (Newfoundland) has similar equipment and standby capabilities to those of Summerside, but of course response times to Sable Island are considerably longer. Gander's 103 Rescue Squadron would transit from Gander to Sydney or Port Hawkesbury, refuel, to Halifax and refuel, and then out to Sable Island.

CFS Shearwater is home to one squadron (HS-423) of anti-submarine warfare (ASW) CH-125 Sea King helicopters. These aircraft are normally not SAR tasked due to their weight/equipment restrictions. Configured for ASW, the Shearwater Sea Kings have no rescue specialist/rescue swimmer, have room for only three survivors and have no internal engine-start capabilities. In other words, once started, these helicopters cannot shut down unless an external air-power unit (APU) starter is available. Therefore, with their three-hour fuel endurance, they would require "hot refuelling", something not done except in extreme emergencies. Shearwater (and ship-based)
Sea Kings are not usually tasked for SAR operations. CFS Shearwater is also home to VU 32, a utility aircraft squadron which flies jet trainers and the army version (Huey) of a Bell 212 utility helicopter. The Huey does have internal starter power, but as the skid landing gear is not equipped with flotation devices, RCC Halifax is understandably reluctant to send this aircraft out over water. The Huey has no external hoist fitted.

The Department of Fisheries has one S-76 helicopter based in Yarmouth, Nova Scotia for fisheries patrol and (secondary) SAR tasking. The machine is fitted with hard-points to mount an external rescue winch, but it is normally not mounted. When on fisheries patrol the helicopter carries only observers and would be required to return to base to board rescue personnel and fit the winch, prior to assisting in a SAR mission. It does not (normally) fly night missions.

There are a number of marine resources available to assist in an offshore evacuation emergency. RCC Halifax has two Coast Guard rescue cutters normally on station at either end of the province (Shelburne and Mulgrave). To assist near Sable Island, the Mulgrave unit (CCGC Alert or CCGS Mary Hitchens) would be approximately 12 hours steaming time away. Other Coast Guard vessels (involved in the Navigation Aids program) may be available. Military warships have no patrol areas and may or may not be available. Ship-based Sea King helicopters have the same limitations as Shearwater-based units.

Industry SAR support would be provided by our own standby vessels. IASMO would divert any in-transit supply vessel to the last known position of the helicopter and commence sea search operations. Depending upon the ongoing well operation and environmental conditions, IASMO would consider dispatching the offshore installation's standby vessel to assist in the search and rescue of the helicopter occupants.
In order to ensure that the correct decisions regarding emergencies can be made quickly and with all the most current information, various data bases will be available. The most current and useful data on which to base decisions during an incident will be real-time data. This information is best obtained through the Regional Environmental Emergency Team (REET), from field reconnaissance, and phone calls. Examples of this regional historical data would be as follows:

- regional meteorological and oceanographic conditions
- regional biological resource distribution by season
- generalized seasonal fishing activity

Additionally, this section would contain sources and inventories of well control equipment and spill response equipment. The actual data provided would be tailored to match the individual's job responsibilities.
# MILITARY LABRADOR HELICOPTER

## Crew
- Five personnel consisting of two pilots, one flight engineer and two SAR techs

## Endurance
- 5-1/2 hours

## Speed
- Cruise: 125 knots
- Maximum: 148 knots
- Full Load: 100 knots

## Range
- 600 nautical miles

## Maximum Gross Weight
- 21,400 lbs, giving a 1,000 lb. payload immediately upon lift-off

## Fuel Capacity
- 6,000 lbs, burning 1,100 lbs/hr cruising speed
- Gravity refuelling only

## Survivor Capacity
- Fifteen survivors seated or
- Eight survivors sitting with four litters in the aisle

## Operational Limits
- Maximum start-up speed 52 knots steady winds
- Cannot start up/shut down with greater than 15 knots of gusting winds
- Cannot fly when freezing/icing conditions are forecast
- When deployed from Gander, must refuel in St. John's
- VFR Limits: 300' at 1/2 mile
- IFR Limits: 200' at 1/4 mile

## Rescue Equipment
- Rescue hoist (permanent mount)
- Horse collar (single man)
- Rescue harness (rescuer and survivor)
- Two-man Billy Pugh rescue basket
- One Stokes (wire) litter
- Can carry SKAD kit* if circumstances warrant (SKAD not normally carried)

---

* Sea Kit Air Droppable

Like the industry SEA Kit, the SKAD is a 400' line with life rafts on each end and two equipment pods on the line between them at a 200' spacing.

---

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12.16
### Army Sea King Helicopter

| **Crew**          | - Three personnel consisting of two pilots and one tactical coordinator  
|                   | - One electronics specialist as required  
| **Endurance**     | - Three hours (full fuel)  
|                   | - With hot refuelling, can run for 12 continuous hours  
|                   | - Sea King has no internal starters and no APU  
|                   | - Requires either AC/DC boost  
| **Speed**         | - Cruise: 100 knots  
|                   | - Maximum: 150 knots  
| **Range**         | - 300 nautical miles  
| **Maximum Load**  | - 5,000 lbs external load  
| **Fuel Facts**    | - Maximum load 4,000 lbs.  
|                   | - Burns 1,000 to 1,200 lbs/hr in forward flight  
|                   | - Burns 1,500 lbs/hr when hovering  
|                   | - Both gravity and pressure refuelling points  
| **Survivor Capacity** | - Three survivors (normal)  
|                   | - Six survivors (standing)  
|                   | - One stretcher from ship will reduce capacity by three survivors  
| **Rescue Equipment** | - Rescue hoist (permanent mount)  
|                   | - Two-man Billy Pugh rescue basket  
|                   | - Double lift harness  
|                   | - SKAD kit launched from cabin door. SKAD not available on Shearwater or ship-launched Sea Kings  
|                   | - The Sea King is equipped with auto-hover and the hoist operator can fly the machine by direct control from the rescue hoist doorway. It is fitted with one HF/SSB, one VHF, and one UHF radio. The SSB/VHF are on military tactical frequencies and the UHF is used to speak with shipping/other traffic.  

* This unit does not carry a rescue specialist if launched from a naval vessel. It may carry a ship's rescue diver, however, this man is not a SAR tech specialist.
MILITARY BUFFALO FIXED-WING AIRCRAFT

Crew
- Six personnel consisting of two pilots, one navigator, one flight engineer and two SAR techs

Endurance
- 5-1/2 hours (SAR configuration)

Speed
- Cruise: 210 - 220 knots
- Maximum: 225 knots
- Search: 140 - 150 knots (good visibility)
- Search: 105 knots (partial flaps down - bad visibility)

Range
- 1,100 nautical miles

Fuel Capacity
- 13,556 lbs.

Rescue Equipment
- SKAD kit (always carried)
- Air droppable pump
- Two or three litters
- Parachute equipment for SAR techs
  - sea survival package
  - bush survival package

Other
- SAR techs are trained to drop SKAD and then parachute into the water to assist survivors
- This aircraft has no pick-up capability, but usually functions as "Top Cover" or the On-Scene Commander and Local Air Controller.
# MILITARY TRACKER FIXED-WING AIRCRAFT*

<table>
<thead>
<tr>
<th>Crew</th>
<th>Three personnel consisting of two pilots and one electronics tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endurance</td>
<td>7-1/2 hours (SAR configuration) (6-hour flights)</td>
</tr>
</tbody>
</table>
| Speed | Cruise: 150 knots  
Maximun: 220 knots |
| Maximum Weight | 26,500 lbs. |
| Operational Limits | 25 knots crosswind on take-off  
60 knots in headwind  
10 knots with tailwind  
IFR flight limits:  
Normal 200' and 1/2 mile  
Emergency 100' and 1/4 mile |
| Rescue Equipment | Two SKAD normally carried  
Four SKAD total may be fitted  
Paraflares - 5 min. illumination rockets (2 always) |
| Communications | 1 UHF  
1 VHF (FM)  
1 VHF (AM)  
1 HF |

* Tracker aircraft are being phased out of SAR and fisheries patrol duties during 1990-91.
MILITARY AURORA FIXED-WING AIRCRAFT

Much of the information about the Aurora is classified. However, this multi-engined aircraft is used on anti-submarine and fisheries patrol by the Canadian Forces and one is always in the air off Canada’s east coast.

The Aurora is capable of carrying a SKAD kit just above the forward bomb bay doors which it can deploy very accurately.

This aircraft can assume O/S Commander and can drop long life data markers or radio transmitting sonobuoys near the survivors to mark positions for pick-up units. If near the end of its patrol, the Aurora has the capability of identifying multiple contacts on its radar and transferring the knowledge to another aircraft who can assume control (hot hand-over).

Rescue Equipment

- SKAD
- FLIR (forward looking - infrared radar)
SECTION 13
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   13.1.1 Preliminary Studies
   13.1.2 Drilling and Completions
   13.1.3 Well Jacket Structures
   13.1.4 Interfield Flowlines and Export Line
   13.1.5 Production Facilities
   13.1.6 Management and Engineering

13.2 Operating Cost Summary
   13.2.1 Management and Engineering
   13.2.2 Production Operations
   13.2.3 Production Facilities
   13.2.4 Tanker Operations
   13.2.5 Well Workovers
   13.2.6 Abandonment
   13.2.7 Capital Cost Accuracy
   13.2.8 Project Economics and Fiscal Terms

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13.2-1 Operating Cost Estimate

MARCH 7, 1990
SECTION 13. DEVELOPMENT COSTS

13.1 CAPITAL COST SUMMARY

Capital costs for development were estimated in the following major categories:

- Preliminary studies
- Development drilling and completions
- Well jacket structures
- Interfield flowlines and export line
- Production facilities
- Management and engineering

The major categories are discussed in the sections that follow.

The capital costs for development are summarized in Table 13.1-1.

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<tbody>
<tr>
<td>Preliminary Studies</td>
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<tr>
<td>Drilling and Completions</td>
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<tr>
<td>Well Jacket Structures</td>
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<tr>
<td>Interfield Flowlines and Export Line</td>
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<tr>
<td>Production Facilities</td>
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<tr>
<td>Management and Engineering</td>
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</tr>
</tbody>
</table>

| NOTE: For commercial reasons, individual component capital and operating costs are being kept confidential. |

| Totals                                    | 4.0  | 25.0 | 85.5 | 33.1 | 12.4 | 160.0 |

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13.1.1 PRELIMINARY STUDIES

Preliminary studies include all the third-party and consultant studies completed prior to initial production.

13.1.2 DRILLING AND COMPLETIONS

Drilling and completion costs are included for both Cohasset and Panuke. These costs are based on the assumption that the wells will be drilled with a jack-up drilling unit through steel piled well jackets.

13.1.3 WELL JACKET STRUCTURES

The well jacket structures category includes the cost to design, fabricate, and install two steel piled well jackets using a derrick barge. Alternative methods of installation are under review.

13.1.4 INTERFIELD FLOWLINES AND EXPORT LINE

In this category, the costs of design, fabrication, and installation of the following lines are included:

- Eight-inch production line
- Six-inch injection line
- Six-inch export line and dynamic riser
- Control bundle
- Power cable (if determined to be necessary)

Both line pipe and flexible pipe alternatives are being evaluated.

13.1.5 PRODUCTION FACILITIES

This category includes the cost of the design, fabrication, manufacture, and assembly of production facilities to be installed.

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on the deck of a jack-up drilling unit to process well fluids, treat produced water to regulated specifications, and provide water injection. The estimated costs for rig modification and installations of the production equipment are included.

**13.1.6 MANAGEMENT AND ENGINEERING**

LASMO has established a Halifax office and will provide experienced management, engineering, and support staff throughout the field life. This category includes all staff costs, and general and administrative expenditures that will be incurred prior to production start-up.

**13.2 OPERATING COST SUMMARY**

Operating costs were estimated in the following major categories:

- Management and engineering
- Production operations
- Production facilities
- Tanker operations
- Well workovers
- Terminal Operations
- Abandonment

The major categories are discussed in the following sections.

The development operating costs are summarized in Table 13.2-1

**13.2.1 MANAGEMENT AND ENGINEERING**

The management and engineering category includes the Operator's Halifax staff and general and administrative costs from the time of initial production to depletion.
TABLE 13.2-1
OPERATING COST ESTIMATE
(1990 $ millions CDN)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Producing Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanker Operations</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well Workovers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abandonment (prorated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: For commercial reasons, individual component capital and operating costs are being kept confidential.

Totals 53.1 67.4 71.2 71.2 71.2 71.2 405.3

13.2.2 PRODUCTION OPERATIONS

The following components are included in the production operations category during the period when they are not charged to the drilling of wells:

- Leased jack-up unit
- One supply vessel
- One stand-by vessel
- Helicopter service
- Communications services
- Meteorological services
- Supply base
- Operating insurance
- Mobilization and demobilization
13.2.3 PRODUCTION FACILITIES

The following components are included in the operating cost estimate for production facilities:

- Operator's offshore supervision, and contracted production operators

- Catering

- Maintenance, capital replacement, and insurance on production facilities

- Maintenance, capital replacement, and insurance on well jackets

- Fuel

- Chemical consumables

- Maintenance, capital replacement, and insurance on flowlines and condensate export system

13.2.4 TANKER OPERATIONS

The following are included in the operating cost estimate for the tanker operations:

- CALM mooring and offloading system

- Storage tanker charter, fuel, and operating costs (year-round)

- Shuttle tanker charter, fuel, and operating costs (part year - seasonal)
13.2.5 WELL WORKOVERS

The well workovers category includes the cost of recompletions and pump maintenance for Cohasset, and initial pump installation and subsequent pump maintenance at Panuke.

13.2.6 ABANDONMENT

The abandonment category includes the costs to abandon all the wells, remove the well jackets, remove the interfield flowlines and control lines, and remove the tanker mooring and offloading buoy.

13.2.7 CAPITAL COST ACCURACY

These preliminary capital and operating cost estimates have been prepared based on experience in other offshore areas using similar development methods and technology. More specific definition will take place when the final design engineering is completed and quotations, tenders and contracts have been reviewed and evaluated.

13.2.8 PROJECT ECONOMICS AND FISCAL TERM

The project economics, royalties, and taxation are not included as part of the Development Application. This information is available for limited distribution to the CNSOPB as may be required.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCSV</td>
<td>Annular surface-controlled safety valve</td>
</tr>
<tr>
<td>BIO</td>
<td>Bedford Institute of Oceanography</td>
</tr>
<tr>
<td>BOP</td>
<td>Blowout preventer</td>
</tr>
<tr>
<td>CALM</td>
<td>Catenary anchor leg mooring system</td>
</tr>
<tr>
<td>CAM</td>
<td>Catenary anchor mooring</td>
</tr>
<tr>
<td>CNSOPB</td>
<td>Canada - Nova Scotia Offshore Petroleum Board</td>
</tr>
<tr>
<td>CPI</td>
<td>Corrugated plate interceptor</td>
</tr>
<tr>
<td>D.A.</td>
<td>Development Application</td>
</tr>
<tr>
<td>DFO</td>
<td>Department of Fisheries and Oceans</td>
</tr>
<tr>
<td>ESD</td>
<td>Emergency shutdown</td>
</tr>
<tr>
<td>ESP</td>
<td>Electrical submersible pumps</td>
</tr>
<tr>
<td>FLOT</td>
<td>Formation leak-off tests</td>
</tr>
<tr>
<td>FSO</td>
<td>Floating Storage and Offloading</td>
</tr>
<tr>
<td>GCR</td>
<td>Gas-condensate ratio</td>
</tr>
<tr>
<td>GWC</td>
<td>Geostrophic wind climatology</td>
</tr>
<tr>
<td>HJP</td>
<td>Hydraulic jet pump</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>KO</td>
<td>Knockout</td>
</tr>
<tr>
<td>L.D.</td>
<td>Long-delivery</td>
</tr>
<tr>
<td>MCC</td>
<td>Motor Control Centre</td>
</tr>
<tr>
<td>MEDS</td>
<td>Marine Environment Data Service</td>
</tr>
<tr>
<td>PER</td>
<td>Polished bore receptacle</td>
</tr>
<tr>
<td>PERD</td>
<td>Federal Panel on Energy Research and Development</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable logic controller</td>
</tr>
<tr>
<td>PLEM</td>
<td>Pipeline end manifold</td>
</tr>
<tr>
<td>ppb</td>
<td>Part per billion</td>
</tr>
<tr>
<td>ppm</td>
<td>Parts per million</td>
</tr>
<tr>
<td>SCSSV</td>
<td>Surface-controlled subsurface safety valve</td>
</tr>
<tr>
<td>SOWM</td>
<td>US Navy spectral ocean wave model</td>
</tr>
<tr>
<td>TCP</td>
<td>Tubing conveyed perforating</td>
</tr>
<tr>
<td>TD</td>
<td>Total Depth</td>
</tr>
<tr>
<td>TVD</td>
<td>Total Vertical Depth</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptable Power Supply</td>
</tr>
<tr>
<td>WES</td>
<td>Waterways Experiment Station</td>
</tr>
</tbody>
</table>
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SECTION 5. PRODUCTION AND EXPORT SYSTEMS

Codes and Standards

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>API RP 2A</td>
<td>Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms.</td>
</tr>
<tr>
<td>API 2C</td>
<td>Specification for Offshore Cranes.</td>
</tr>
<tr>
<td>API RP 2D</td>
<td>Recommended Practice for Operation and Maintenance of Offshore Cranes.</td>
</tr>
<tr>
<td>API RP 2G</td>
<td>Recommended Practice for Production Facilities on Offshore Structures</td>
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<tr>
<td>API 2F</td>
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<td>API RP 2H</td>
<td>Specification for Carbon - Manganese Steel Plate for Offshore Platform Tubular Joints</td>
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<tr>
<td>API RP 2L</td>
<td>Recommended Practice for Planning, Designing and Constructing Heliports for Fixed Offshore Platforms.</td>
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<tr>
<td>API RP 2M</td>
<td>Recommended Practice for Qualifications Testing of Steel Anchor Designs for Floating Structures.</td>
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<td>API 5L</td>
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<td>API RP 14E</td>
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<td>API RP 14F</td>
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<td>Recommended Practice for Use of Surface Safety Valves and Underwater Safety Valves Offshore.</td>
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<tr>
<td>API RP 17B</td>
<td>Recommended Practice for Flexible Pipe.</td>
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<tr>
<td>API RP 500A</td>
<td>Recommended Practice for Classification of Locations for Electrical Installations in Petroleum Refineries.</td>
</tr>
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API RP 500B  Recommended Practice for Classification of Areas and Electrical Installation at Drilling Rigs and Production Facilities on Land and on Marine Fixed and Mobile Platforms.

API RP 500C  Recommended Practice for Classification of Areas for Electrical Installations and Petroleum and Gas Pipeline Transportation Facilities.

API RP 520  Recommended Practice for the Design and Installation of Pressure-relieving Systems in Refineries.

API RP T-2  Recommended Practice for Offshore Production Personnel Who Work With Anti-Pollution Safety Devices.

API RP T-4  Recommended Practice for Training of Offshore Personnel in Non-Operating Emergencies.

API Bull T-5  Employee Motivation Programs for Safety and Prevention of Pollution in Offshore Operations.

ASME ASPPE-2  Accreditation of Testing Laboratories for Safety and Pollution Prevention Equipment Used in Offshore Oil and Gas Operations.

ASME SPPE-2  Quality Assurance and Certification of Safety and Pollution Prevention Equipment Used in Offshore Oil and Gas Operations.


CSA B.51  Construction and Inspection of Boilers and Pressure Vessels.

CSA CAN 3G 40.20M  General Requirements for Rolled or Welded Structural Quality Steel.

CSA CAN 3G 40.21M  Structural Quality Steels.

CSA C.22.1  Canadian Electrical Code Part I.

CSA Z.183  Oil Pipeline Transportation Systems.

CSA Z.184  Gas Pipeline Systems.

CSA Z.245  General Requirements for Plain-Ended Welded and Seamless Steel Line Pipe.

CSA  Offshore Pipeline Design Standards.
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Codes and Standards (Cont'd)

IEEE  Recommendations for Electrical and Electronic Equipment of Mobil and Fixed Offshore Installations.
NACE RP-01-76  National Association of Corrosion Engineers Recommended Practice-Control of Corrosion on Steel, Fixed Offshore Platforms Associated with Petroleum Production.
NFPA 10  Portable Fire Extinguishers.
NFPA 20  Centrifugal Fire Pumps.
NFPA 30  Flammable and Combustible Liquids Code.
NFPA 70  National Electrical Code.
NFPA 72D  Proprietary Protection Signalling Systems.
NFPA 75  Computer and Data Processing Equipment.
NFPA 91  Blowers and Exhaust Systems.
NFPA 231  General Indoor Storage.
NFPA 496  Purged and Pressurized Enclosures for Electrical Equipment.
TP 2586  Transport Canada, Heliport and Helideck Design Criteria.

Aeronautics Act
- Rotorcraft Air Transport Operation Order

Canada Labour Code
- Canada Occupational Safety and Health Regulations
- Marine Occupational Safety and Health Regulations
- Oil and Gas Occupational Safety & Health Regulations

Canada Shipping Act
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Navigable Waters Protection Act
- Navigable Waters Works Regulations

Oil and Gas Production and Conservation Act
- Canada Oil and Gas Operations Regulations

Radio Act
- General Radio Regulations

American Bureau of Shipping
- Rules for Building and Classing Steel Vessels
- Rules for building and Classing Single Point Moorings
- Rules for Building and Classing Underwater Systems and Vehicles

Lloyd's Register of Shipping
- Rules & Regulations for the Classification of Ships
- Rules and Regulations for the Classification of Mobile Offshore Units
- Code for Lifting Appliances in a Marine Environment
- Guidance Notes for Single Point Moorings, Buoys and Similar Tethered, Floating Structures
- Provisional Rules for the Design, Construction and Classification of Submarine Pipelines

Det Norske Veritas
- Rules for Classification of Ships
- Rules for the Classification of Mobile Offshore Units
- Rules for the Construction and Classification of Offshore Loading Systems
- Rules for the Design, Construction and Inspection of Submarine Pipelines and Pipeline Risers

International Maritime Organization
- International Convention for the Prevention of Pollution from Ships (MARPOL)
- International Convention for the Safety of Life at Sea (SOLAS)
- International Convention on Load Lines
- International Convention on Standard of Training, Certification and Watchkeeping for Seafarers
- Regulations for Preventing Collision at Sea (COLREG)
- International Maritime Dangerous Goods Code (IMDG)
Oil Companies International Marine Forum
- International Safety Guide for Oil Tankers and Terminals
- Design and Construction Specification for Marine Loading Arms
- Oil Spill Contingency Planning
- Single Point Mooring, Maintenance and Operations Guide
- Standards for the Equipment Employed in the Mooring of Ships at Single Point Moorings
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